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Economic Analysis of Solid-Set Sprinklers to Control Dust in Feedlots

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Abstract:

Feedlot dust is a critical problem that contributes to cattle death and illness, as well as, air pollution. This analysis identifies the effects of feedlot dust on cattle and the benefits/methods of controlling feedlot dust. A cost analysis of one popular method of controlling dust, solid-set sprinklers is presented.

Keywords: Air Quality, Cost Analysis, Dust Control, Feedlots, Solid-Set Sprinkler

JEL Classifications: Q000, Q100, Q160, Q520, Q530

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Introduction

A growing issue for livestock producers, the general public, and environmental regulators is feedlot dust control. Feedlot dust is a critical problem that contributes to cattle death and illness, air pollution, and is a nuisance to humans. Several dust-controlling methods have been implemented by feedlots including solid-set sprinkling systems, mobile sprinkling systems, manure removal, water curtains, stocking density, and even pen design. Other less proven and less popular techniques include windbreaks, concrete or similar pens, and chemical application. All methods prove to be effective in controlling dust leading to improved animal productivity, less air pollution, and happier, neighboring humans.

Sources of Dust

Researchers have tried to identify the main sources of agricultural air pollution and how it affects both humans and animals. One large source of the air-borne dust particles is the amount of manure in the pens. Each animal can leave behind approximately 900 kg of dry manure during its time in the feedlot (Sweeten et al., 1998). High temperature, low humidity, and wind help to dry this manure that then becomes light, loose dust particles and can easily be emitted into the atmosphere by wind and cattle movement.

Increased cattle movement at certain times of the day is the main reason that dust events occur. The peak time for dust problems is in the afternoon and early evening. Moisture in the manure and soil has mostly evaporated from the day's temperature, and the cooler temperatures of the evening make the cattle more active. Usually in the evening the wind speeds decrease, and the dust particles form a dust cloud that floats just above the surface (Auvermann et al., 2000).

In the Texas Panhandle, dust problems in feedlots are even more significant because the Texas High Plains has relatively little rainfall and high winds. Average annual rainfall for Amarillo, Texas is 20 inches and the average annual wind speed for Amarillo is approximately 13.1 miles per hour (City of Amarillo, 2005). The dust problem is further intensified in the spring when the wind speed increases. Stronger winds tend to dry the manure and soil faster and also help blow the loose dry particles into the atmosphere. However, the spring also brings more rainfall which partially offsets the impact of higher wind speeds.

Drought conditions make it even more difficult to combat high wind speeds and temperatures to keep the dust from blowing. In the year 2000, Amarillo battled drought conditions, above average temperatures and high winds. These conditions caused the dust problem to be worse than normal. However, by the end of 2004 and the beginning of 2005, above normal moisture occurred, which helped alleviate the number and magnitude of dust events.

Air Quality Concerns

Researchers have conducted experiments to determine the amount and size of particles released from feedlots. According to an air emissions report from Alberta, Canada, the agricultural industry in Alberta produced 430,633 tonnes of non-greenhouse gas pollutants in the year 2000. Of the 430,633 tonnes, 59.8% was comprised of particulate matter emissions less than 10 microns (μm) in size, and 39.5% of the agricultural air emissions were ammonia (Chetner and Sasaki, 2001). Cattle, especially cattle in feedlots, are a large cause of ammonia and particulate matter.

There are three main size classes of particulate matter. The first category is total suspended particles (TSP) with a diameter of 0.005 μm to 100 μm . The subcategory of TSP is

PM10, which are particles with an average diameter of less than 10 μm . Another subcategory of TSP is PM2.5, which are particles with an average diameter of less than 2.5 μm . The particles with a diameter larger than 10 μm are filtered by the nasal cavity, PM10 particles are able to enter the respiratory tract, and PM2.5 particles are able to enter the lower respiratory tract (Chetner and Sasaki, 2001).

One study was performed in three Texas feedlots to determine the TSP concentrations for a 24 hour sampling period. The purpose of this study was to compare the size and amount of particles emitted into the atmosphere from different feedlots. The objectives of the experiment were to use high volume samplers to determine the amount and size of total suspended particulate matter (TSP) and particulate matter less than 10 μm (PM10) released from the feedlots and to determine and compare the mass fraction less than 10 μm of PM. The data showed that nearly 34% of the particles collected by the PM10 sampler were indeed larger than 10 μm (Sweeten et al., 1998).

