Laboratory Evaluation of the Dust-Emission Potential of Cattle Feedlot Surfaces

E. B. Razote, R. G. Maghirang, B. Z. Predicala, J. P. Murphy, B. W. Auvermann, J. P. Harner III, W. L. Hargrove

Abstract. *A laboratory apparatus was developed for measuring the dust-emission potential of cattle feedlot surfaces as affected by manure surface characteristics. A feedlot surface was simulated with a layer of dry, loose, sieved feedlot manure, either with or without a compacted soil layer underneath. The vertical action of the cattle hoof was reproduced by dropping a steel weight onto the manure surface. High-volume samplers for PM_{10} (particulate matter smaller than 10 μm aerodynamic equivalent diameter) were used to collect suspended PM_{10}. The effects of kinetic energy of the falling weight, manure depth, manure moisture content, bulk density, and surface amendment (sawdust, wheat straw, and surface water application) were investigated. For each manure depth, PM_{10} emission was directly related to the kinetic energy of the falling weight. For each weight drop, PM_{10} emission did not differ significantly with manure depth. In addition, PM_{10} emission was inversely related to the manure moisture content. Compaction of the manure surface reduced PM_{10} emission. Increased amounts of water, sawdust, or wheat straw to the manure surface also significantly decreased PM_{10} emission in initial tests, but dislodging/displacement of wheat straw and penetration of the wetted surface crust by the falling weight increased the emission potential for subsequent tests. The weight drop test chamber developed is a simple and repeatable method that can be used to compare relative effectiveness of different dust abatement measures. While the measurements are reproducible, the vertical action of the cattle hoof is highly simplified; thus, the WDTC might not fully reproduce the actual vertical action of the cattle hoof on a feedlot surface. In addition, the resulting aerosol may not have similar physical characteristics as those of dust emitted from feedlots.*

Keywords. *Cattle feedyard, Dust control, Fugitive dust, PM_{10} emission.*

Particulate emission is one of the major air-quality concerns from open cattle feedlots and dairies. Major sources of particulate emissions from feedlots include the uncompacted soil/manure mixture on the pen surface, as well as the feedlot roads and alleyways (Grelinger and Lapp, 1996). Particulate emission from open feedlots can reduce visibility, especially in the early- to mid-evening periods when the atmosphere is more stable and winds are light. It also has health implications for the animals, workers, and the neighbors close to these facilities. MacVean et al. (1986) linked the health and performance of feeder cattle to the onset and magnitude of dust events. Airborne dust particles from livestock facilities can be potentially irritating and allergenic. Particles between 4 to 10 μm are deposited in the upper airways and are associated with asthma and bronchitis, while particles smaller than 2.5 μm maybe absorbed by the terminal bronchioles and alveoli and may have systemic effects (Merchant et al., 2002). Furthermore, dust particles may carry bacteria and viruses, as well as irritating gases, which may be deposited deep into the lungs where their toxic effects may be enhanced (Merchant et al., 2002). Researchers (Donham, 1991; Schiffman et al., 1995; Thorne et al., 1996; Cole et al., 2000; Iversen et al., 2000; Thu, 2002) have linked a series of respiratory problems such as asthma, organic dust toxic syndrome, and chronic bronchitis of both workers and neighbors to air-pollutant emissions from swine confinement; for open feedlots, however, the effects of air pollutant emissions on workers and neighbors are largely unknown.

With the increasing concerns for human health effects due to fine particulate matter, the U.S. Environmental Protection Agency (USEPA) replaced its total suspended particulate (TSP, particulate matter having an aerodynamic diameter less than 30 to 40 μm) standards with a PM_{10} (particulate matter having an aerodynamic diameter of 10 μm or less) standard. With the new PM_{10} standards, the primary and secondary standards for a 24 h sampling period were changed from 260 and 150 μg/m^3, respectively, to 150 μg/m^3 for both (USEPA, 1987). In addition, primary and secondary standards for $PM_{2.5}$ (particulate matter having an aerodynamic diameter of 2.5 μm or less) were added in the revised National

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Ambient Air Quality Standards (NAAQS) (Sweeten et al., 1998). As more stringent air-quality standards are being developed, there is a need to characterize and reduce air-pollutant emissions from cattle feedlots.

