

HORSE RIDING ARENA DUST MEASUREMENTS

E. F. Wheeler, N.K. Diehl, J. L. Zajaczkowski, D. Brown¹

ABSTRACT

Horses and riders are exposed to irritating levels of dust that is lofted during activity in riding arenas. The riding surface, or footing material, is typically a soil-like or organic-based material. A study was conducted in two indoor horseback riding arenas where total and respirable dust was collected over three sampling periods via gravimetric methods. Gravimetric procedures necessitate humidity and static electricity control during weighing evaluations. Even with these precautions, redundant samplers are recommended. Dust was associated with the overall quality of the footing in the arena, with greater dust detected from the footing of lower moisture content with a greater percentage of fine particles (inorganic footing). Dust detection in the arenas was greater and more appropriate when calculated according to level of horse activity in a session. Total dust level was 0.612 mg/m³ or 3.395 mg/m³ (organic and inorganic footing, respectively) when calculated based on time arena was occupied by horses. Both dust levels were 2-1/2 to 3 times higher than this during times of horse activity faster than a walk. Respirable particles were 54 to 60% of the total dust during riding activity.

KEYWORDS. Equine, particulate matter, gravimetric, riding arena, horse, dust

INTRODUCTION

Extensive studies have linked inhalation of stable dusts from hay and bedding with clinical signs of lower respiratory tract disease in the horse (Clarke, 1987). Furthermore, it has been well established that particulate matter (PM) measured at the level of the horse's nose will be significantly higher than that measured from a static location elsewhere in the horse's local environment (Bartz and Hartung, 1993; Clarke, 1993). Besides the stable environment, horses, riders, and instructors are exposed to irritating levels of particulate matter (PM) arising from the footing material used in the arena riding surface (Barton et al., 2001). Unfortunately, the scientific literature has very limited quantitative information on the riding arena environment as a source of respiratory irritants.

Studies quantifying stable dust have largely used the gravimetric sampling technique, where dust is collected on a filter and weighed, using stationary samplers: Navarotto et al (1994) gravitational w/pump and filters; Woods et al (1993) gravimetric impactor, 6 hours. However, gravimetric personal samplers have been used to measure respirable dust in the horse's breathing zone: Bartz and Hartung (1993) 6 hour sampling time, Woods et al (1993) 6 hours and McGorum et al (1998) 4 to 10 hours. Gravimetric samplers require several hours to accumulate sufficient measurable dust so cannot give real-time data. Of interest is the respirable portion of dust (< 5µm aerodynamic diameter) that is likely to travel further into a horse respiratory tract. Total dust is of interest from an air quality and nuisance standpoint.

A close examination of the research that quantifies dust in horse environments reveals some studies with poorly defined methods and lack of compliance with standards, such as ASTM

¹ E. F. Wheeler, Associate Professor, J. L. Zajaczkowski, Senior Research Technologist, D. Brown, Graduate Student, Agricultural and Biological Engineering Department, N.K. Diehl, Assistant Professor, Dairy and Animal Science Department, The Pennsylvania State University, University Park, PA 16802.

(2003), when methods are well-defined. Ambient temperature and relative humidity affect footing material moisture content and drying time so should be monitored. Ventilation rate affects the levels of dust in the air and settling time of suspended particles (Wang et al, 1997). Most stables and indoor riding arenas use natural-ventilation so determination of ventilation rate is not straightforward. This paper describes efforts to achieve quality assurance in measurement of dust in the horse riding arena environment and the results of dust quantification in two riding arenas over several sampling periods. The primary project objective was to develop and use quality-assured gravimetric protocols to collect reliable and repeatable measurements of total and respirable particulate matter in riding arenas.

MATERIALS AND METHODS

Indoor Arenas

Two indoor riding arenas in central Pennsylvania were monitored for PM during riding sessions in spring 2004. Farm J indoor arena (45.8 by 19.5 x 4.9 m height); wood frame, metal siding, eave-ridge and endwall door ventilation) had a low-density organic footing material footing composed of stall waste (sawdust-shavings and manure) that was usually replaced annually. Farm Q indoor arena (30.5 by 45.8 x 6.1 m height); steel rigid arch, metal siding, endwall door ventilation) had a sand footing, with the only organic material source being manure deposited by horses present in the arena. The sand footing was closer in consistency to a sandy soil than pure sand and was relatively easy to compact compared to a new, pure sand footing material. These two arenas were chosen in order to evaluate widely different arena surface materials. Farm J had a low density, organic (organic matter content 85.4%, std. dev. 5.6%, n=9 subsamples of arena footing) and Farm Q a dense, inorganic material (5.4%, std. dev. 1.4% organic matter content). Both farms were well managed by experienced owners.

