Dust Emissions in Cattle Feedlots

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Dust from cattle feedlot surfaces, alleys, and roads can annoy neighbors, irritate feedlot employees, and possibly impair cattle performance. In acute instances, feedlot dust can create a traffic hazard on adjacent highways. Total particulate emissions are affected by feedlot area, cattle density in pens, wind speed, and precipitation and evaporation patterns.[9]

PREVIOUS RESEARCH

Elam and colleagues collected feedlot dust inside of 65 pens at 10 feedlots using a Staplex high-volume air sampler with glass fiber filters.[4] The 24-hour continuous sampling was conducted in successive increments of 1 to 3 hours. Peak particulate concentrations, collected between the hours 1900 and 2200 Pacific Daylight Time (PDT), ranged from 1,946 to 35,536 μg per m^3 and averaged 14,200 μg per m^3 ($\pm$11,814 μg per m^3 standard deviation). Minimum concentrations were usually observed in early morning when concentrations on the order of 130 to 250 μg per m^3 were obtained in some feedlots.[4]

Algeo and colleagues measured total suspended particulates using 24-hour samplings both upwind and downwind of 25 California feedlots (Table 1).[1] The net particulate concentrations (downwind minus upwind) for 24-hour continuous sampling time ranged from 54 to

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Table 1. *Summary of 24-Hour Particulate (TSP) Concentrations at 25 California Cattle Feedlots*[1]

	DOWNWIND (N = 25)	UPWIND (N = 24)	NET DOWNWIND MINUS UPWIND (N = 24)
Mean	836	206	654
Standard deviation	±437	±116	±376
Range			
Minimum	100	46	54
Maximum	1,599	460	1,268

1,268 μg per m³. The average value for all 25 feedlots was 654 ± 376 μg per m³. Upwind concentrations were 5 to 46 per cent (25 per cent average) of the downwind concentrations. In most instances, both ambient (upwind) and feedlot particulate levels exceeded U.S. Environmental Protection Agency ambient air-quality standards of 150 μg per m³ by a wide margin. However, much of the particulate matter inside dusty feed pens will settle out rapidly.[9] Limitations of these results included the following: (1) all sampling was performed in the dry season; and (2) details such as feedlot size, cattle number, distances from samplers to feedpens, and climate conditions were not reported.[9]

Guidelines on feedlot dust control[2,5,8,11,12] usually involve water sprinkling at strategic times and in proper amounts. Carroll and colleagues compared two feedlots, one unsprinkled and the other sprinkled at the rate of 2 hours on 2½ hours off, 1½ hours on each day, and reported that sprinkling reduced dust emissions by at least half and maximum temperatures by about 10°F while raising relative humidity by less than 10 per cent.[3]

At another feedlot, particulate concentrations (24-hour averages) increased from 3,150 to 23,300 μg per m³ when daily water sprinkling was terminated for 7 days.[4] A manure moisture content of 20 to 30 per cent was reportedly important for dust control.

REGULATORY STANDARDS

In 1971, the U.S. Environmental Protection Agency promulgated primary and secondary national ambient air-quality standards for total suspended particulate matter (TSP). The primary standards were set at 260 μg per m³ for 24-hour average not to be exceeded more than once per year and an annual geometric mean of 75 μg per m³.[16] Secondary standards were set at 150 μg per m³ for a 24-hour sampling period not to be exceeded more than once per year.

Effective July 31, 1987, the U.S. Environmental Protection Agency replaced TSP as the indicator for particulate matter for the ambient standards in favor of a new indicator that includes only those particulates with an aerodynamic particle diameter less than or equal to a nominal 10 μm (PM-10).[16] The new standard replaced the 24-hour primary TSP standard with a PM-10 standard of 150 μg per m^3 with no more than one expected exceedance per year; replaced the annual primary standard for TSP with a PM-10 standard of 50 μg per m^3 expected annual arithmetic mean; and replaced the secondary TSP standard with 24-hour and annual PM-10 standards that are identical to the primary standards.

Using the California data from Algeo and coworkers,[1] Peters and Blackwood developed what they considered to be worst-case projections for the U.S. Environmental Protection Agency to use in developing source emission factors for cattle feedlots.[9] They estimated an emission rate of 0.036 ± 0.022 g/s/m of feedlot length. The projections would place feedyards with more than 500 head at 140 square feet per head above 100 tons per year of particulate emissions, not including the feedmill.

Based on the Peters and Blackwood report,[9] the U.S. Environmental Protection Agency in 1979 published air pollutant emission factors for cattle feedlots, terming them *crude estimates* at best.[15] The emission factors were based on size of cattle feedlot and cattle throughput as follows: (1) feedlot capacity basis—(280 lbs per day per 1,000 head), and (2) feedlot throughput (27 tons per 1,000 head fed). Other factors were similarly established for ammonia, amines, and total sulfur compounds.

These U.S. Environmental Protection Agency factors could be applied in the future by state air pollution control agencies for regulatory purposes or for establishing inspection fee schedules. However, major climate differences exist between cattle feeding regions of California and the Great Plains and the Midwest. Also, California has less than 4 per cent of the cattle on feed in the United States, while Texas feedlots have 20 per cent of the 11,527,000 head on feed (January 1, 1988).

State air pollution control agencies have adopted ground level particulate matter concentration limits, such as the following property line standards:[13]

Consecutive Sampling Time (hours)	Maximum Concentration ($\mu g/m^3$)
5	100
3	200
1	400

In addition, at least 11 states have established property-line odor emission standards, based on various odor-intensity measurement methods.[7,10] Other researchers have correlated odor intensity with dust concentrations and manure moisture content in confinement swine and poultry buildings. The possibility of such correlations for cattle feedlots needs to be investigated.

OBJECTIVES

Objectives of the cattle feedlot dust project included the following: (1) to determine the concentrations of dust emitted from typical cattle feedlot surfaces in terms of total suspended particulates and particulates with aerodynamic diameters below 10 μm (PM-10); (2) to determine the particulate size distribution of feedlot dust; and (3) to determine if dust emissions were correlated with surface manure moisture content, which could possibly be managed, and with odor intensity.