Individuals who strive to improve air quality have increasingly scrutinized air pollution from agricultural production activities. With an increasing number of people moving to rural areas and living closer to agricultural sources, air quality has become a major concern. Human illnesses, resulting from short-term exposure to agricultural pollution, may include allergies or mild respiratory problems. More serious health problems have been associated with long-term exposure to PM2.5 particles and include lung diseases such as chronic bronchitis. Most studies have not been able to quantify the effect of feedlot dust in relation to human illnesses. Dust affects humans relatively less than cattle because they are not exposed to the large amounts of blowing dust. When there is blowing dust, people can go inside or protect themselves with

masks and/or other respiratory protection. The dust particles people do breathe are usually large enough to be filtered by the nasal cavity and never reach the lungs.

In addition to possible adverse health effects, feedlot dust is a nuisance to neighboring homes and communities. People are mainly concerned with the dust, odor, and flies from feedlots. In addition, noise, traffic, and animal treatment have also been scrutinized by the public. The city dwellers that move to rural areas do not have an understanding or patience for these factors adding pressure to livestock producers to fix the problem (Brink, 2002).

The Effects of Dust on Cattle

The main concern of feedlot managers related to dust control is that dust has been shown to contribute to pneumonia in cattle. Cattle are exposed to dust particles daily and cannot protect their lungs from the particles. Respiratory problems caused by dust can result in illness or death of animals. The more sickness and death in the feedlot, the less revenue and profit earned.



Photo by: Natural Resources Conservation Service

One of the most economic damaging problems to a feedlot is the bovine respiratory tract disease. Bovine respiratory tract disease causes 75% of all illness and 64% of all cattle death in feedlots (MacVean et al., 1986). Acute interstitial pneumonia (AIP) is the second most

important respiratory disease found in feedlot cattle. Acute interstitial pneumonia is the cause of histologic lesions, accumulation of fluid on the lungs, and the formation of hyaline membranes. The fatality rate of AIP can be as high as 60%. It has been reported that feedlot associated AIP, also known as dust pneumonia, is typically found in cattle that are close to market weight (Loneragan et al., 2001).

Studies have been conducted to help determine the variables which cause the feedlot associated AIP. One such study took place in Greeley, Colorado, during 1982 and 1983. The experiment was conducted at Farr Feeders that feeds approximately 75,000 cattle per year. The objective of the study was to compare the amount and size distribution of particles in the feedlot, weather conditions, and other variables to the corresponding incidences of pneumonia. The study showed a relationship between the range of daily temperature, 2.0 to 3.3 μm particles, and pneumonia incidence. This relationship shows that an increase in particle concentration causes an increase in the incidence of pneumonia. In addition, a wide variation in daily range of temperature further enhances the association between particulate exposure and pneumonia incidence (MacVean et al., 1986).

This study helps show the problem with dust in feedlots. When there are dry conditions in feedlots, manure and dust particles are allowed to become airborne and are breathed by cattle. The more dust particles in the air, the greater the chance cattle have of acquiring pneumonia and possibly dying. The health of the animals is a primary concern of a feedlot manager because of the high cost of medicines, labor, and the high investment cost of each animal. Therefore, it is essential that feedlot managers practice effective dust controlling techniques.

Benefits of Dust Control

There are many benefits that can result from controlling feedlot dust. Livestock producers can improve the environment, minimize neighbor complaints, and increase cattle productivity through the implementation of dust management practices. Different feedlots have their own reason why they choose to control dust. First, some feedlots must use dust control practices in order to comply with strict environmental guidelines set forth by the Environmental Protection Agency (EPA). Second, some feedlots want to control dust simply to improve neighbor relations. This has become very important with the amount of agricultural land being lost to urbanization. Through sprinkler systems, it is very easy to reduce the amount of dust and odor and also control flies. Feedlot managers simply run insecticide through the sprinkler system to control flies by applying a water/insecticide mixture to the entire feedlot. These management techniques help feedlot managers make their operation more acceptable to the public.

