Water Requirements for Controlling Dust from Open Feedlots

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Species: Beef, Dairy
Use Area: Animal Housing
Technology Category: Management
Air Mitigated Pollutants: Odor and Particulate Matter

Description:

The beef cattle industry has been faced with environmental concerns, including air quality impairment within and downwind of the beef cattle feedlots. Particulate matter (PM) emission is a major factor that impacts air quality from the feedlot and poses health concerns to humans and animals alike. MacVean et al. (1986) linked the health and performance of newly received feeder cattle to the onset and magnitude of dust events. Sweeten et al. (2000) indicated that particulate matter emission annoy neighbors and irritate feedlot employees.

In general, the major source of PM emission from a cattle feedlot is the pen surface. Particulate matter is emitted when cattle hooves trample on the dry, uncompacted layer of manure and soil. Other sources of PM emission are unpaved roads, hay grinding, grain handling, and feed processing, including loading and delivery (Auvermann et al., 2006). Dust problems are most likely to occur during the period of July through September, but can occur whenever extended periods of low rainfall are combined with high evaporation rates to produce surface drying.

Sweeten et al. (1988) monitored the total suspended particulate (TSP) concentration in three commercial cattle feedlots in Texas. They reported overall mean net TSP concentration (i.e., downwind - upwind) 410 $\mu g/m^3$, ranging from 68 to 882 $\mu g/m^3$, for 24-h sampling periods. In addition, for 4- and 5-h time intervals within the 24-h sampling periods, TSP concentrations ranged from 16 to 17,000 $\mu g/m^3$. In a related study, Sweeten et al. (1998) measured the concentrations of both the TSP and PM_{10} (particulate matter with nominal diameter of 10 μm or less) at three commercial cattle feedlots in Texas. They reported mean downwind concentrations of TSP and PM_{10} of 700 $\mu g/m^3$ (ranging from 97 to 1,685 $\mu g/m^3$) and 285 $\mu g/m^3$ (ranging from 11 to 866 $\mu g/m^3$), respectively. Rozate et al (2007) studied the concentrations of PM_{10}, TSP, and odor detection threshold downwind and upwind of a water-sprinkled commercial cattle feedlot in Kansas. This study found the measured PM_{10} concentrations varied considerably with time. PM_{10} concentrations were generally larger during the early evening hours within a given day and during the summer months. Odor DTs, upwind and downwind of the feedlot, varied considerably with sampling period and ranged from 11 to 101 OU/m^3 and 13 to 99 OU/m^3, respectively. Razote et al. (2007) reported the PM_{10} mass concentration generally decreased with an increase in manure moisture content.

Mitigation Mechanism:

Dust problems develop during dry weather and often occur during dusk when cattle activity begins to increase as the temperatures start to decline. Cattle that have been resting during the heat of the day become active including movement to the feed bunk, water trough and socializing. A dust inversion remains in the vicinity of the feedlot area with movement creating potential air quality standard non attainment dependent upon wind speed and direction. Increasing the moisture content of the pen surface reduces the particles that become air borne due to cattle activity.

Several abatement strategies, including manure compaction and harvesting, increased stocking density, and timing of feeding, have been proposed to mitigate PM emissions from open cattle feedlots (Auvermann et al., 2006; Auvermann and Romanillos, 2000). One of the most common practices is surface water application. In this practice, water is applied on the corral surface using an irrigation system or water trucks equipped with spray nozzles.

Sprinkler systems can be effectively used to control dust in open feedlots. There is less potential for dust events as the water applied increases. Excess water used in dust control can create anaerobic conditions in the manure pack and odor problems. Also, too dry or too wet of conditions can lead to animal health problems. Auvermann (2001) and Auvermann and Romanillos (2001) report that manure pack moisture from 25 to 40% by weight will limit both odor and dust from open feedlots. Therefore, feedlot operations must balance between applying too much or too little water to maintain optimum animal weight gain while limiting the environmental impacts of dust and odor.

Applicability:

Dust abatement utilizing water is applicable to beef cattle feedlots or dairy dry lots. Normally, dust abatement is necessary in areas with high daily evaporation such as the High Plains region. Evaporation results in earthen lot surfaces having moisture contents of less than 10 percent since rainfall and urine are evaporated. Water sprinkling systems are used to increase the surface moisture content to 25 to 35 percent to minimize the impact or PM_{10} emissions. Research suggests surface moisture contents in excess of 35 percent may lead to odor problems. Therefore, proper design and operation of the system is necessary to minimize particulate and odor emission problems.