Manure harvesting, surface water application, and increased cattle stocking density have been recommended to control dust emission from feed pens (Carroll et al., 1974; Sweeten, 1979; Auvermann and Romanillos, 2000). Frequent removal of loose manure (Auvermann, 2001) with one to two inches maximum depth is recommended (Sweeten, 1979) to reduce the amount of material exposed to hoof action. When using surface water application, the moisture content (MC) of the surface manure should be between 25% and 40% wet basis (w.b.) to control both the dust and the odor (Sweeten, 1979; Auvermann, 2001). One way of achieving desired manure moisture to control dust emission is by manipulating the stocking density. A study on doubling the stocking density (from 14 m^2/head to 7 m^2/head cattle spacing) in a cattle feedlot showed about 20% decrease in PM_{10} concentration downwind of the feedyard (Auvermann and Romanillos, 2000). The reduced space, however, may result in increased stress and reduced cattle performance (Auvermann, 2001). Other methods, such as topical application of crop residues and chemical resins, have also been identified (Auvermann, 2001) but are still in their experimental stages. Although the abatement measures mentioned above have been reported, no studies have been done to examine their relative effectiveness in a controlled scientific manner. Therefore, research is needed to document and/or evaluate the effectiveness of the different control measures as well as to understand the relationship between dust emission rate and feedlot surface characteristics such as MC, bulk density, and organic matter content, among others.

Miller and Woodbury (2003) developed a protocol to test feedlot samples for their ability to produce dust under a variety of environmental conditions. The protocol involved mixing a small amount of feedlot sample in a modified laboratory blender and collecting the emitted particles on filters. Miller and Woodbury (2003) reported that sample moisture and organic matter content had the greatest effect on the dust potential of the samples. Their protocol gave the dust potential of feedlot samples under different field conditions. While the Miller and Woodbury (2003) protocol was simple and effective, it cannot be used to evaluate the benefit of surface amendments, e.g., application of straw.

Auvermann (2003) developed an experimental apparatus to simulate the mechanics of dust emission from a cattle feedlot. The apparatus was based on the assumption that dust emission from the corral surface is caused by the mechanical shearing action of cattle hooves on a dry, uncompacted layer of manure. The cattle hoof action that causes dust emission can be simplified into vertical and horizontal components corresponding to fore-hoof action and rear-hoof action, respectively. Auvermann's experimental apparatus simulated the vertical hoof action by dropping steel weights of standardized geometry onto a loose layer of dried, sieved feedyard manure. Auvermann (2003) observed that dust emission was proportional to the kinetic energy of the falling weight and that the depth of the loose manure layer influenced the mass of dust emitted, although the nature of the relationship was unclear.

Objectives

This particular study measured the PM_{10} emission potential caused by the vertical component of the cattle hoof action through the impact of a falling weight on a simulated manure surface. The objectives were to:

- Develop a simple and repeatable laboratory method that can be used to evaluate the dust emission potential of cattle feedlot surfaces and screen abatement measures.
- Determine the PM_{10} emission potential as affected by: (1) weight drop energy, manure depth, and presence of a compacted base soil underneath the manure layer; (2) MC of the manure layer; and (3) degree of compaction of the manure layer.
- Compare the relative effectiveness of surface amendment, i.e., water sprinkling and topical application of wheat straw and sawdust, in reducing PM_{10} emission potential.

Materials and Methods

Weight Drop Test Chamber

A laboratory apparatus, referred to as the weight-drop test chamber (WDTC), was developed and instrumented (fig. 1) for investigating the dust emission potential of cattle feedlot surfaces and screening abatement measures. The WDTC consists of 3.7 m long benchtop enclosure with a 0.61 × 0.61 m cross-section, mounted over a simulated feedlot surface (i.e., sieved feedlot manure). A cylindrical, steel weight (4.5 kg, 8.6 cm diameter) was dropped from various heights above the manure surface to reproduce the vertical hoof action on the surface. By varying the drop heights, different impact energies resulting from varying cattle weights were taken into account. The motion of the falling weight is a simple way of simulating the vertical action of a single hoof. For each height, the weight was dropped four times so that measurable masses of PM_{10} could be collected. In addition, multiple weight drops were more reproducible compared with single drops because they take into account slight variations in the alignment of the weight as it impacts the manure surface.

The WDTC was equipped with five high-volume samplers for PM_{10} (model 1200, Thermo Electron, Atlanta, Ga.) and a tapered-element oscillating microbalance or TEOM (model 1400a, Rupprecht and Patashnick Co., Inc., Albany, N.Y.) particulate mass monitor. Four of the PM_{10} samplers were used to collect the PM_{10} emission from the simulated feedlot surface; one PM_{10} sampler was placed at the inlet side of the WDTC to account for the background PM_{10} concentration. The TEOM was used to measure the PM_{10} concentration at the center of the chamber in real time. The chamber was designed to pass all dust generated through the PM_{10} samplers; the entire air volume passing through the chamber goes through the filters in the four high-volume PM_{10} samplers. Prior to the start of the experiment, the air velocity profiles at three locations in the chamber (immediately upstream of the tray, in the middle of the tray, and immediately downstream of the tray) were measured using an air velocity transducer with an omnidirectional probe tip (model 8475, TSI, Inc., Shoreview, Minn.). Results of the velocity traverse indicated that the air velocity profile became more uniform as it approached the samplers, with air