Three PM monitoring sessions were conducted over a week and timed to coincide with arena dust-suppression activity. A water sprinkling system was used in each arena to wet the footing material; tractor-pulled water tank with gravity-spray boom at Farm J and manually placed sprinklers at Farm Q. Watering events are designated as: immediately following wetting of the footing material (WET), approximately 3 days following wetting representing moderate conditions (MOD), and just before another planned wetting of the footing material (DRY), approximately 7 days after wetting.

During sampling, temperature and relative humidity in each indoor riding ring were recorded using indoor/outdoor dataloggers (Hobo Pro, H08-032-08; Onset Computer Corporation; Bourne, MA, USA). During monitoring periods, both arenas were under minimum natural ventilation conditions with all endwall doors closed resulting in low expected air speeds over the footing surface.

Particulate matter measurement

Particulate matter samples in each indoor riding ring were collected using gravimetric 37 mm diameter personal samplers (AFC123; BGI Incorporated; Waltham, MA). Some of these samplers also used respirable dust cyclones (BGI4L, BGI Incorporated; Waltham, MA; 50% cut-off at 4 μ m). During each evaluation period four samplers were used: two collecting respirable dust; two collecting total dust. Two samplers were used for each feature for redundancy and to indicate variability of measurement. The instrumentation was placed in a stationary location 0.5 m above the footing surface in an area of horse traffic. Dust was collected over sampling times of 5-10 hours when the arenas were occupied by horses.

Filter papers must be non-hygroscopic and the relative humidity in the lab where measurements were made must be maintained under 50% (ASTM, 2003) to reduce the effect of moisture absorption on the filter paper weight. Mixed-cellulose ester (MCE) filter papers were used. The filter papers and support for the cassettes were stored inside a desiccator. After a dust collection event, cassettes and filters were allowed to equilibrate in the desiccator for 24 hours before being

weighed. During weighing, the laboratory temperature and relative humidity were monitored, recorded and found to be below 50%.

Static charge of the filter paper and of the dust collected on the paper can cause poor repeatability of the balance readings and possibly cause the filter paper to repel dust during sampling. Static charge control was the single largest challenge in quality assurance for the gravimetric evaluations. Before static charge control was enacted in this project, the filter paper would cling to objects and was attracted to the metal components of the balance. Prior to weighing, each filter paper for dust collection was removed from the desiccator, set on a balance chamber ionizer (StaticMaster® 1U400, by NRD, LLC, Grand Island, NY, USA) for approximately 5 seconds to neutralize static electricity, and then weighed on an annually-calibrated analytical balance with a precision of 0.0001 g.

All samples were weighed three times in a row for repeatability and the average of the three weights was used as the pre or post sampling weight for gravimetric calculations. Filter paper tongs were used to handle filter paper to prevent oils from the hand contaminating the sample. The amount of arena dust collected during sampling was calculated as the average of the three filters weighing of mass post-sampling minus the average mass pre-sampling. The average dust concentration for each personal sampler was then calculated using the following equation:

$$C = \frac{10^6 m_{dust}}{Qt}$$

m_{dust} = mass dust collected on each filter, g

C = average dust concentration, mg/m³

Q = average sampler pump flow rate during sample period, L/min

t = length of the sampling period, minutes

10⁶ = conversion 1000 mg/g x 1000 L/m³

Low or pulsating flow from the personal sampler pumps will decrease in the amount of dust captured on the filters. The flow rate of air over the filters in the cassettes also determines the size range of particles captured. Pump flow rate was measured (Visi-Float Series Flowmeters, Dwyer Instruments Inc., Michigan City, IN, USA) to determine there was no effective difference in flow rate in relation to the length of the tubing (30-50 cm), however the cassette with filter paper consistently reduced the flow rate by 0.1 L/min. Therefore, for all sampling periods, the pumps on the personal samplers were checked in the field prior to the start of sampling, with the tubing and dust collection cassettes attached, to assure an initial flow rate of 1.9 L/min. At the end of the sampling period the flow rates were again measured and it was determined that they did not all stay within the ASTM (2003) 5% variability standard. Flow rates presumably changed over the long sampling period from the effect of dust accumulation over the filter papers, although this rate of change was unknown. The average of pre- and post-test flow rates was used in calculations of dust concentration.