EQUIPMENT AND PROCEDURES

Feedlots

Particulate sampling was performed at three Texas cattle feedlots with unpaved vehicle alleys as follows:

	Capacity, Head	Region of Texas
Feedlot A	45,000	Northern High Plains
Feedlot B	42,000	Southern High Plains
Feedlot C	17,000	West Central

Feedlots A and B are within a 50-mile radius of Amarillo, and feedlot C is near San Angelo, approximately 300 miles south of feedlots A and B. The sampling program was conducted for 1 year, from January to December 1987. Each feedlot was sampled on three occasions, and a total of 15 complete experiments were conducted (Table 2).

Dust Sampling Equipment

The feedlots were monitored using high-volume samplers that were designed, built, and operated to conform to the reference method

Table 2. *Schedule of Dust Experiments at Three Texas Cattle Feedlots, 1987*

FEEDLOT	REPORT	EXPERIMENT NO.	1987	NOMINAL SAMPLE DURATION PER FILTER (HR)
Feedlot A	I	1	January 12–13	24
	I	7	May 20–21	24
	II	8	May 21–22	24
	I	11	October 6–7	4–5
	II	12	October 7–8	4–5
Feedlot B	I	2	January 14–15	24
	I	5	May 18–19	24
	I	15	December 7–8	4–5
	II	16	December 8–9	5
Feedlot C	I	3	April 14–15	24
	II	4	April 15–16	24
	I	9	August 17–18	6
	II	10	August 18–19	6
	I	13	October 14–15	4–5
	II	14	October 15–16	4–5

for total suspended particulates, which favors collection of particles up to 25 to 50 μm.[14] The air-handling systems and shelters were patterned after a commercial unit except that the support base consisted of steel legs that extended to the ground at an angle to increase stability in wind. These samplers were fabricated in the Agricultural Engineering Department at Texas A&M University. The samplers were individually calibrated using a Meriam laminar flow meter, model 50 MC2-4, to measure air flow rate for selected orifice pressure differentials at known air temperatures, station pressure, and humidity.

Each high-volume sampler was equipped with an electric blower to induce air flow downward at a known flow rate through a preweighted cellulose filter for dust capture. The Dayton vacuum motor (0.45 kw, 8 amp, 60 Hz, 120 volt) rated at 99 cfm flow rate was mounted beneath a vertical aluminum cylinder 14.0 in in length, with 3.0-in inside diameter, and 4.2-in outside diameter. Midway up the cylinder, a 1.5-in circular orifice plate was inserted between bolted flanges. Copper pressure taps were inserted 3.0-in above and 1.5-in below the orifice plate, which was 0.06-in thick, with edges beveled at 45°. The upper aluminum cylinder was threaded and screwed into a steel transition fitting, 6.0-in long that reduced the flow cross-section from the rectangular opening immediately below the filter holder cartridge to the 3-in I.D. aluminum cylinder with orifice plate. Four 1-in × 1-in steel angle iron support legs sloping outward at 20 to 26°, with crossbraces and leveling extensions on two legs, were bolted to the orifice flanges.

The shelter body was fabricated of sheet steel and had cross-sectional dimensions of 15 in × 15 in and a total height of 17 in. A horizontal metal tray with a center hole measuring 7½ in × 8¾ in was bolted directly onto the transition fitting described above and was placed 2.0-in below the top rim of the shelter body. The gable cover of sheet steel was 8-in high and had base dimensions of 21 in × 16⅝ in. The lower edges (that is, base) of the hinged cover were located 36½ to 39¼-in above the ground and 0.5-in below the top rim of the sampler body, creating a horizontal control inlet area of 118 in^2. Thus, the effective particle capture air velocity ranged from 0.81 to 1.22 ft per sec when the air flow rate was set at 40 to 60 cfm.

Filter holder cartridges from General Metal Works were used in all high-volume samplers. The filter holder area exposed to air flow was 7⅛ in × 9 in.

The air flow rate was controlled by adjusting the motor speed using a Dayton speed control (10 amp, model 4X797) mounted inside a portable plastic switch fuse box. The pressure drop across the orifice was measured with a Dwyer magnehelic gauge (0 to 5-inch water pressure). Orifice pressure differentials of 2.0 to 3.0 in were generally set.

The Sierra Andersen model 321-A selective 10μ inlet (PM-10 Sampler) was mounted atop a standard high-volume sampler body manufactured by General Metal Works. Three Wedding and Associates critical-flow high-volume PM-10 samplers were also used in some of these experiments.

Filters

Each cellulose filter with 8-in × 10-in dimensions was cut from a roll of filter material, numbered, equilibrated for moisture in a dessicator, weighed on a Mettler balance (calibrated to 0.0001 g), and placed in protective packaging until installed on a sampler. After use, the filters were folded inside a paper card filter holder, marked, and sealed in an envelope until removed for moisture equilibration and final weighing. The difference between filter weights before and after use was the weight of the dust collected. The particle weight was divided by the product of air flow rate and sampling time to yield the particulate concentration (μg per m^3).

The concentration of airborne particulates measured by upwind samplers was considered to be the ambient or background concentration. The upwind concentration was subtracted from the downwind concentration, and the difference represented the net dust emission from the feedlot.

Dust Sampling Procedures

At each feedlot, it was endeavored to place two high-volume samplers upwind of the feedpens, three samplers downwind, and one sampler at a crosswind location in case of wind shift. With sample durations of 4 to 24 hours, wind shifts of at least intermittent frequency occurred in most of the experiments. In most cases, the samplers were placed within 30 to 100 feet of the nearest feedpen, with a perimeter vehicle alley (unpaved) between the feedpen and the sampler. Greater separation distances were selected when available, but usually this would have involved placement in adjacent fields or pastures with livestock and/or under different ownership.

When the Sierra Andersen PM-10 sampler was used (experiments 11 to 16), it was always placed alongside the central downwind high-volume sampler (10 to 15 feet away) In experiments 15 and 16, the Wedding PMs were placed as follows: one upwind and two downwind with one of the downwind samplers located within 10 to 15 feet of the Sierra Andersen and center high-volume sampler at some distance from feedpens.