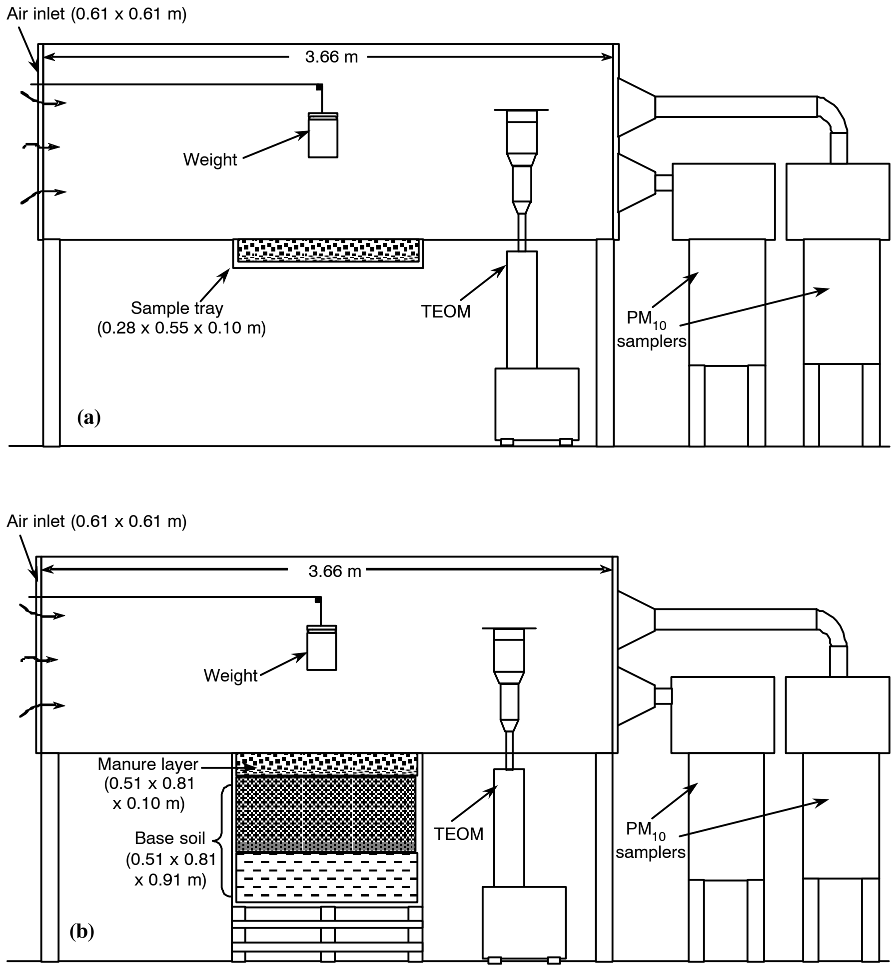

Figure 1. Schematic diagram of the weight-drop test chamber: (a) without a base soil, and (b) with a compacted base soil underneath the manure layer.

velocity ranges from 0.15 to 0.35 m/s immediately upstream of the tray, from 0.17 to 0.34 m/s in the middle of the tray, and from 0.20 to 0.30 m/s immediately downstream of the tray.

The initial design of the WDTC (fig. 1a) did not include base soil. To simulate actual feedlot conditions, a compacted base soil was added underneath the loose manure layer (fig. 1b). The base soil layer was approximately 91 cm deep and consisted of 51 cm of compacted soil from the Kansas State University (KSU) experimental feedlot and 40 cm of sand. The depth of the base soil chosen for the WDTC was determined by performing a series of tests that dropped a weight on the manure layer over varying base soil depths (0, 10, 31, 41, and 91 cm depths) and comparing the PM_{10} emissions generated. Results showed no significant difference between the PM_{10} measured with the 41 and 91 cm base soil depths, indicating that the 91 cm base soil was enough to absorb the impact of the weight. To validate this result, a chamber similar to the WDTC was placed directly on the ground and similar drop tests were conducted. High-volume samplers for TSP were used to collect particulate emissions. Similar tests were conducted in the WDTC using high-volume TSP samplers. No significant differences were detected in the TSP collected for both test cases (ground test = 59 to 65 mg; WDTC test = 64 to 69 mg).

The manure sample used in the test chamber was taken from a feedlot and was further dried and sieved to remove the clods. Standard laboratory analysis of this sample at the KSU Soil Testing Laboratory indicated an organic matter content of approximately 38%, based on the total carbon content, and sand, silt, and clay contents of 62%, 32%, and 6%, respectively. In addition, analysis of the particle size distribution by sieving (*ASAE Standards,* 2002) showed a geometric mean diameter of 117 µm and a geometric standard deviation of 2.2.