Horse riding activity

Monitoring an arena where no horse riding activity occurs will not provide useful information since dust is generated by horse hoof action. In order to correlate dust concentrations with horse activity, a video camera with VCR recorded horse activity in each indoor riding ring during sampling. Time of horse activity was used as the base time for dust collection calculations. The area near the personal samplers was the focus of the filming, but an estimated 80% of the entire arena interior was within camera view. Video recordings over the entire sampling period were reviewed and the times recorded in minutes for each horse's total time in the arena, time at stand or walk, time at trot, and time at canter.

Horse Stable Dust Comparison

In order to determine if riding arena dust measurements were reliable, measures were done on stabled horses to replicate previous studies. Total dust was measured within the breathing zone of two horses (two cassettes per horse) for 6 hours and 40 minutes during December 2003 while horses were in a stall. Stalls were well ventilated and horses were provided free choice hay on the ground. Relatively low concentrations of total dust were obtained here (0.987 mg/m³ average; std.dev. 0.348 mg/m³) as compared with those obtained by Bartz and Hartung (1993) averaging 2.05 mg/m³ total dust and Woods et al (1993) averaging 17.5 mg/m³ total dust.

Footing Material Characteristics

Footing samples of the top 5 cm of footing material were collected at the start of each monitoring period. Four samples were taken in a half-circular pattern within 10 m of the PM monitoring location and mixed to form a composite sample. To determine footing moisture content, three small sub-samples of the composite footing material from each sampling period were dried and measured according to standard methods (24-48 hrs, 50 °C) using a relatively low temperature to avoid organic material destruction.

Footing fines were submitted to the Particle Characterization Laboratory at the Pennsylvania State University for particle size analyses. The composite footing sample from one monitoring session at each farm was sieved by standard methods (oven dried sample overnight 50°C; pre- and post-weight on scale PG3001 Mettler Toledo [Switzerland]; top sieve capped; shaken 20 min.) using 6.35, 4, 10, 18, 30, 60, and 140 sieve sizes corresponding, respectively to 19.05, 4.76, 2.00, 1.00, 0.60, 0.25, 0.106 mm equivalent diameter particles. The sieved component representing <106 micron diameter particles was submitted for particle size distribution using a laser diffraction instrument (Mastersizer S, wet and dry, range 0.05-900um, Malvern Instruments Ltd., Worcestershire, UK). This fine portion of the footing material was presumed to contribute to arena dust due to its small size and mass. Additional evaluations (elemental, microscope particle size analysis) were performed on footing samples and dust collected on the filter papers and reported in Diehl et al 2004.

RESULTS AND DISCUSSION

Particulate Matter Concentration

Total and respirable PM concentrations in two riding arenas on three occasions each are summarized in Table 1 as measured by gravimetric methods. The ratio of respirable to total dust averaged over the total time of collection sessions for each farm showed that about 66% of the dust collected was respirable at Farm J and about 60% at Farm Q. Dust collected over the entire sampling interval “All Time” were low but when dust concentration was expressed in terms of actual riding time, dust exposure greatly increased.

The dust concentration was calculated according to the arena’s horse-occupied time (Occup) and horse activity (Riding) time at gait faster than a walk. Table 2 documents horse activity. Final calculation of occupied and riding time was the sum of individual horse times. For example, the Farm J WET total horse occupied time of 314:43 min:sec out of 338 minutes recording time does not indicate there were horses in the arena all 314 minutes; it indicates the occupied time by summing all the horses times of occupation. For example during a riding lesson with three horses in the arena at once over 25 minutes, that sums to 75 minutes of occupied time. It should be noted how little of the “occupied” time is spent exercising at faster than a walk and subsequently little opportunity for significant dust dispersal into the environment over the sampling period. The two stables studied were considered average in activity level across similar recreational and competitive activities.