Most of the samplers were operated by portable gasoline generators of various sizes, makes, and models. Generators were placed 50 to 150 feet away from the samplers in a downwind or crosswind direction. Some samplers were operated off electrical plugs at feedlot facilities.

In the first seven experiments, samplers were operated 24 hours continuously without changing filters. For the last eight experiments, filters were changed at 5- or 6-hour intervals. The samplers and generators were attended at intervals of approximately 1 to 3 hours around the clock except in rare instances. The magnehelic gauge reading was reset to the original value when necessary by controlling the rheostat.

Difficulty was occasionally encountered with generator failure caused by overheating or mechanical failure, especially in hot weather. In most of these breakdowns, there was insufficient knowledge of when generator failure occurred to allow use of the filter data, but in some cases the data were usable. Heavy rainfall soon after starting caused cancellation of experiment 6, which was to be a replicate of experiment 5. In another instance, an early morning windstorm turned over two Wedding samplers, causing severe damage to one of them such that subsequent data could not be used (experiments 15 and 16). Data from several filters used at upwind samplers were not used because final weights were slightly less than the original weights. In these cases, improper moisture equilibration or static electricity was believed primarily responsible. Of the 338 filters used in these experiments, data from 306 filters were acceptable for use in the analysis.

Weather Data

Wind speed and direction were recorded in the field using a Dwyer wind speed indicator. Temperature was measured using a Taylor stainless steel thermometer before each round for checking air samplers and generators. Barometric station pressure, temperature, and relative humidity were obtained from official nearby U.S. Department of Commerce weather stations in Amarillo (for feedlots A and B) and San Angelo (feedlot C). These data were plotted for the experimental periods.

Calculation of Dust Concentrations

The mean temperature and orifice pressure differential for each time interval were calculated from field data. Humidity and station pressure for each time interval were computed by interpolating from graphs of data from the official weather data for Amarillo or San Angelo. Time-weighted averages of the above parameters representing each filter were then calculated, and these values were used to compute the actual air flow rate through each sampler from the following equation, where

$$Q = 5.976\ K\ D^2\ (\Delta P/\rho)^{1/2}$$

Q = air flow rate, cmf
K = orifice coefficient (constant for each orifice)
D = diameter of orifice plate, inches
ΔP = pressure drop across orifice plate, inches H_2O gauge
ρ = air density (function of temperature, humidity, and station pressure), lbs per ft^3

The dust concentration was calculated as:

$$\text{Concentration, } \mu g/m^3 = \frac{\text{Final Filter Weight} - \text{Initial Filter Weight}}{\text{Air Flow Rate (Q)} \times \text{Sampling Time}}$$

The concentration values for upwind samplers and for downwind samplers were averaged separately. In a few cases, there was only one upwind sampler due to wind shifts or malfunction.

The Wedding samplers use a critical flow device for air flow rate control. Equations governing the air flow rate for the Wedding samplers are described by Heber and Parnell.[6]

Particle Size Distribution

Dust particles collected on filters were subsampled and injected in a lithium chloride electrolyte solution into the Coulter particle counter (model TAII) to obtain particle size distribution (PSD) in the range of 1.26 to 100 μm. The PSD data can be useful for determining the fraction of particles below 10 μ and 2 μ (respirable dust fraction).

Odor Data

Odor measurements were taken alongside particulate samplers in most experiments. The odor measurements were made using a Barnebey-Cheney scentometer. An attempt was made to establish a correlation between dust concentrations and odor intensity levels.

Manure Sampling

In each feedlot, surface manure was sampled in five or six feedpens that were randomly selected to represent all sectors of the feedlot. The manure samples were manually extracted from two strata: (1) loose surface manure, subsampled with scoop shovel (0- to ½-in depth); and (2) loose surface manure plus compacted manure to total depth of 0 to 1 in. For both sampling depths, 15 to 20 subsamples per feedpen were collected and mixed, and 2 composite samples were extracted. These manure samples were analyzed for moisture content, ash, and nitrogen. Linear correlation between feedlot dust emissions, odor intensities, and manure moisture content was attempted.

RESULTS AND DISCUSSION

Average Dust Concentrations

The average upwind, downwind, and net dust concentrations for all experiments in chronologic sequence are presented in Table 3. Experiments 1 and 2 were conducted in January 1987 after several weeks that included precipitation. These experiments produced the lowest upwind, downwind, and net dust concentrations. The other experiments were carried out under normally dry conditions several days or weeks after rainfall and without unexpected precipitation.

High values of upwind dust concentrations relative to downwind concentrations usually resulted from variable wind patterns, which reduced the net increase in concentrations across the feedlot. A notable exception occurred in experiment 15 when a very strong wind and dust storm occurred between 3 AM and 6 AM and caused large increases in both upwind and downwind concentrations.

The highest net dust concentration for any interval (see Table 3) was 1700.1 μg per m^3. The greatest dust concentrations within 24-hour sampling periods occurred in the time interval that included the late afternoon and early evening hours of between 6 PM and 8 PM, with the exception of experiment 16, in which peak dust concentrations occurred during the day. In most cases, the lowest net concentrations occurred after midnight until almost noon the next day.

Table 3. *Average Upwind, Downwind, and Net Dust Concentrations of Total Suspended Particulate Matter, 1987*