Experiments

This study investigated PM_{10} emission potential as a function of drop height (or drop energy), depth of the loose manure layer, bulk MC of the manure layer, and degree of compaction of the manure layer. The effectiveness of topical applications of wheat straw and sawdust, and surface water application in controlling PM_{10} emission were also evaluated. Table 1 summarizes the different treatments. All tests had three replicates for each treatment or treatment combination.

Test 1: Drop Energy, Manure Depth, and Base Soil

Test 1 considered the effects of weight-drop energy (9, 32, 54 J), presence of a compacted soil underneath the manure layer, and manure depth (2.5, 5.1, 10 cm) on the emission from the dry, loose manure layer (mean MC of 6.6% w.b.). The three levels of energy were achieved by dropping the 4.5 kg weight four times each from heights of 5, 18, and 31 cm, which were equivalent to drop energies of 9, 32, and 54 J, respectively. After each drop, the weight was raised

Table 1. Experimental parameters for the weight-drop experiments.

Test	Factors Investigated	Base Soil Depth (cm)	Drop Energy (J)	Manure Depth (cm)	Moisture Content (MC), Amount of Material Used, or Moisture Applied	Bulk Density (kg/m^3)
1	Drop energy, manure depth, base soil	0, 91	9, 32, 54	2.5, 5.1, 10	MC: 6.6% w.b.	759
2a	Manure bulk moisture content	0	9, 32, 54	2.5, 5.1, 10	MC: 6.1%, 20.3% w.b.	759
2b	Increasing bulk moisture content	91	54	10	MC: 6.2%, 12%, 14% w.b.	759
3	Degree of compaction of manure layer	91	14	10	MC: 6% w.b.	759, 813
4a	Topical application: wheat straw or sawdust	91	54	10	Amount of material used: 0, 242, 484, 726 g/m^2	759
4b	Surface water application	91	54	10	Amount of moisture applied: 3.2, 6.4 mm	759

carefully and moved approximately 6 cm (for those tests without base soil) or 15 cm (for those tests with base soil) longitudinally over the sample tray so that the weight impacted on an undisturbed surface on each drop. After each test, the manure was removed, replaced with a new sample, and leveled before the start of a new test.

Test 2: Manure Bulk Moisture Content

Tests 2a and 2b evaluated the effects of the MC of the manure layer on the particulate emission. Test 2a considered two levels of MC, 6.1% and 20.3% w.b. The manure sample with bulk MC of 20.3% w.b. was prepared by placing the dry sample (6% w.b. MC) into a small concrete mixer and adding a known amount of water with a water spray-fogging system. The opening of the concrete mixer was sealed during water application to minimize loss of fine particles. Moisture was added in small increments to minimize sample agglomeration. Like test 1, test 2a had three manure depths (2.5, 5.1, and 10 cm) and three levels of drop energy (9, 32, and 54 J).

Test 2b considered intermediate values of MC (12% and 14% w.b.), which were achieved by gradually adding moisture to the dry sample (6.2% w.b. MC) with the concrete mixer and spray-fogging system described earlier. Test 2b involved a drop energy of 54 J and a manure depth of 10 cm with a compacted soil layer underneath, since this combination resulted in the highest dust emission potential from test 1.

Test 3: Degree of Compaction

Dust emission from the feedlot surface is affected by the degree of compaction of the manure surface. Loose manure could potentially result in greater dust emission, compared with that from a compacted manure surface (Auvermann, 2001). Test 3 compared particulate emissions from a loose manure surface (bulk density = 759 kg/m^3) and a slightly compacted surface (mean bulk density = 813 kg/m^3). A manure depth of 10 cm with a compacted soil layer underneath and a drop energy of 14 J was used. The slightly compacted surface was prepared by filling the sample tray with loose manure (approximately 12.5 cm) and gradually applying a uniform compaction force on the entire manure surface. The drop energy of 14 J was achieved by dropping the 4.5 kg weight once from a height of 31 cm above the manure surface.

Test 4: Surface Amendment

Potential reduction in PM_{10} emissions from surface application of wheat straw, sawdust, and water (water sprinkling) was examined. Tests involving wheat straw and sawdust used pre-determined amounts of wheat straw (MC = 9.4% w.b.) and sawdust (MC = 7.5% w.b.) (242, 484, and 726 g/m^2) that were uniformly placed on the surface of the dry manure sample (test 4a). Emission tests were conducted with a drop energy of 54 J and a manure depth of 10 cm with base soil. A dry manure sample with no materials placed on the surface served as control. Five consecutive tests, in which the weight was dropped on the same spot for each successive test without restoring the manure surface, were conducted on the treatment that gave the least PM_{10} emission.

Tests involving water sprinkling uniformly applied pre-determined amounts of moisture (3.2 and 6.4 mm) on the surface of the dry manure surface with a manual sprayer (test 4b). After spraying, the sample was allowed to stand for 30 min to allow the applied water to infiltrate into the sample. Five consecutive tests similar to that for surface addition of materials were conducted on each sample.