Another reason, and perhaps the most important benefit that feedlots receive from controlling dust, is the increase in cattle productivity which results in greater profitability. Controlling dust improves the overall health of cattle in many different ways. Sprinkling pens lowers the temperature 10 to 15 degrees which creates a healthier, more comfortable environment for the cattle. The cooler environment regulates feeding patterns so that the cattle eat smaller meals throughout the day, which reduces the incidences of bloating (Feedlot Environmental Systems, 2005). In addition, a study conducted by the University of Nebraska found that sprinkling reduces soil temperature, providing a cool area for cattle to obtain relief from heat stress. The study concluded that morning sprinkling was better than evening sprinkling because the cattle stayed cooler during the day. However, cattle that received evening

mound wetting still had a dry matter intake that was .55 lbs/day higher than the cattle that had no sprinkling at all (Davis, et al., 2001).

Sprinkling also reduces the amount of airborne bacteria and pathogens in the air cattle breathe. This leads to a reduction in death loss and cattle pulls. Controlling dust can reduce death loss 10 to 15 percent and can decrease cattle pulls by 40 to 50 percent (Feedlot Environmental Systems, 2005). With the decrease in the amount of money spent on medicine, as well as the profits recaptured through the reduction in death loss, feedlot owners and operators are able to increase their profits.

Sprinkler Systems

A popular method of controlling dust in feedlots is the use of sprinkler systems. As studies indicate, water sprinklers have been recommended to help control dust by keeping the surface manure moisture above 30 percent (Sweeten et al., 1988) which reduces dust potential directly and facilitates compaction to the maximum practical extent (Auvermann, 2005 – unpublished data). The sprinklers are used to spray water onto the pen's surface and raise its moisture content, thus helping to keep the matter from blowing. The sprinklers are mostly used when the moisture content of the surface is low. This usually occurs in the early to late afternoon when the day's heat has evaporated the moisture from the ground. Without the moisture content, the soil and manure become lighter and are easily sent into the air either by the wind or cattle movement.



Photo by: Texas Cooperative Extension

A study conducted by the USDA Agricultural Research Service, U.S. Meat Animal Research Center, tried to identify the relationships between environmental factors, dust generation, and particulate matter emissions from cattle feedlots. This study attempted to determine if soil moisture and organic content had any effect on the amount of dust emissions. Previous studies have found a negative correlation between dust concentrations downwind of cattle feedlots and feedlot surface moisture (Sweeten et al., 1988). This study also attempted to find if there was a relationship between dust emissions and different sample sites within a feedlot.

The study determined that dust potential was the highest when the samples were the driest. This indicated that more moisture leads to less dust, and corresponds to previous studies (Sweeten et al., 1988). The data also indicated that there was a rapid change from dust-producing to dust-free by addition of a small amount of moisture to the sample. The mound and down-gradient samples, which had low moisture content and were dusty when collected, had a high dust potential while the ditch and feed bunk samples, which had high moisture content and

were not dusty when collected, had a low dust potential. This showed that areas throughout the feedlot can produce different levels of dust depending on the moisture level.

The rapid change from dust-producing to dust-free with the addition of moisture varied for each sample. This was hypothesized to be caused by the amount of organic matter in the soil. Based on this study it was determined that the higher the organic matter in the soil, the more moisture was needed to control the dust (Miller and Woodbury, 2003).

The study shows that adding water to feedlot surfaces is an effective way to reduce dust. However, using sprinkler systems to control dust can be tricky because just the right amount of water must be applied to the surface. Too much water will cause the ground to become too wet and muddy. When the surface becomes muddy and slippery, cattle begin to slip, fall, and possibly damage their legs. When cattle cannot walk, they cannot make it to the feed. Therefore, they do not eat, and gain weight. If the cattle do not gain weight, they are money losing assets. In addition, too much water can increase odor and fly problems. However, if insufficient water is applied, it will not adequately control the dust. It is suggested to keep pen surface moisture between 25 and 35 percent to be most effective (Davis et al., 1997).