EXPERIMENT NO.	FEEDLOT	AIR FLOW RATE (CFM)	SAMPLE DURATION (MIN)	DUST CONCENTRATION ($\mu G/M^3$) *Average Upwind*	*Average Downwind*	*Net Increase*	NOMINAL TIME INTERVAL
1	A	52.6 ± 0.6	1550 ± 60	22.3	109.6	87.3	
2	B	51.8 ± 0.6	1465 ± 44	16.5	84.0	67.5	
3	C	54.5 ± 0.3	1470 ± 17	248.8	1131.2	882.4	
4	C	55.4 ± 0.5	1435 ± 17	280.9	551.1	270.2	
5	B	57.5 ± 0.7	1452 ± 12	79.0	459.2	380.2	
7	A	56.9 ± 0.6	1452 ± 10	101.1	735.0	633.9	
8	A	56.7 ± 0.6	1382 ± 5	69.3	843.9	774.6	
9	C	56.8 ± 0.7	335 ± 13	52.5	514.3	461.8	6 PM – 12 AM
		56.3 ± 0.4	351 ± 5	59.1	187.1	128.0	12 AM – 6 AM
		55.7 + 0.6	356 ± 4	39.2	190.1	151.9	6 AM – 12 PM
		57.4 ± 0.7	365 ± 5	46.0	122.9	76.9	12 PM – 6 PM
				Mean = 49.2	253.6	204.4	
				SD = 8.6	176.5	174.4	
10	C	56.7 ± 0.6	354 ± 2	33.2	579.8	546.7	6 PM – 12 AM
		55.8 ± 0.5	385 ± 1	38.0	206.3	168.3	12 AM – 6 AM
		55.8 ± 0.7	325 ± 4	50.3	159.2	109.0	6 AM – 12 PM
		56.8 ± 0.5	363 ± 3	53.0	149.3	96.3	12 PM – 6 PM
				Mean = 43.6	273.6	230.1	
				SD = 9.6	205.6	213.4	
11	A	57.4 ± 0.6	296 ± 12	69.3	857.0	787.7	1 PM – 6 PM
		56.0 ± 1.2	310 ± 4	62.0	1762.1	1700.1	6 PM – 11 PM
		57.5 ± 2.2	298 ± 6	119.8	456.3	336.5	11 PM – 4 AM
		55.2 ± 0.7	308 ± 3	128.7	505.4	376.7	4 AM – 9 AM
		56.0 ± 0.6	245 ± 2	89.0	1197.1	1108.1	9 AM – 1 PM
				Mean = 93.7	955.6	861.8	
				SD = 29.7	541.0	565.7	

Table 3. *Continued*

Experiment No.	Feedlot	Air Flow Rate (CFM)	Sample Duration (MIN)	Dust Concentration ($\mu g/m^3$)				Nominal Time Interval
					Average Upwind	*Average Downwind*	*Net Increase*	
12	A	57.0 ± 0.5	296 ± 3		155.3	1072.8	917.5	1 PM – 6 PM
		56.9 ± 0.5	298 ± 6		63.2	1116.1	1053.0	6 PM – 11 PM
		56.4 ± 0.5	284 ± 3		47.1	438.8	391.7	11 PM – 4 AM
		55.7 ± 0.5	294 ± 2		92.1	458.6	366.5	4 AM – 9 AM
		56.8 ± 0.5	227 ± 9		123.6	332.1	208.6	9 AM – 1 PM
				Mean =	96.2	683.7	587.4	
				SD =	44.1	378.4	372.9	
13	C	55.5 ± 0.6	307 ± 4		84.8	378.2	293.5	10 AM – 3 PM
		56.5 ± 0.2	301 ± 3		64.5	552.0	487.5	3 PM – 8 PM
		55.2 ± 0.5	301 ± 6		47.2	354.0	306.9	8 PM – 1 AM
		54.8 ± 0.6	315 ± 1		29.7	181.5	151.9	1 AM – 6 AM
		55.0 ± 0.5	217 ± 10		78.9	211.3	132.4	6 AM – 10 AM
				Mean =	61.0	335.4	274.4	
				SD =	22.8	148.5	143.2	
14	C	55.1 ± 0.5	298 ± 2		42.3*	368.9	326.6	10 AM – 3 PM
		55.8 ± 0.3	303 ± 6		42.3*	720.4	678.1	3 PM – 8 PM
		55.1 ± 0.5	300 ± 11		47.5	289.8	242.3	8 PM – 1 AM
		54.7 ± 0.6	296 ± 9		95.6	111.3	15.7	1 AM – 6 AM
		54.5 ± 0.5	211 ± 9		83.8	387.0	303.3	6 AM – 10 AM
				Mean =	62.3	375.5	313.2	
				SD =	25.4	221.5	238.2	

15	B	45.8 ± 0.9	294 ± 5	103.4	576.3	473.0	5 PM–10 PM
		45.7 ± 0.4	305 ± 12	201.6	260.0	58.4	10 PM–3 AM
		45.5 ± 0.6	296 ± 6	883.7	1053.4	169.7	3 AM–8 AM
		46.0 ± 0.6	304 ± 26	229.0	398.0	169.0	8 AM–1 PM
		46.0 ± 0.5	209 ± 6	146.2	284.8	138.6	1 PM–5 PM
				Mean = 312.8	514.5	201.7	
				SD = 322.9	326.1	158.3	
16	B	44.8 ± 0.3	266 ± 10	228.4	720.3	491.9	5 PM–10 PM
		44.5 ± 0.4	365 ± 15	245.0	357.2	112.2	10 PM–3 AM
		44.4 ± 0.5	239 ± 11	155.9	463.8	307.9	3 AM–8 AM
		45.6 ± 0.5	306 ± 4	232.6	867.2	634.6	8 AM–1 PM
		46.0 ± 0.8	289 ± 14	203.7	744.8	541.2	1 PM–6 PM
				Mean = 213.1	630.7	417.5	
				SD = 35.3	211.9	208.1	
		Grand mean		116.7	529.1	412.4	
		Standard deviation		97.1	305.0	271.2	
		Range					
		Minimum		16.5	84.0	15.7	
		Maximum		883.7	1762.1	1700.1	

*Filters were used for two consecutive sampling periods.

The grand mean values for 24-hour TSP sampling at all feedlots (see Table 3) resulted in net dust increases of 412.4 ± 271.2 μg per m^3, about 37 per cent less than Algeo and coworkers reported for California and the U.S. Environmental Protection Agency used as the basis for source emission factors.[1,9] The mean upwind TSP concentration was 22.1 per cent of the mean downwind concentration, which is consistent with the findings of Algeo and coworkers.[1] Our values for upwind, downwind, and net increase all averaged lower than Algeo and colleagues measured in California feedlots.[1]

On the average, feedlot A had the lowest upwind TSP concentrations but also had the highest downwind and net increase in TSP concentrations of the three feedlots studied (Table 4). Feedlot C produced the highest 24-hour TSP concentrations both downwind and as net increase in TSP concentrations. Feedlot B produced the lowest downwind and net TSP emissions. All three feedlots exceeded the U.S. Environmental Protection Agency and the Texas Air Control Board standards for TSP on most sampling days. However, several individual sampling intervals did not exceed Texas Air Control Board standards for 5-hour sampling periods.