Particulate Sampling and Ancillary Measurements

The emitted particulates were collected on pre-conditioned 20 × 25 cm, type A/E, glass-fiber filters (Gelman Sciences, Ann Arbor, Mich.) in the four high-volume PM_{10} samplers downstream of the WDTC. Each sampler was operated at a sampling flow rate of 1.13 m^3/min. The combined flow rate of the four samplers generated an airflow within the chamber that was equivalent to approximately 0.8 km/h average wind speed, as measured by an omnidirectional probe (model 8475, TSI, Inc., Shoreview, Minn.). The samplers were run for 15 min, after which the filters were immediately removed and placed in a conditioning container. The filters were conditioned in the container (25°C, 50% relative humidity) for 24 h before weighing (for both pre-sampling and post-sampling weights) to minimize the humidity effect on filter weights. The MC of the manure sample, before and after each test, was determined by using the ASTM D 2216-98 oven-drying method (ASTM, 2002). The PM_{10} emission potential (in mg) was determined as the mass difference between particulate collected on the four downstream filters and that collected on the upstream filter.

Air temperature, relative humidity, and air pressure were measured during all the tests. Average air temperature from all the tests was 25°C ±0.89°C, average relative humidity was 44% ±11%, and average barometric pressure was 742 mm ±7 mm Hg.

Data Analysis

The General Linear Model procedure was used to analyze the effects of drop energy, manure bulk density, and manure MC on the PM_{10} emission potential and average TEOM concentrations (SAS v9.1, Cary, N.C.). A 5% level of significance was used throughout, unless otherwise stated.

Results and Discussion

Test 1: Drop Energy, Manure Depth, and Base Soil

Measured PM_{10} emissions from the manure surface as a function of drop energy for each of the three manure depths, both with and without the base soil underneath the manure layer was plotted (fig. 2). For the trial with no base soil, comparison of all test combinations of drop energies and manure depths showed that the 10 cm manure depths at 9 J drop energy gave the lowest PM_{10} emission potential, while the 2.5 cm manure depth at 54 J drop energy gave the highest PM_{10} emission potential (fig. 2, table 2). Comparison of the drop energy levels showed that the PM_{10} emission potential increased with each increase in drop energy level. Additionally, results indicated an inverse relationship between PM_{10} emission and manure depth, with the 2.5 cm manure depth having significantly higher PM_{10} emission potential compared with the 5.1 and 10 cm manure depths for the 54 J drop energy. The same trend was observed from the time-resolved measurements with the TEOM. At a drop energy of 54 J, the greatest peak PM_{10} concentration was measured for the 2.5 cm manure depth (722 $\mu g/m^3$), and the lowest peak concentration was measured for the 10 cm manure depth (485 $\mu g/m^3$) (fig. 3). As indicated by Auvermann (2003), this unexpected relationship between manure depth and dust emission can be attributed to the possibility of experimental artifacts in the test chamber, wherein the greater manure depth might have absorbed the impact of the falling weight. In an actual feedyard, the impact of the cattle hoof is absorbed both by the manure layer and the soil underneath. In the test chamber, however, there was nothing to absorb the impact of the falling weight except for the manure layer. Thus, the greater manure depth might have absorbed the impact more than the shallower manure depth did, resulting in lower PM_{10} emission potential. Another set of tests with a base soil underneath the manure layer was then conducted.

With the presence of base soil, the effect of drop energy on PM_{10} emission potential followed the same trend as that without base soil; the highest drop energy (54 J) generated the greatest PM_{10} emission for all manure depths, compared with drop energies of 32 J and 9 J (fig. 2, table 2). Comparison of the drop energy levels showed that the PM_{10} emission potential increased with each increase in drop energy level. No significant differences between PM_{10} emissions were measured among the three manure depths within each level of drop energy. Time-resolved measurements showed similar trends (fig. 3). These results suggest that the drop energy affects the PM_{10} emission potential more than the manure depth. Furthermore, for a given drop energy and manure depth, PM_{10} emission potential was significantly less from the manure surface with the 91 cm base soil than from the manure surface without any base soil underneath, except for the 9 J drop energy, in which no significant difference was measured for the 5.1 cm and 10 cm manure depths (fig. 2, table 2). These results support the assumption that the base soil absorbed the extraneous impact energy, causing a reduction in PM_{10} emission.

Table 2. Mean PM_{10} emission potential as affected by drop energy, manure depth, and presence of base soil.