Two frequently used sprinkler types include mounted and mobile systems. The mounted sprinklers are more effective in covering large pens or several pens simultaneously. The sprinkler or “water gun” can be mounted on a fence and positioned to cover the majority of the pen surface. While the initial capital cost of the mounted sprinkler is high, less labor is required, it can be automated to come on at any time, and it can apply water exactly when and where it is needed (Queensland Gov., 2003).

The mobile sprinkler system is most likely a water truck. The water truck can be driven throughout the feedlot to spray water onto the pen surface. Water trucks are better on small pens

and pens located adjacent to roads. Advantages of the water truck include less initial capital cost, and the truck can move throughout the feedyard with relative ease. However, the water truck requires higher labor cost and has an increased risk of breakdowns (Queensland Gov., 2003).

Both sprinkler systems are helpful in controlling dust when used correctly. Another advantage of using sprinklers is that it is a good method to recycle feedlot waste water. Waste water can be pumped into the sprinklers and continually reused. Use of sprinkler systems to control dust is most effective when combined with other dust controlling methods such as frequent manure removal or harvesting.

Cost of Solid-Set Sprinkler Systems

Solid-set sprinkler systems are considered an effective, yet expensive way to control dust in feedlots. The initial investment cost for a permanent fence-line sprinkler system can approach \$1,000 per pen. However, one of the advantages of the system is once it is installed the operational expense, especially labor, is minimal (Davis et al., 1997). There are government programs in place that help relieve some of the financial burden of these systems.

Government Assistance Programs

The Environmental Quality Incentives Program (EQIP) provides financial and technical assistance to farmers and ranchers that apply conservation practices on their land. EQIP is administered by the United States Department of Agriculture - Natural Resources Conservation Service (USDA-NRCS) and was reauthorized with new authorities and increases in funding in the 2002 Farm Bill. The goal of the EQIP program is to help producers comply with current regulatory requirements and eliminate the need for future regulation (EQIP, 2005).

Commercial beef cattle feeding operations in Texas must agree to meet certain requirements to be eligible for EQIP funding. The operation must agree to be in compliance with all federal and state regulatory requirements by the completion of the contract. In addition, the operation must obtain all needed regulatory permits before assistance is furnished on layout or construction of any conservation practice (EQIP, 2004).

There are three main categories that EQIP will cost share when installing a solid-set sprinkler system that includes the sprinkler system, pipeline, and storage tank costs. The EQIP program cost share rate is normally 50% of the costs associated with the conservation practice, not to exceed \$450,000. The cost associated with each of the categories depends on the size and shape of the feedlot, current well capacities, and water storage available. Normally, the cost of a sprinkler system for a square shaped feedyard with square pens is less than the cost for a feedyard that has an odd shape and/or odd shaped pens. If the current well(s) do not have the capacity to provide 1/8 inch net sprinkler application per day in addition to the livestock water requirement, the feedyard may have to drill an additional well. EQIP currently does not cost share the expense of a new well, but will cost share the expense of the pipeline from the well to the sprinkler system. Finally, the feedyard may have to install a large storage tank in order to have an adequate water supply to operate the sprinkler systems throughout the day (Sokora, 2005-personal communication).

The Natural Resources Conservation Service assigns a minimum 10 year life to all sprinkler systems. However, with proper maintenance, repair, and possible computer upgrades, the basic components of the feedlot dust control sprinkler systems should last a minimum of 20 to 25 years (Sokora, 2005-personal communication). Feedlot Environmental Systems, an Idaho Company that installs dust sprinklers nationwide, says they are designed to last 30 years.

Project Cost

Project costs have been estimated for three different size capacity feedlots: 10,000 head, 30,000 head, and 50,000 head. Capital costs for installing a solid-set sprinkler system include the sprinkler system, pipeline, and water storage tank costs (Table 1). The cost of the sprinkler distribution system itself includes a pumping station, big gun sprinkler heads, pipeline manifolds, control valves and a computer with software to operate the sprinkler system. In addition, the design of each system must be sufficient to apply at least 1/8 inch of water net per day to the feedlot surface. It should be noted that the cost of a new well to pump groundwater, if needed, is not included in this analysis. Each expense has been estimated using average costs developed by the Natural Resources Conservation Services for use in the EQIP Program.

Table 1. Estimated project cost for a solid-set sprinkler system for various feedlot capacities.