PM-10 Dust Concentrations

A major purpose of these experiments was to compare feedlot dust emissions measured as total suspended particulate matter (TSP) with the newer methods for 10-μm median aerodynamic particle size (PM-10). Results of a side-by-side comparison of Sierra Andersen PM-10 and one of three high-volume samplers are shown in Table 5. These results represent downwind locations with one noted exception. The mean PM-10 downwind concentrations of 233.2 μg per m^3 was only 40 per cent of the mean TSP dust concentration of 587.8 μg per m^3 for experiments 11 to 16. Net increases in PM-10 concentrations with the Andersen sampler were not measured because a second such sampler was not available for upwind monitoring.

As shown in Figure 1, there was good linear correlation between the Andersen PM-10 and the TSP results from Table 5. The following is a least-squares regression equation:

$$\text{Andersen PM-10 concentration } (\mu\text{g per m}^3) = 7.14 + 0.385 \text{ TSP concentration } (\mu\text{g per m}^3)$$

The correlation coefficient (r^2) was 0.858.

The three Wedding PM-10 samplers, used only in experiments 15 and 16 at feedlot B, collected much lower dust concentrations than the Sierra Andersen-321 and the high-volume samplers, as shown in Table 6. The mean for all Wedding PM-10 concentrations was 93.1 ± 49.9 μg per m^3. Hence the ratio of Wedding PM-10 to TSP concentrations was 19.0 per cent. The least-squares regression equation was as follows (Fig. 2):

$$\text{Wedding PM-10 concentration } (\mu\text{g per m}^3) = 40.0 + 0.109 \text{ TSP concentration } (\mu\text{g per m}^3)$$

The correlation coefficient (r^2) was 0.634.

Table 4. *Summary of High-Volume and PM-10 Particulate Matter Sampling Data for Each Feedlot (24-Hour Composite)*

	EXPERIMENT NO.	HIGH-VOLUME SAMPLERS (TSP) ($\mu g/m^3$) *Average Upwind Concentration*	*Average Downwind Concentration*	*Net Increase*	MANURE MOISTURE (%) *(0–½″) Loose Surface Manure*	*0–1 in Manure Depth**	DOWNWIND ODOR INTENSITY†
Feedlot A							
Report I	1	22.3	109.6	87.3	—	39.4 ± 5.5*	—
I	7	101.1	735.0	633.9	7.1 ± 1.5	19.9 ± 4.0	13.2
II	8	69.3	843.9	774.6			14.6
I	11	93.7 ± 29.7	955.6 ± 541.0	861.8 ± 565.7	18.3 ± 6.7	25.0 ± 3.2	25.0
II	12	96.2 ± 44.1	683.7 ± 378.4	587.4 ± 373.0			16.2
Mean ± SD		76.5 ± 32.7	665.6 ± 327.9	589.0 ± 301.1			17.3
Feedlot B							
Report I	2	16.5	84.0	67.5	—	44.0 ± 8.7*	—
I	5	79.0	459.2	380.2	8.6 ± 1.1	20.2 ± 4.1	46.3
I	15	312.8 ± 322.8	514.5 ± 326.1	201.7 ± 158.3	21.4 ± 6.7	27.8 ± 5.4	—
II	16	213.1 ± 35.3	630.7 ± 211.9	417.5 ± 208.1			—
Mean		155.4 ± 133.2	422.1 ± 236.5	266.7 ± 162.8			46.3
Feedlot C							
Report I	3	248.8	1131.2	882.4	9.7 ± 4.2	32.8 ± 4.3	—
II	4	280.9	551.1	270.2			—
I	9	49.2 ± 8.6	253.6 ± 176.5	204.4 ± 174.4	19.0 ± 7.6	26.1 ± 3.0	26.0
II	10	43.6 ± 9.6	273.7 ± 205.6	230.1 ± 213.4			46.1
I	13	61.0 ± 22.8	335.4 ± 148.5	274.4 ± 143.2	22.1 ± 5.0	28.6 ± 4.4	—
II	14	62.3 ± 25.4	375.5 ± 221.5	313.2 ± 238.2			49.4
Mean		124.3 ± 109.6	486.8 ± 333.0	362.5 ± 257.5			40.5
Grand mean		116.7 ± 97.1	529.1 ± 305.0	412.4 ± 271.2			

*Values represent manure samples at 0- to 2-in depth.
†Arithmetic mean of downwind observations.

Table 5. *Direct Comparison of Particulate Concentrations Measured with Standard High Volume Versus PM-10 Sampler at Same Downwind Location (October to December, 1987)*

FEEDLOT	EXPERIMENT NO.	NOMINAL TIME INTERVAL	HIGH VOLUME SAMPLER (TSP) (μG/M^3)	ANDERSEN PM-10 INLET (μG/M^3)
Feedlot A			*Sampler 4*	*Sampler 7*
	11	1 PM–6 PM	1,684.6	531.3
		6 PM–11 PM	1,016.5	378.5
		11 PM–4 AM	466.1	235.6
		4 AM–9 AM	658.8	222.3
		9 AM–1 PM	1,603.5	865.5
	12	1 PM–6 PM	1222.7	421.7
		6 PM–11 PM	967.6	367.9
		11 PM–4 AM	387.2	195.2
		4 AM–9 AM	207.5	23.7
		9 AM–1 PM	221.9	100.3
Feedlot C			*Sampler 6*	*Sampler 7*
	13	10 AM–3 PM	331.3	190.8
		8 AM–1 AM	412.6	225.4
		1 AM–6 AM	233.1	70.3
	14	3 PM–8 PM	777.0	274.0
		8 PM–1 AM	365.8	106.9
		1 AM–6 AM	96.8	10.5
		6 AM–10 AM	115.5*	9.5*
Feedlot B			*Sampler 3*	*Sampler 7*
	15	5 PM–10 PM	706.7	229.7
		10 PM–3 AM	191.6	116.2
		3 AM–8 AM	1,098.5	381.8
		8 AM–1 PM	373.4	145.0
		1 PM–5 PM	302.7	117.5
	16	5 PM–10 PM	228.4	190.8
		10 PM–3 AM	412.2	216.0
		3 AM–8 AM	426.0	171.4
		8 AM–1 PM	730.2	249.9
		1 PM–6 PM	632.3	249.5
Mean			587.8	233.2
Standard deviation			431.6	179.3
Ratio of means (per cent) = PM-10/TSP			—	39.7

*Upwind sample.