Drop Energy (J)	Manure Depth (cm)	Mean PM_{10} Emission Potential (mg)[a]	
		Without Base Soil	With Base Soil
54	2.5	60.5 a *	23.3 a +
	5.1	39.4 b *	22.9 a +
	10.0	39.0 b *	22.7 a +
32	2.5	44.2 ab *	17.6 ab +
	5.1	32.1 bc *	17.0 ab +
	10.0	34.8 bc *	16.2 ab +
9	2.5	25.1 bc *	10.0 b +
	5.1	16.9 cd +	11.0 b +
	10.0	12.4 d +	11.7 b +

[a] Column means followed by the same letter and row means followed by the same symbol are not significantly different at the 5% level.

Test 2: Manure Bulk Moisture Content

For all drop energies and manure depths, the mean PM_{10} emission from the 20.3% MC sample (ranging from negligible to 3.0 mg) was significantly less than that from the 6.1% MC sample (ranging from 12.4 to 60.5 mg) (fig. 4) when the WDTC was used without base soil. In addition, for the low-moisture sample (6.1% w.b.), drop energy (from 9 to 54 J) greatly affected PM_{10} emission. This could be attributed to the increased impaction and penetration of the steel weight on the loose manure surface resulting in more loose manure displacement and, thus, more fine particles in the air. For the high-moisture sample (20.3% w.b.), on the other hand, drop energy had a limited effect on emission. For the TEOM measurements, similar trends were observed; PM_{10} concentration was higher for the 6.1% w.b. MC than for the 20.3% w.b. MC sample for all drop energies and manure depths (fig. 5).

With the intermediate values of MC, drop tests in the WDTC with base soil showed that the PM_{10} emission

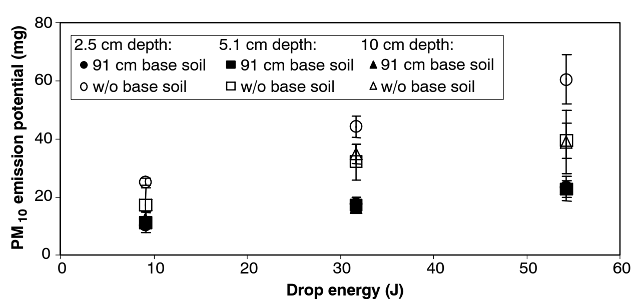

Figure 2. Mean PM_{10} emission from the manure surface, with and without base soil, as affected by drop energy and manure depth. Each data point is the average of three replicates; error bars represent 95% confidence intervals.

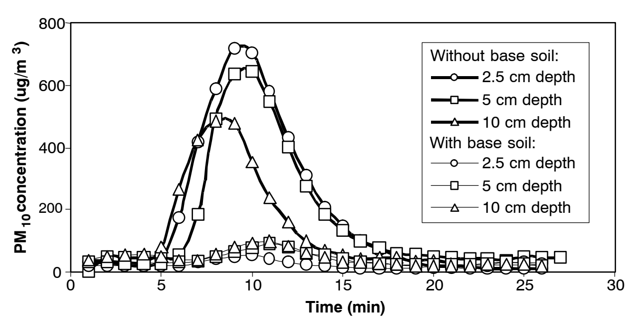

Figure 3. Time-resolved TEOM PM_{10} concentrations at different manure depths, as affected by the presence of a base soil underneath the manure layer. Drop energy was 54 J. Each data point is the average of three replicates.

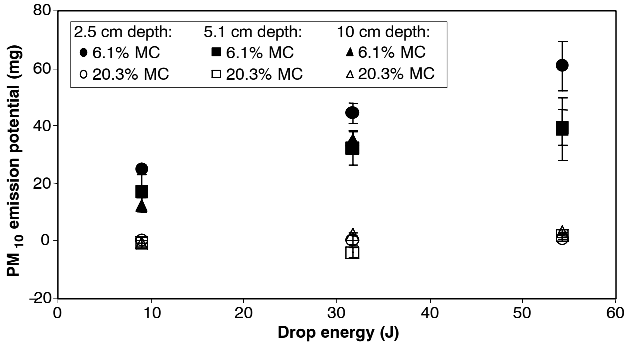

Figure 4. Mean PM_{10} emission for the 6.1% and 20.3% w.b. MC manure samples, as affected by drop energy and manure depth. Each data point is the average of three replicates; error bars represent the 95% confidence limits.

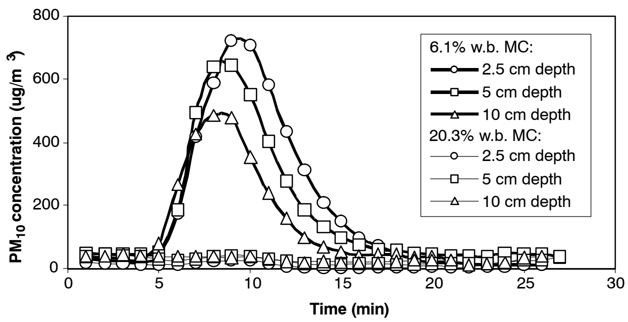

Figure 5. Time-resolved TEOM PM_{10} concentrations at different manure depths, as affected by manure bulk moisture content. Drop energy used was 54 J. Each data point is the average of three replicates.