Head Capacity	Sprinkler System	Pipeline	Irrigation Reservoir	Project Cost	Project Cost \$/Hd Capacity
10,000	\$200,025	\$8,346	\$99,000	\$307,371	\$30.74
30,000	\$456,750	\$20,803	\$171,000	\$648,553	\$21.62
50,000	\$752,550	\$27,193	\$235,000	\$1,014,743	\$20.29

Fixed Costs

Fixed costs for a solid-set sprinkler system include the initial investment, interest and depreciation. Annualized costs are based on a useful life of 25 years with an annual interest rate of 6 percent. The straight-line method was used to calculate depreciation. There was no salvage value assumed after the useful life of the system (New, 2005). Annualized fixed costs are presented in Table 2.

Table 2. Annualized fixed cost for a solid-set sprinkler system based on a 25 year useful life for various feedlot capacities.

Head Capacity	Project Cost	Interest Rate (6%)	Depreciation	Annualized Cost	Annualized Cost \$/Hd Capacity
10,000	\$307,371	12.8	\$12,295	\$36,339	\$3.63
30,000	\$648,553	12.8	\$25,942	\$76,676	\$2.56
50,000	\$1,014,743	12.8	\$40,590	\$119,970	\$2.40

Operational Costs

Operational costs include annual energy cost, and maintenance and repair for the system (Table 3). Once the system is installed, labor expenses are minimal and therefore are not included in the analysis. Energy costs include the cost of the energy required to pump the amount of water needed per day in addition to electrical maintenance and repair. Maintenance and repair costs include pump replacement and well maintenance for the system.

Energy costs were calculated based on sprinkler application of 1/8 inch of water net to 150 square feet per head of cattle per day of operation (Table 3). Total pump head of 723 feet was calculated using 140 psi pump discharge to the sprinkler head (Auvermann, 2005) plus a pumping lift of 400 feet (New, 2005). In addition a pump efficiency of 60 percent was assumed. Annual sprinkler duty cycle used was 2,045 hours per year, running 12 hours per day, 8 months of the year, 70 percent of the time (Sokora, 2005). A power rate of \$0.08 per kwh was assumed to calculate energy costs. Energy requirements, 105 kwh per acre-inch, were estimated using the guidelines provided by Texas Cooperative Extension Agricultural Engineer, Leon New (New, 2005). In addition, an electrical maintenance and repair cost of \$3.00 per hp per year was used (New, 2005) assuming a pumping capacity of 0.023 gpm per head of cattle (Sokora, 2005). Details of energy requirements and costs of energy for a solid-set sprinkler system are given in Appendix A, Table A-1. The total energy cost is a major component of the operational cost and is approximately \$0.37 per head capacity per year.

Pump replacement and well maintenance costs have also been calculated and included in the annual operational costs. On average, most systems require less than \$1,000 per year to maintain. Pumps for the system should last 7 to 10 years before needing repaired or replaced (Sokora, 2005-personal communication). Replacing one pump every ten years for a 30,000 head feedlot would cost about \$2,900, or \$290 per year. In addition, well repair and maintenance has also been included in operational costs at the rate of \$7,500 every 10 years (New, 2005).

Table 3. Annual operational costs for a solid-set sprinkler system for various feedlot capacities.

Head Capacity	Energy Cost	Pump Replacement	Well Maintenance	Operational Cost	Operational Cost \$/Hd Capacity
10,000	\$3,700	\$145	\$750	\$4,595	\$0.46
30,000	\$11,100	\$290	\$750	\$12,140	\$0.40
50,000	\$18,500	\$435	\$750	\$19,685	\$0.39

Total Cost

Estimated annual fixed costs, as well as operational costs, have been combined to determine the total costs associated with a solid-set sprinkler system to control dust in a feedlot (Tables 4 & 5). Annualized fixed cost ranges from \$3.63 per head capacity for a 10,000 head feedlot to \$2.40 per head capacity for a 50,000 head feedlot. In addition, operational costs range from \$0.46 per head capacity for a 10,000 head feedlot to \$0.39 per head capacity for a 50,000 head feedlot. Total costs in terms of \$/head are \$4.09, \$2.96, and \$2.79 per head for a 10,000, 30,000, and 50,000 head capacity feedlot, respectively. Total costs decrease as the number of head capacity increases due to economies of scale.