Limitations:

Water sprinkling has been considered a best management practice for mitigating particulate matter (PM) emissions from open beef cattle feedlots; however, limited data are available on its impact on air pollutant emissions from the feedlots. Razote et al. (2007) measured the concentrations of PM_{10} downwind and upwind of a water-sprinkled commercial cattle feedlot in Kansas. PM_{10} concentrations were measured with collocated Tapered Element Oscillating Microbalances™ (TEOMs), federal reference method (FRM) high-volume PM_{10} samplers, and FRM low-volume PM_{10} samplers. In addition to the PM_{10} concentration, the following parameters were monitored: (1) TSP concentration downwind and upwind of the feedlot; (2) particle size distribution downwind of the feedlot; (3) odor detection threshold (DT) upwind and downwind of the feedlot; (4) manure moisture content; (6) weather conditions; and (7) sprinkler water use. PM_{10} mass concentration also generally decreased with an increase in manure moisture content. Comparison of collocated PM_{10} samplers showed that the measured PM_{10} mass concentration was largest with the TEOM PM_{10} sampler and smallest with the low-volume PM_{10} sampler. Odor DTs, upwind and downwind of the feedlot, also varied considerably and ranged from 11 to 101 OU/m^3 and 13 to 99 OU/m^3, respectively. The operation of the water sprinkling system and manure moisture content did not seem to influence mean odor DT.

Cost:

Economists participating in the federal Air Quality Initiative have evaluated the cost per head marketed for different size feedlots using either a traveling gun or solid set sprinkler system (Amosson et al., 2006; 2007). Table 1 summarizes the results of these economic studies.

Table 1 Total annual cost per head marketed for various feedlot capacities and turnover rates. The traveling gun sprinkler system is evaluated based on a 20 year useful life and the solid set sprinkler system utilizes a 25 year useful life.

Feedlot Capacity (Head)	Turnover Rate (hd marketed / hd capacity)	Type of Sprinkler System	
		Traveling Gun[1]	Solid Set[2]
10,000	1.75	$0.95	$2.34
	2.00	$0.83	$2.05
	2.25	$0.74	$1.82
30,000	1.75	$0.79	$1.69
	2.00	$0.69	$1.48
	2.25	$0.61	$1.32
50,000	1.75	$0.78	$1.60
	2.00	$0.68	$1.40
	2.25	$0.61	$1.24

[1] Amosson et al. (2007)
[2] Amosson et al. (2006)

Implementation:

A computer model was developed to provide individual operations a preliminary estimate of water requirements and monthly cost of per head for dust abatement. Model inputs include parameters related to feedlot, water supply and location, initial system investment and electrical cost. These inputs provide information on pump capacity and horsepower, operating pressure, main and branch water line sizes, number of sprinkler zones, operational time per sprinkler zone, pumping cost and fixed monthly cost. Figure 1 provides an illustration of the input and outputs from