A direct comparison between PM-10 concentrations measured with Wedding and Sierra Andersen-321 samplers is also shown in Table 6. The Wedding instrument collected only 47.2 per cent of the amount of particulates as the Andersen-321A sampler.

The net increase in PM-10 dust concentration collected with the Wedding sampler was low, ranging from essentially zero to only 62.0 μg per m^3 for the six sets of filters wherein complete upwind and downwind results were available (Table 7), less than half the 1987 U.S.

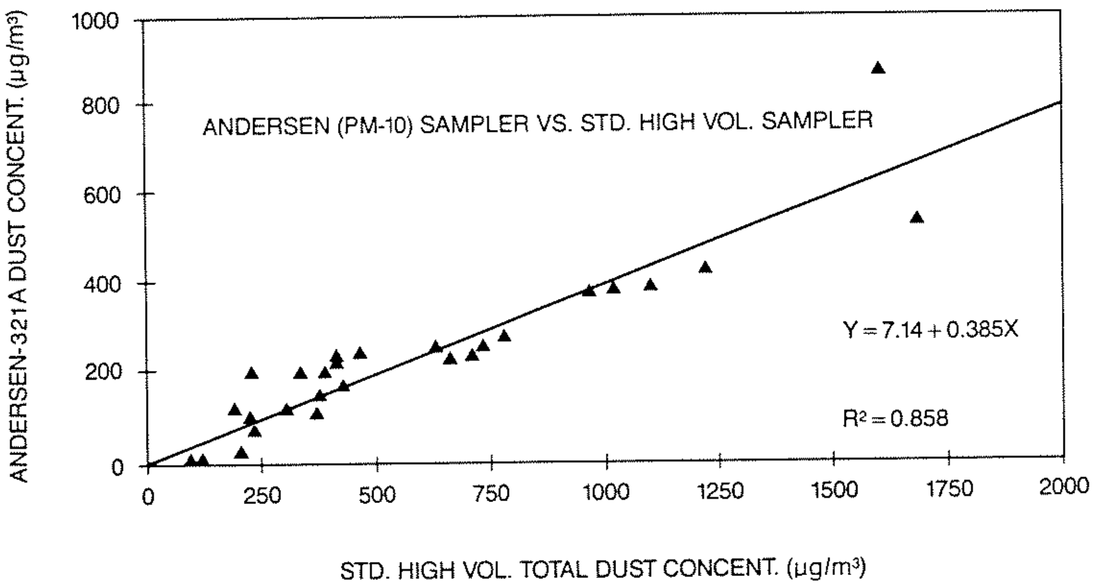

Figure 1. Relationship between dust concentrations measured with Andersen PM-10 sampler and high-volume sample (TSP).

Environmental Protection Agency standards for PM-10 particulates. The peak concentrations picked up with the Wedding PM-10 did not appear to coincide with the expected peaks in early evening caused by cattle activity. These data suggest that comparatively little of the actual feedlot manure dust may have been captured in the Wedding PM-10 instruments.

Moisture Content versus Dust Concentration

Moisture content of loose surface manure (approximately 0- to ½-in depth) in most feedpens was determined for experiments 3 to 16. The average values shown in Table 4 represented 10 to 12 subsamples (2 per feedpen sampled), and they ranged from 7.1 to 22.1 per cent. Linear regression between net TSP concentrations and the average moisture contents, using data in Table 3, resulted in a low correlation coefficient $r^2 = 0.237$, with the following equation:

$$\text{Net TSP concentration } (\mu g \text{ per } m^3) = 780 - 20.24 \text{ moisture } (\%)$$

When the top 1 or 2 in of manure was sampled (that is, including a portion or all of the compacted manure layer as well as the loose surface layer), the moisture contents were much higher (20 to 44 per cent), as shown in Table 3. Linear regression of net TSP and moisture content resulted in the relationship shown in Figure 3. However, deleting the first two experiments (representing high antecedent moisture) in which manure was sampled to 2-in depth lowered the correlation coefficient to only 0.050.

Hence, regression equations from these experiments appear to

Table 6. *Feedlot Dust Concentrations ($\mu g/m^3$) Measured with Standard High-Volume Sampler Versus Two Types of PM-10 Samplers at Same Locations*

EXPERIMENT NO.	SITE A			SITE B		SITE C	
	Standard High Volume	*Sierra Andersen PM-10*	*Wedding PM-10*	*Standard High Volume*	*Wedding PM-10*	*Standard High Volume*	*Wedding PM-10*
15	*Sampler 3*	*Sampler 7*	*Sampler 8*	*Sampler 1*	*Sampler 10*	*Sampler 5*	*Sampler 9*
	706.7	229.7	122.2	461.2	99.9	112.9*	49.0*
	191.6	116.2	47.3	157.2	35.1	67.9*	21.8*
	1098.5	381.8	164.8	—	—†	—	—†
	373.4	145.0	43.2	123.1*	30.9*	—	—†
	302.7	117.5	68.8	146.2*	17.3*	—	—†
16							
	228.4	190.8	112.4	411.3	109.5	—	—†
	412.2	216.0	106.8	431.2	167.6	—	—†
	426.0	171.4	84.8	716.2	139.6	—	—†
	730.2	249.9	110.0	1250.5	182.2	—	—†
	632.3	249.5	116.2	1279.7	126.4	—	—†
Mean	510.2	206.8	97.6	553.0	100.9	90.4	35.4
Standard deviation	280.4	79.2	37.1	446.0	60.7	31.8	19.3

*Upwind sample.
†Comparison not available because Wedding PM-10 sampler was tipped over in wind storm.