Table 4. Total annual cost including fixed and operational costs (\$/head capacity) for a solid-set sprinkler system based on a 25 year useful life for various feedlot capacities.

Head Capacity	Fixed Cost \$/Hd Capacity	Operational Cost \$/Hd Capacity	Total Cost \$/Hd Capacity
10,000	\$3.63	\$0.46	\$4.09
30,000	\$2.56	\$0.40	\$2.96
50,000	\$2.40	\$0.39	\$2.79

Three different turnover rates were used to convert dollars per head capacity to dollars per head marketed. A five year average from the Southwestern Public Service Company Fed Cattle Survey determined the average cattle turnover rate for feedlots of 2.01 (head marketed / head capacity) (SPS, 1996-2000). With these three turnover rates, annual fixed cost, operational cost, and total cost were calculated on a per head marketed basis. The annualized total cost to install and operate a solid set sprinkler system ranges from \$2.34 per head marketed to \$1.24 per head marketed depending on the capacity of the feedlot and the respective turnover rate, (Table 5).

Table 5. Total annual cost including fixed and operational costs (\$/head marketed) for a solid-set sprinkler system based on a 25 year useful life for various feedlot capacities and turnover rates.

Head Capacity	Turnover Rate (Hd Marketed/ Hd Capacity)	Fixed Cost \$/Hd Marketed	Operational Cost \$/Hd Marketed	Total Cost \$/Hd Marketed
10,000	1.75	\$2.08	\$0.26	\$2.34
	2.00	\$1.82	\$0.23	\$2.05
	2.25	\$1.62	\$0.20	\$1.82
30,000	1.75	\$1.46	\$0.23	\$1.69
	2.00	\$1.28	\$0.20	\$1.48
	2.25	\$1.14	\$0.18	\$1.32
50,000	1.75	\$1.37	\$0.22	\$1.60
	2.00	\$1.20	\$0.20	\$1.40
	2.25	\$1.07	\$0.17	\$1.24

Conclusion

Dust control is a growing concern for feedlot managers and environmentalists in the Texas Panhandle. Solid-set sprinklers are an effective way to control dust and create a better environment for cattle and neighboring communities of a feedlot. While the cost to establish a solid-set sprinkler system is \$20 to \$31 per head capacity, depending on the size of the feedlot, annual operational costs are only \$0.39 to \$0.46 per head capacity. This translates into a total annual cost of \$2.79 to \$4.09 per head capacity or \$1.24 to \$2.34 per head marketed based on a 25 year useful life. To determine if benefits of installing a solid-set sprinkler system warrants the costs, more research is needed on the actual effects of sprinkling on cattle behavior, weight gain, health, etc. Most feedlots that have installed solid-set sprinkler systems seem to be very satisfied with the improvements it has made to their operation. These feedlots have installed the sprinkler system in order to take a proactive approach to the dust problem.

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Table A-1. Details of energy costs.

Water Pumped	.125 inches/day (sprinkler application) * 150 ft ² /head (cattle spacing) * 1 ft/12 in (conversion) * 7.48 gal/ft ³ (conversion) * 1 ac-ft/325,851 gal (conversion) * 2,045 hours/8,766 hours per yr (annual sprinkler duty cycle) * 365.25 days/yr (conversion) = .00306 ac-ft per head per year
Electricity Requirement	Total Head: (140 psi to sprinkler head * 2.31) + 400 ft lift = 723 feet 119 kwh is required to pump an acre-inch of water 723 feet.
Energy Cost Calculation	119 kwh (electricity requirement) * \$0.08/kwh (energy price) * 12 ac-in/1 ac-ft (conversion) * .00306 ac-ft/head (water pumped per head) = \$0.35 per head per year
Electrical Maintenance and Repair	Pump Capacity: 0.023 gpm/ head 0.023 gpm/head * 723 ft total head / (3960 * 0.60 Pump Efficiency * 0.95 Gear Head Efficiency) = .00737 hp/head @ \$3.00/hp/yr *.00737 hp/head = \$0.02 per head per year
Total Energy Cost per Head per Year = \$0.37	