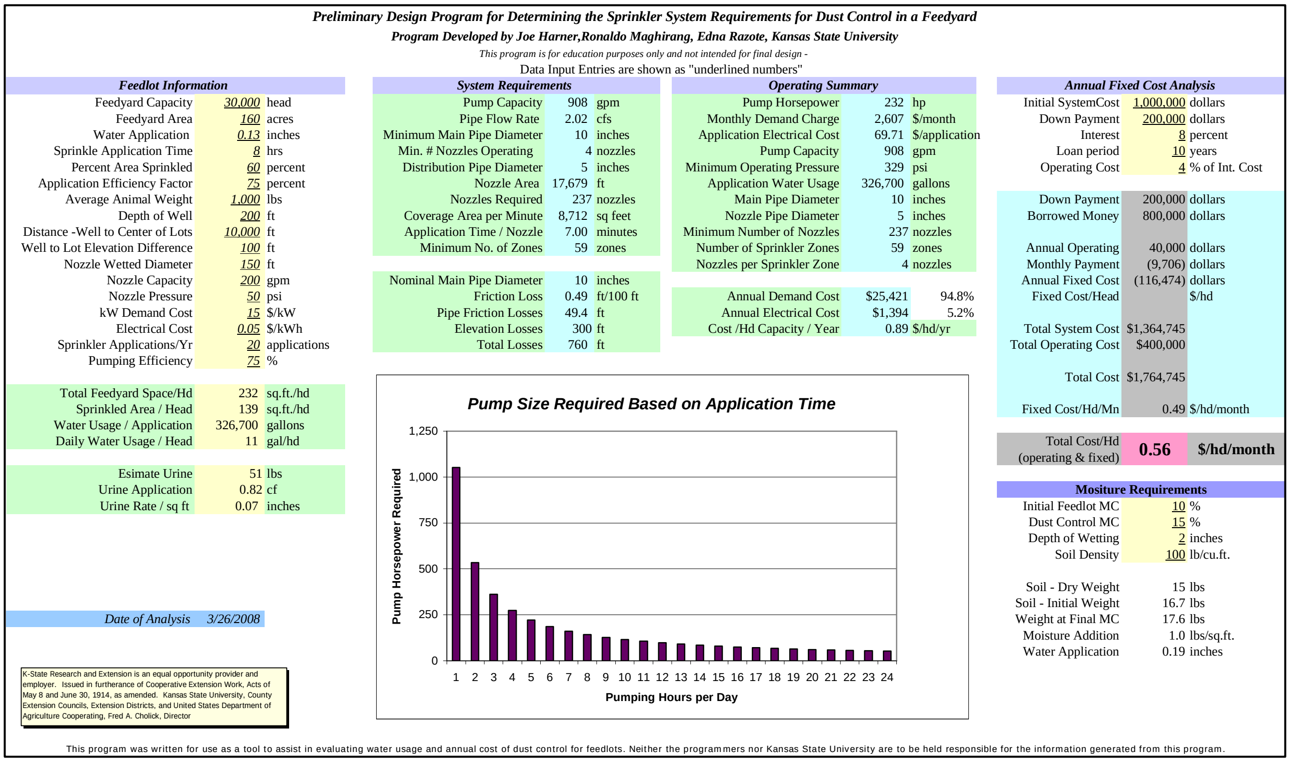

Figure 1 Computer screen of the spreadsheet model used to provide preliminary design information and estimate the annual cost for controlling dust with a sprinkler set.

The computer model. A single screen format was used to enable individuals to view the impact of input changes. Also, a graph is used to illustrate the impact of pumping time on pump horsepower requirements. Optimum dust abatement is obtained with water applications two to three hours prior to dusk to minimize the impact of evaporation and drying of the surface prior to cattle activity. The graph shows the impact on pump horsepower requirements as the application rate period is reduced from 24 hours to 1 hour.

A Kansas cooperator involved with air quality monitoring project recorded daily water meter readings of a well supplying a sprinkler system for feedlot dust abatement. The average water usage was 41.6 liters per day per head (l/d/hd). The solid set sprinkler system operated 142 days during 2007. The peak application rate during a single 24 hour period was 91.9 l/d/hd. Twenty four percent of the applications were 60.5 l/d/hd or greater and 33 percent of the applications were less than 25.3 l/d/hd. Table 2 shows the estimated daily water usage based on feedlot stocking density and the initial and final surface moisture content the model predicted water use requirements. The daily water usage per head ranges from 76 to 438 l/d/hd and well capacity ranges from 105 to 425 liters per second (l/s). This table was based on dust abatement for a 20,000 head feedlot and assumes the surface is wetted a depth of one inch and the total feedlot surface area is wetted within an 8 hour period. The water usage exceeds the rates application rates reported by the cooperating Kansas feedlot.

Table 3 shows the impact of stock density when water is limited to 41.6 l/d/head based on data collected at the Kansas feedlot. The surface moisture content does not reach the desired moisture content of 25 % regardless of the stocking density. This may explain why Razote et al. (2007) reported inclusive evidence on the benefits of sprinkling feedlots based on the field observations at a single feedlot.

Table 2 Estimate of daily water usage and well capacity as a function of initial and final surface moisture contents and stocking density.

Initial Surface Moisture Content (%)	Final Surface Moisture Content (%)	Feedlot Stocking Density (square meters per head)					
		9.3		18.6		27.9	
		Water Usage (l/d/hd)	Well Capacity (l/s)	Water Usage (l/d/hd)	Well Capacity (l/s)	Water Usage (l/d/hd)	Well Capacity (l/s)
10	25	113	100	151	140	227	210
	35	219	200	295	270	438	410
15	25	76	70	98	90	148	140
	35	174	160	234	220	348	320

Table 3 Impact of limiting daily water usage to 41.6 l/d/hd on final surface moisture content as a function of stocking density

	Feedlot Stocking Density (square meters per head)		
	9.3	18.6	27.9
Water Application Rate (mm/square meter)	0.31	0.19	0.14
Estimate of Final Surface Moisture Content assuming 1" depth wetting zone and Initial moisture content of 10 %	16.5%	14.5%	13%
Pump Size (kW)	83	103	114
Well Capacity (l/s)	43	36	39

Technology Summary:

The beef cattle industry has been faced with environmental concerns, including air quality impairment within and downwind of the beef cattle feedlots. Particulate matter (PM) emission is a major factor that impacts air quality from the feedlot and poses health concerns to humans and animals alike. In general, the major source of PM emission from a cattle feedlot is the pen surface. Particulate matter is emitted when cattle hooves trample on the dry, uncompacted layer of manure and soil. Other sources of PM emission are unpaved roads, hay grinding, grain handling and feed processing. Sprinkler systems can be effectively used to control dust in open feedlots. There is less potential for dust events as the amount of water applied increases. Excess water used in dust control can create anaerobic conditions in the manure pack creating odor problems. Studies suggest the manure pack moisture from 25 to 35% by weight will limit both odor and dust from open feedlots. Economic studies indicate the cost per marketed head per year ranges from $0.60 to $2.40 depending on feedlot turnover and type of sprinkler systems installed. A computer has been developed to help evaluated the water requirements necessary to obtain the 25- to 35 % moisture on the feedlot surface and well capacity. The model also provides a indicator of monthly cost per feedlot head capacity based on economic inputs.

Additional Resources:

More information is available at The Air Quality: Odor, Dust and Gaseous Emissions from Concentrated Animal Feeding Operations (CAFOs) in the Southern Plains website. Their web address is http://cafoaq.tamu.edu/.

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