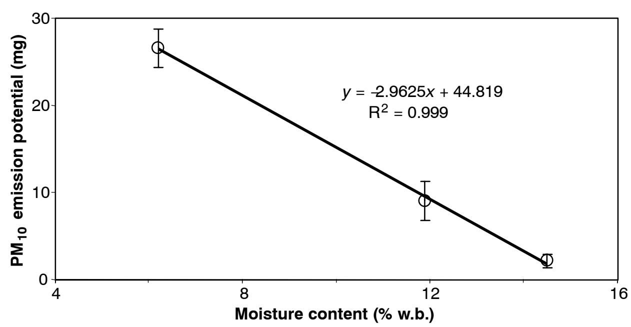

Figure 6. PM_{10} emission potential of the manure sample with 91 cm base soil underneath, as affected by manure bulk moisture content (drop energy = 54 J, manure depth = 10 cm). Each data point is the average of three replicates; error bars represent 95% confidence intervals.

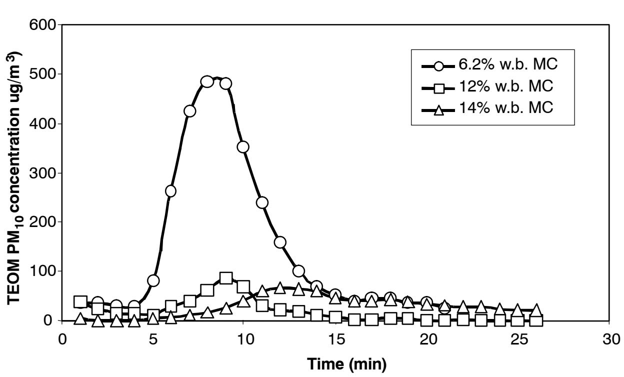

Figure 7. Time-resolved TEOM PM_{10} concentrations at increasing manure bulk moisture content. Drop energy used was 54 J. Each data point is the average of three replicates.

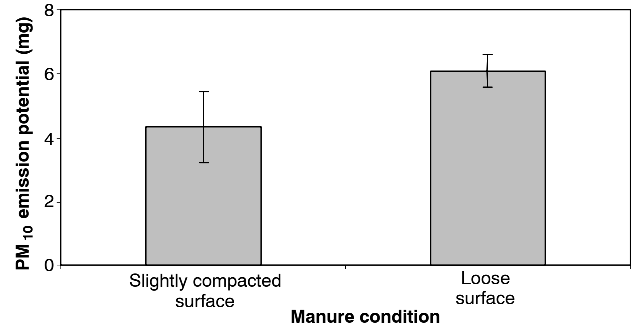

Figure 8. Comparison of the PM_{10} emission potential between loose (759 kg/m^3 bulk density) and compacted (813 kg/m^3 bulk density) manure at 14 J drop energy and 10 cm manure depth. Each data point is the average of three replicates; error bars represent 95% confidence intervals.

potential of the manure sample was inversely related to manure bulk MC. The PM emissions for the 6.2%, 12%, and 14% w.b. MC manure were 26, 9, and 2 mg, respectively (fig. 6). Time-resolved measurements using the TEOM showed a similar trend (fig. 7). These results suggest that increasing the manure bulk MC from 6.2% w.b. to 12% w.b. alone can reduce the emission potential by 66%.

Test 3: Degree of Compaction

PM_{10} emission potential was significantly less for the slightly compacted manure surface than for the loose manure surface (4.35 mg vs. 6.10 mg) (fig. 8). Compaction of the dry manure layer, even without adding water to it, could still reduce the potential emissions by about 30%, at least with respect to the vertical cattle hoof action. This observation agrees with the current field recommendation of maintaining 2 to 5 cm of compacted manure to reduce dust emission (Auvermann, 2001).

Test 4: Surface Amendment

Relative to the control (emission = 19.2 ±1.64 mg), PM_{10} emissions decreased by 36% and 14% with application of 242 g/m^2 of wheat straw and sawdust, respectively (fig. 9). Increasing the amount of wheat straw and sawdust to 726 g/m^2 reduced the PM_{10} emission by 76% and 69%, respectively. No significant difference in PM_{10} emission potential was measured between sawdust and wheat straw in all application rates except at 242 g/m^2, where wheat straw