The ratio of respirable to total dust collected on average over the active “Riding” time of the monitoring sessions was about 60% for Farm J and 54% for Farm Q. This indicates that very fine material was becoming airborne by hoof action from the footing material so that the

majority of the dust captured at the 0.5m high sampler site was respirable. Larger particles could not be expected to loft or travel as far in the air as the lighter respirable particles.

Both total and respirable dust concentrations were uniformly greatest when calculated according to horse “Riding” time (ride at speed > walk). This, along with the observation that a significant portion of the usual riding activity in an arena is associated with standing or walking the horse, may be why so little dust was measured during a session of riding arena activity when calculated based on “All Time” of sampling. Average respirable dust during “Riding” time over all monitoring sessions for each arena was 0.892 mg/m³ for Farm J and 5.12 mg/m³ for Farm Q. There was 2-1/2 times (Farm J) to almost 3 times (Farm Q) as much respirable or total dust when calculated based on riding activity as compared to occupied time. The levels of total dust concentration were higher when horses were riding faster than a walk than typical exposures found in horse stabling during this study 0.987 mg/m³ but similar to the 2.05 mg/m³ found by Bartz and Hartung (1993). Arena total dust concentration was not as high as the 17.5 mg/m³ found by Woods et al (1993).

Table 1. Dust concentration as determined by gravimetric method in two horse riding arenas during three sampling periods right after water was used for dust suppression (WET), within three days of wetting (MOD), and seven days after wetting (DRY).

Condition	Gravimetric					
	Total (mg/m ³)			Respirable (mg/m ³)		
	All Time	Occup	Riding	All Time	Occup	Riding
Farm J						
WET 1	0.3590	0.3898	0.9822	N/A		
WET 2	0.5642	0.6126	1.5437	0.6668	0.7240	1.8244
MOD 1	0.7348	0.8329	1.9493	0.1837	0.2082	0.4873
MOD 2	N/A			0.1378	0.1562	0.3656
DRY 1	N/A	M	M	0.3197	M	M
DRY 2	0.3996	M	M	0.3996	M	M
Average	0.514	0.612	1.492	0.342	0.363	0.892
std. dev.	0.172	0.222	0.486	0.210	0.314	0.809
Respirable % of Total Dust				66	59	60
Farm Q						
WET 1	0.7562	5.927	15.124	0.4235	3.319	8.470
WET 2	0.726	5.690	14.520	0.3932	3.082	7.864
MOD 1	N/A			0.2117	0.342	1.204
MOD 2	0.3932	0.635	2.236	0.3327	0.538	1.892
DRY 1	0.8097	2.313	7.519	0.6073	1.735	5.639
DRY 2	0.8435	2.410	7.833	0.6073	1.735	5.639
Average	0.706	3.395	9.446	0.429	1.792	5.118
std. dev.	0.181	2.315	5.392	0.156	1.239	3.002
Respirable % of Total Dust				61	53	54

M = missing data due to videotape turned off by arena owner; N/A = data not available

All Time = whole monitoring interval; Occup = time arena occupied; Riding = time horses faster

Gravimetric sampling must be carefully done and even so can provide variable results. Three of 24 cassette readings could not be used in analysis due to low dust collection below minimum useable 0.2 mg by ASTM (2003) standard measurement protocols. In this study most of the remaining samplers measured useable results but in two cases one of the samplers would provide questionable data: in one case respirable dust was greater than total; in a second case the

respirable and total values were the same. Providing redundant samplers for total and respirable dust collection allowed rescue of most monitoring event data and is recommended in future work. Additional and repeated measures of dust concentration are necessary due to the high variability of dust measurements under seemingly identical conditions, as evidenced by the large standard deviation of dust concentration found over these monitoring periods. Confounding variables such as footing dampness and horse activity are difficult to accurately quantify in relation to dust generation.

Table 2. Horse activity from video recording analysis showing total time of riding activity that generates dust versus the gravimetric dust monitors time collecting dust. Tapes were evaluated for time the arena was occupied by horses and time horses were exercising at different gaits.