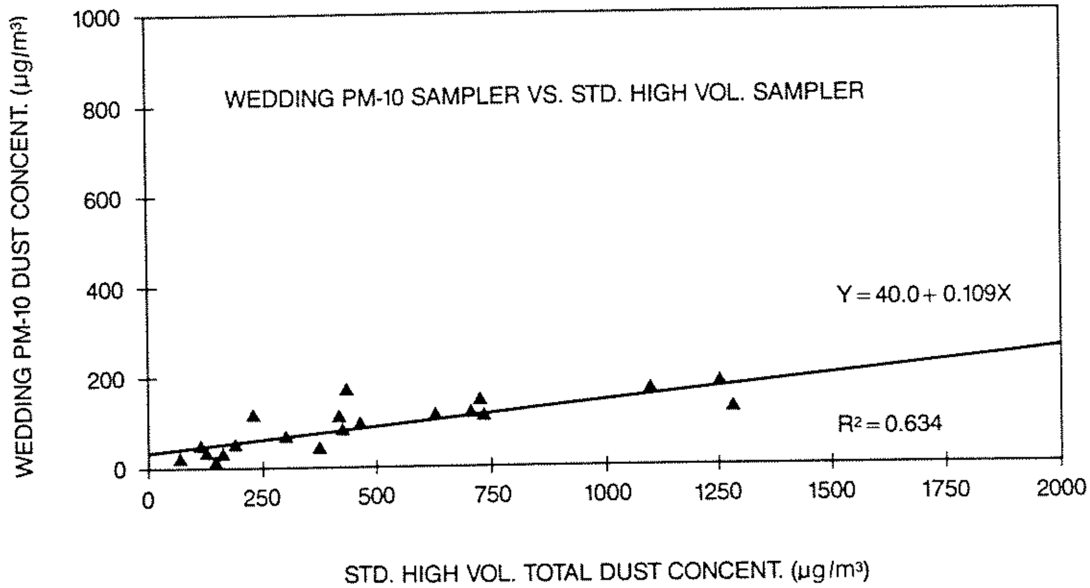

Figure 2. Relationship between dust concentrations measured with Wedding PM-10 samplers and high-volume samplers (TSP).

indicate that the range of moisture contents needed for controlling dust to allowable TSP limits of 150 and 260 μg per m^3 is 26 to 31 per cent in loose surface manure and 35 to 41 per cent in the 0- to 1-in depth.

Odor Intensity versus Dust Concentration

Scentometer observations made during eight experiments at upwind and downwind locations alongside the samplers were clearly distinguishable regardless of dust concentration. Upwind odor intensities were typically in the range of 0 to 2 dilutions to threshold (DT), while downwind concentrations were 7, 31, or 170 DT. Arithmetic average odor intensities ranged from 13 to 49 dilutions to threshold.

Linear regression of odor intensity versus net increase in dust concentration indicated that feedlot odor intensity decreased as dust emissions increased (Fig. 4), possibly due to the influence of manure moisture on odor intensity. However, both odor and manure moisture were measured in only four experiments, and the correlation coefficient for odor versus moisture content was low.

Particle Size Distribution

Particle size distribution (PSD) of dust collected on 50 exposed filters was determined for experiments 1 to 8. PSDs were determined both as per cent volume of all dust particles and as per cent of total particle population.

On a volume basis, the mean particle diameter for downwind particles ranged from 89.6 to 12.2 μm and averaged 10.2 $\pm$ 1.1 μm. Upwind particles were slightly smaller, with mean particle diameters of

Table 7. *Average Upwind, Downwind and Net Concentrations ($\mu g/m^3$) for Three Types of Particulate Samplers*

	TYPE OF SAMPLER	AVERAGE UPWIND	AVERAGE DOWNWIND	AVERAGE NET CONCENTRATION	NOMINAL TIME INTERVAL
Experiment 15					
12/7/87 – 12/8/87	Standard high volume	103.35	576.30	472.95	5 PM – 10 PM
	Wedding PM-10	49.03	111.02	61.99	
	Andersen PM-10		229.20		
	Standard high volume	201.60	260.03	58.43	10 PM – 3 AM
	Wedding PM-10	21.80	41.20	19.40	
	Anderson PM-10		116.20		
	Standard high volume	883.70	1053.37	169.67	3 AM – 8 AM
	Wedding PM-10		164.83		
	Andersen PM-10		381.80		
	Standard high volume	229.00	398.03	169.03	8 AM – 1 PM
	Wedding PM-10	30.85	43.24	12.39	
	Andersen PM-10		145.00		
	Standard high volume	146.20	284.83	138.63	1 PM – 5 PM
	Wedding PM-10	17.34	68.77	51.43	
	Andersen PM-10		117.50		

Experiment 16 12/8/87–12/9/87	Standard high volume	228.40	720.30	491.90	5 PM–10 PM
	Wedding PM-10	112.39	109.49	−2.90	
	Andersen PM-10	190.80			
	Standard high volume	245.00	357.15	112.15	10 PM–3 AM
	Wedding PM-10	106.79	167.61	60.82	
	Andersen PM-10	216.00			
	Standard high volume	155.93	463.80	307.87	3 AM–8 AM
	Wedding PM-10		112.21		
	Andersen PM-10		171.40		
	Standard high volume	232.60	867.17	634.57	8 AM–1 PM
	Wedding PM-10		146.08		
	Andersen PM-10		249.90		
	Standard high volume	203.65	744.83	541.18	1 PM–6 PM
	Wedding PM-10		121.27		
	Andersen PM-10		249.50		