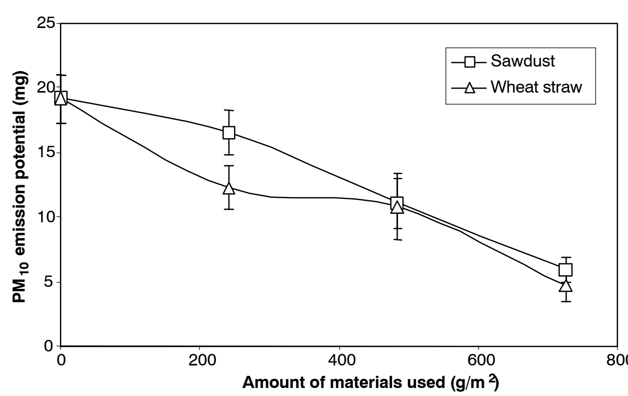

Figure 9. Effect of topical application of wheat straw and sawdust on PM_{10} emission. Emission tests were done with 54 J drop energy and 10 cm manure depth. Each data point is the average of three replicates; error bars represent 95% confidence interval.

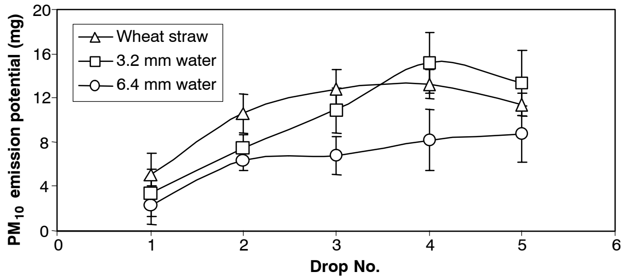

Figure 10. Effectiveness of wheat straw and surface water application to reduce PM_{10} emission after five successive drops on the same location. Emission tests were done with 54 J drop energy and 10 cm manure depth. Each data point is the average of three replicates; error bars represent 95% confidence intervals.

(emission = 12.2 ±1.46 mg) had significantly lower emission potential than sawdust (emission = 16.5 ±1.54 mg). At lesser application rates, the wheat straw reduced the impact of the falling weight better than the sawdust, which potentially resulted in much lower PM_{10} emissions.

Water sprinkling greatly reduced the PM_{10} emissions (3.4 mg at 3.2 mm water; 2.3 mg at 6.4 mm water), compared to the control (19.2 mg) (fig. 10). However, in subsequent tests in which the weight was again dropped at the same location, PM_{10} emissions significantly increased (fig. 10). Dropping the weight repetitively in the same location caused the weight to penetrate through the wet surface layer, allowing dry dust particles underneath to be released. The increase in emissions during the subsequent tests was greater for the 3.2 mm moisture application than for the 6.4 mm moisture application. These results suggest that moisture application that does not penetrate throughout the vertical profile of the dry, loose manure layer will have limited benefits except immediately after application.

Five successive drop tests using 726 g/m^2 wheat straw were conducted to compare the effectiveness of wheat straw in reducing PM_{10} emission with that of surface water application. The reduction in PM_{10} emission by using 726 g/m^2 of wheat straw was similar to that of surface water application (fig. 10). Subsequent tests resulted in a similarly significant increase in PM_{10} emissions. The impact of the falling weight caused the wheat straw to be dislodged, reducing its cushioning effect on the weight and allowing particles to be released in the subsequent tests.

Summary and Conclusions

A simple and repeatable method for evaluating potential dust abatement measures for open cattle feedlots was developed. Furthermore, this study quantified some of the factors that may affect the emission of dust from a cattle feedlot. Results suggested that the impact energy of the cattle hoof, more than the depth of the manure surface, affects PM_{10} emission potential. This implies that for a given vertical hoof energy and manure surface condition, manure could be left to accumulate for up to 10 cm without significantly increasing the PM_{10} emission potential. Results of the WDTC trials also demonstrated the potential particulate emission reductions of recommended dust control measures. Manure compaction, surface application of moisture, and topical application of crop residues greatly reduced PM_{10} emission potential. Results suggested that to achieve close to negligible PM_{10} emission potential, manure MC should be around 20% w.b., lower than the recommended 25% to 40% w.b. MC. Higher MC is probably needed in the field to account for weather conditions. With respect to the methods tested, surface application of moisture offered the greatest potential reduction in PM_{10} emission values based on WDTC trials. Results implied that moisture should penetrate at least 6.4 mm of the loose manure layer to sustain the reduced potential emission.

While the measurements are reproducible, the vertical action of the cattle hoof is highly simplified and thus the WDTC might not fully reproduce the actual vertical action of a cattle hoof on a feedlot surface. In addition, the resulting aerosol may not have similar physical characteristics as those of dust emitted from feedlots. Additionally, the potential PM_{10} emissions resulting from this study are relative values that can be used to assess the effectiveness of dust abatement measures and/or the relative effects of feedlot surface conditions (e.g., moisture content, depth, degree of compaction). Field studies should be conducted to verify the results obtained from this study as well as the ease and practicality of the method. Future studies will investigate emissions associated with the horizontal shearing action of the hoof on the feedlot surface.

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