Arena Condition	Run Time		Horse Activity Total Time					Total # of horses
	Dust sampler (min)	Video-tape (min)	Occupied (min:sec)	at walk	at trot	at canter	faster than walk	
	(min)		(min:sec)					
Farm J								
WET	342	338	314:43	189:09	105:08	20:26	125:34	10
MOD	382	362	337:32	233:09	112:09	32:14	144:23	12
DRY	439	120	M	M	M	M	M	unknown
Farm Q								
WET	580	403	74:32	45:09	21:51	7:32	29:23	3
MOD	580	546	359:29	257:19	58:41	43:29	102:10	11
DRY	520	496	182:35	126:34	45:53	10:08	56:01	6

M = missing data

Footing Characteristics

There was no pattern of total dust or respirable dust measured relative to wetting time for either arena. Farm J had uniform moisture content of its arena surface near the PM monitoring site (WET 43.5%, MOD 44.6%, DRY 42.8% average) while Farm Q recorded the highest footing moisture content during the MOD period (3.1% WET, 6.3% MOD, 3.5% DRY). Despite having fewer horses occupying the arena and shorter riding times at faster gaits (tab. 2), the Farm Q arena had greater measures of dust concentration and dust/unit of riding time. For Farm Q the MOD monitoring session had the highest “Riding” horse activity while the WET period had about a third of that activity. This difference in horse activity level likely confounded the analysis based on wetness in relation to dust suppression. The managers of these two arenas put a priority on dust suppression and did a good job of keeping the material evenly wet so that it did not dry out rapidly over our one-week study period. The differences between arenas were more significant, with the organic footing material (Farm J) able to hold more moisture than the 3 to 6% moisture content of the sand based arena at Farm Q. This may also be a significant factor for dust collected, with the greater dust concentration obtained most consistently from lower organic content material (Farm Q).

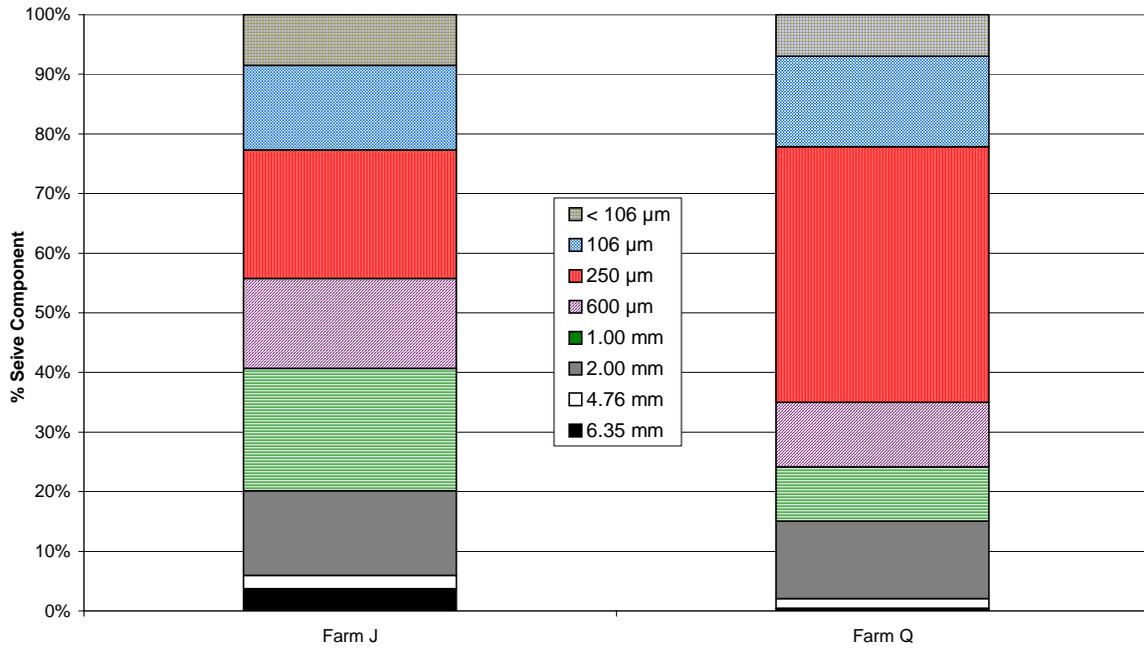


Figure 1. Particle size distribution of footing samples collected during arena dust evaluation.