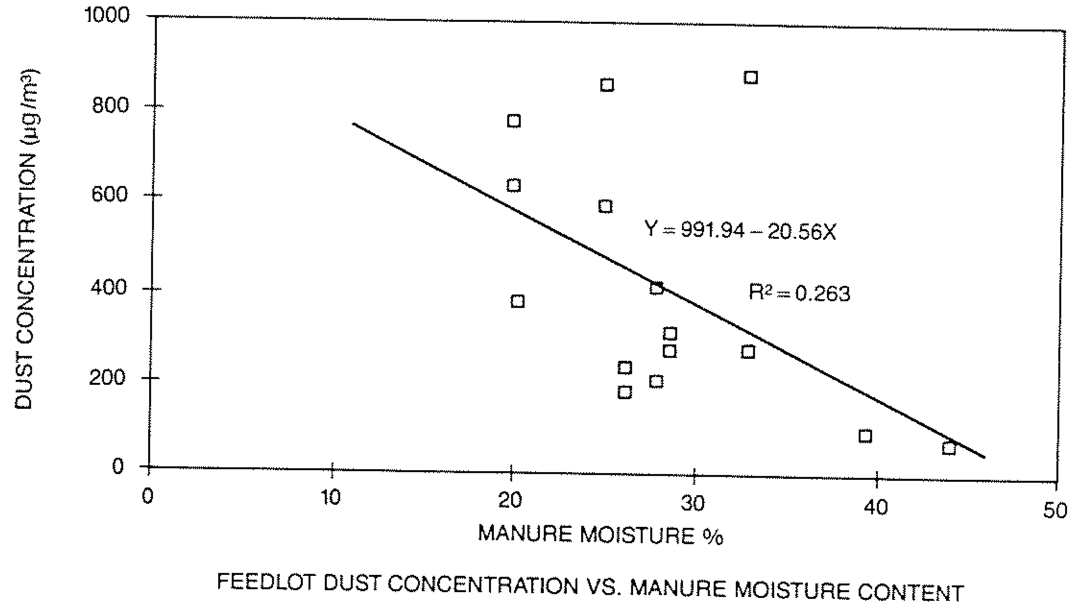

Figure 3. Relationship between manure moisture content (0- to 1-inch depth) and dust (TSP) concentration.

7.4 to 11.4 μm, averaging 9.1 ± 1.0 μm. Median particle diameters were very similar to mean values and averaged 9.4 ± 1.2 μm for upwind and 10.9 ± 1.4 μm for downwind filters. The per cent of particles above 32 μm was very low, ranging from 2.0 to 11.4 per cent.

On a particle population basis, downwind and upwind particles were similar in size, ranging from 2.55 to 3.44 μm. The per cent of respirable dust particles (below 2 μm) was only 2.0 to 4.4 per cent for all filters examined.

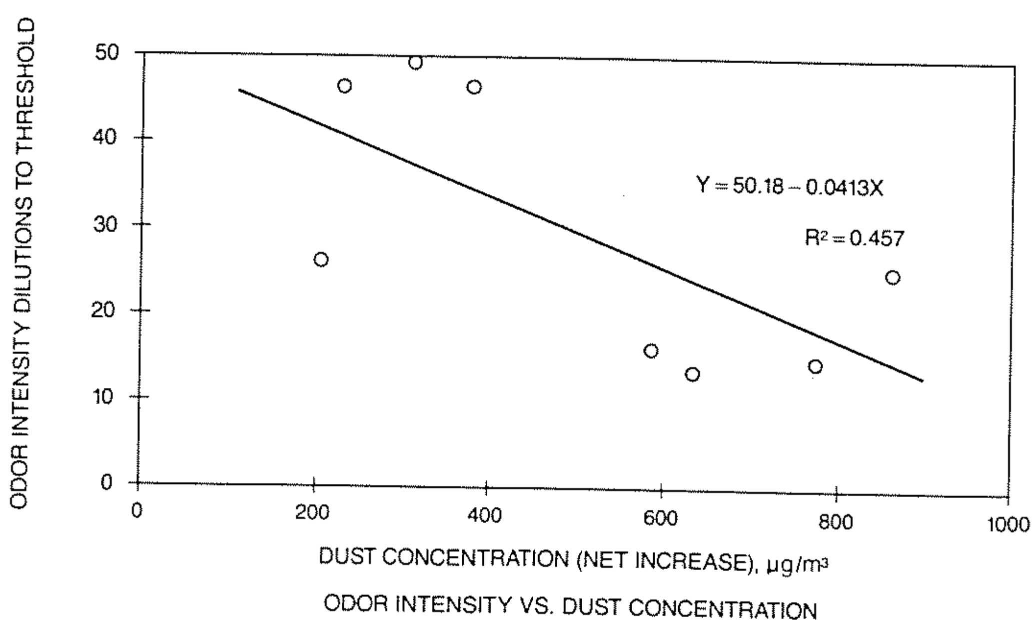

Figure 4. Relationship between odor intensity and dust concentration.

SUMMARY

Dust emissions were measured at three Texas cattle feedlots on 15 occasions in 1987 to determine concentrations of total suspended particulate matter (TSP) and dust with 10 μm or less aerodynamic particle size (PM-10). Net feedlot dust concentrations (downwind minus upwind) ranged from 15.7 to 1,700.1 μg per m^3 and averaged 412.4 $\pm$ 271.2 μg per m^3, which is about 37 per cent less than was determined in feedlot dust research in California approximately 17 years earlier. Upwind concentrations averaged 22 per cent of the downwind concentrations. Feedlot dust concentrations were generally highest in early evening and lowest in early morning.

Using the Wedding and Andersen-321A PM-10 samplers, the PM-10 dust concentrations were 19 and 40 per cent, respectively, of mean TSP concentrations in direct comparisons. There was good correlation between PM-10 and TSP concentrations.

Although dust concentrations decreased with increasing moisture, the correlation coefficients were relatively low. Odor intensity appeared to increase with decreasing net dust concentrations, perhaps due to moisture influences.

Mean particle sizes of feedlot dust were 8.5 to 12.2 μm on a particle volume basis and 2.5 to 3.4 μm on a population basis. Respirable dust (below 2 μm) represented only 2.0 to 4.4 per cent of total dust on a particle volume basis.

Under conditions of these experiments, the feedlots often exceeded both state and federal (U.S. Environmental Protection Agency) standards for TSP concentrations and for PM-10 concentrations measured using the Andersen-321A sampler. However, feedlots were below the new U.S. Environmental Protection Agency standards when the Wedding PM-10 sampler was used for measuring dust emissions.

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