Sieve analysis results for total footing samples from both arenas are shown in Figure 1. In both arena footings about 22% of the material was considered “fine” at less than 0.25 mm diameter. It is recommended that this component of footing be kept below 5% to reduce dust potential (Malmgren, 1999). Another 22% and 43% of Farm J and Farm Q, respectively, footing material was between 0.60 and 0.25 mm indicating that a fairly fine sand material was used at Farm Q.

Finest particles of the sieved footing, containing < 106 μm particles, were analyzed for particle size distribution from Farm J WET and Farm Q DRY sampling periods with results shown in figure 2. The particle size distribution shows a greater fraction of the footing particles in the sand-based footing (Farm Q) were <10 μm in diameter as compared to the organic-based footing. This likely explains the greater dust concentration detected in the sand-based arena, as smaller particles are more likely to be suspended into the air. Farm J organic based riding surface fines had a very small percentage of particles (0.84%) below the 5 μm respirable size while Farm Q footing fines were about 29.0 % respirable size.

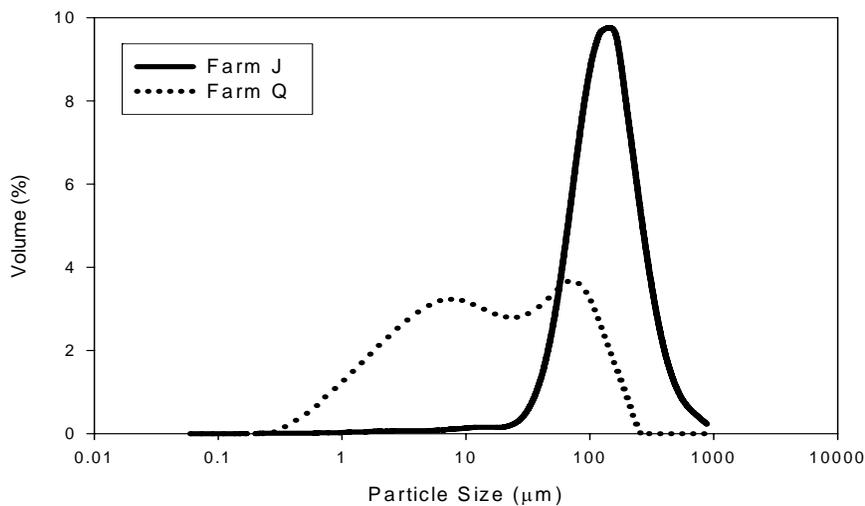


Figure 2. Particle size distribution of sieved fines from footing samples collected in each arena near dust sampling instrumentation.

CONCLUSIONS

Both total (0.514 mg/m³ organic; 0.706 mg/m³ inorganic footing) and respirable (0.342 mg/m³ organic; 0.429 mg/m³ inorganic footing) dust levels were lower than expected based on the gross perception of dust in the arena environment and as compared to data from stable dust studies. For these arena management situations, dust detection did not vary systematically with dust suppression. Dust was associated with the overall quality of the footing in the arena, with greater dust detected from the footing of lower moisture content with a greater percentage of fine particles (inorganic footing). Dust detection in the arenas was greater and more appropriate when calculated according to level of horse activity in a session. Total dust level was 0.612 mg/m³ or 3.395 mg/m³ (organic and inorganic footing, respectively) when calculated based on time arena was occupied by horses. Both total dust levels were 2-1/2 to 3 times higher than this during times of horse activity faster than a walk. Respirable particles were 54 to 60% of the total dust during riding activity. When observing horses traveling in an arena it is readily apparent that dust is suspended in the air behind the tread of the horse's hooves and its suspension is transient in nature. These findings, in addition to the overall low concentrations of dust detected during an entire exercise session, all corroborate the apparently low level of dust to which a horse is exposed during an exercise session in an indoor arena. Horses with chronic respiratory conditions are not exposed to the quantity of respirable dust particles in the riding arena that they are in their stall environment, thus the riding arena is unlikely to be the significant contributor to irritating particles

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