Measurement of respirable dust levels in horse stables

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Dunlea, A.P. and Dodd, V.A. 1995. **Measurement of respirable dust levels in horse stables**. Can. Agric. Eng. 37:205-209. Respirable dust levels were monitored at two different stable complexes. Monitoring of air inside the stables and the outside incoming air was carried out at least once every hour for periods of one week. The respirable dust levels showed a large fluctuation of 0.4 to 305 counts/mL. The highest level recorded (305 counts/mL) was for a sampling point outside the horse stable which may have been a result of the stables proximity to a hay barn and a manure storage area. The high outside levels of respirable dust may have been due to the location of the sampling point in a position that recorded exhaust air rather than inlet air as it may have been located in the wake of the building. Diurnal variation covered a range of approximately 10 counts/mL to 95 counts/mL within a 24 hour period. Seasonal variation at the same location indicated a higher level during the winter period than during the summer period. High levels of respirable dust were recorded outside the mill building (maximum 148.8 counts/mL) which was part of one of the stable complexes and also outside the dwelling house (maximum 128.3 counts/mL) approximately 50 m from the main stable complex. Natural ventilation was the system of ventilation used in all of the stables monitored. The data recorded indicate that natural ventilation may not be relied upon to achieve the current recommended internal dust quality within the stable at all times or that the natural ventilation system used in the stables surveyed was not adequate.

Des expériences ont été réalisées dans deux groupes d'écuries différentes afin de mesure le niveau de poussière présent dans l'air respirable de ces bâtiments. Pendant une semaine, l'air à l'intérieur des écuries et l'air venant de l'extérieur vers l'intérieur dans ces mêmes écuries ont été vérifiés au moins une fois par heure. Le pourcentage de poussière respirable variait alors entre 0,4 et 305 chronomètrage/mL. Notons que le pourcentage le plus élevé (305 chronomètrage/mL) a été enregistré à un endroit d'échantillonnage à l'extérieur de l'écurie; ce résultat pourrait être dû au fait de la proximité d'un grenier à foin et d'un tas de fumier. Ce haut pourcentage de poussière respirable pourrait aussi être dû à la localisation du point d'échantillonnage où l'on enregistrait plutôt le carbone monoxyde de gaz d'échappement plutôt que l'air venant de l'extérieur se situant plutôt à l'arrière du bâtiment, plus protégé. Dans une période de 24 heures, la variation diurne enregistrait une gamme de 10 à 95 chronomètrage/mL. Toutefois, les variations saisonnières enregistrées au même endroit, laissaient apparaître un pourcentage plus élevé de poussière respirable pendant la période d'hiver que d'été. Précisons que lors de cette expérience, le pourcentage de poussière respirable était enregistré à l'extérieur de moulin (maximum 148,8 chronomètrage/mL) qui faisait partie d'un groupe décuries, et également à l'extérieur du bâtiment d'habitation (maximum 128,3 chronomètrage/mL) situé approximativement à 50 mètres des écuries principales. La ventilation naturelle se trouvait entre le système d'aération utilisé dans toutes les dites écuries où ont été réalisées ces expériences. Ainsi, la lecture des données enregistrées nous permet d'indiquer que la ventilation naturelle ne semble pas un système d'aération adéquat pour assurer en permanence "la qualité" de la poussière à intérieur des écuries comme la loi le préconise actuellement.

INTRODUCTION

The problem of dust in horse stables has been much discussed in recent years. Chronic Obstructive Pulmonary Disease (COPD) has been linked to the existence of dust in the horse's stable (Grunig et al. 1989; Webster et al. 1987). The severe form of COPD has been discussed by these researchers and also by McPherson and Thomson (1983) describing the term "heaves" or "broken wind". Leadon (1986) referenced the association of dust with Poor Performance Syndrome (PPS) seen in thoroughbred race horses in training.

Much emphasis has been placed on the size of dust particles. Particles of less than 5 µm aerodynamic diameter make up the major constituents of respirable dust as spores of fungi and actinomycetes (Webster et al. 1987; Crichlow et al. 1980). Mercer (1978) demonstrated graphically the significance of particle aerodynamic diameter of the respirable fraction. This relationship showed that a small proportion of particles with diameter of 10 µm was still respirable, which concurs with the report by Phillips and Thompson (1989). Van Wicklen and Allison (1989) cited respirable particles to be in the range of 0.5 to 5.0 µm, while Carpenter (1986), in a review of published data, concluded that respirable dust had a diameter of less than 7 µm. A figure of 7.07 µm was also suggested by Anon (1986). Particles between 5 and 10 µm diameter are generally agreed to be the upper limit of respirable dust.

Crichlow et al. (1980) monitored dust levels in riding stables using gravimetric methods. These gravimetric results were obtained on four-day averages. More detailed information on dust levels inside horse stables was obtained by Webster et al. (1987) using a particle counter.

Woods et al. (1993) and Clarke (1993) highlighted the importance of the high level of inhalation challenge in the breathing zone of the horse. These authors described the large difference in dust levels under different management criteria.

An assessment of the outside incoming air quality has been carried out by Maghirang et al. (1991) for a commercial cage laying house. These authors reported high levels of outside ambient dust levels which varied with weather conditions (temperature in particular), with higher levels being recorded during hot weather. Possible dust re-entry through the inlet fans was also discussed by these authors. The overall dust levels and in particular the variations of dust levels in the entire stable environment is the main concern of the study reported in this paper. The possible re-entry of dust into the horse stable is also a concern of this study.

MATERIALS AND METHODS

Monitoring was carried out at two different stable complexes. Both stable complexes used straw as the sole form of bedding for the horses. Figures 1 and 2 show layouts of the stables at the Co. Dublin and Co. Kildare locations, respectively. The Co. Dublin stables were located on the farm of University College Dublin while the Co. Kildare stables were a commercial racing stable. Measurements in the University unit were taken in the months of January and August while the measurements in the Co. Kildare unit were taken between late October and December.

The design of the monitoring system was similar to that described by Koberstein et al. (1990) and Feddes et al. (1992).

The stables used natural ventilation.

A particle counter (Hiac Royco Model 1200, Pacific Scientific, Menlo Park, CA) was used in this project. A flow rate of 2.8 L/min was used to sample air inside and outside the stable. This instrument enabled detection of particles with an

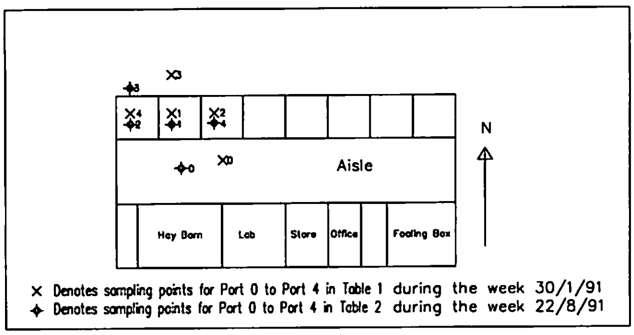

Fig. 1. Layout of stables at U.C.D., Lyons Estate, Co. Dublin, showing location of sampling points.

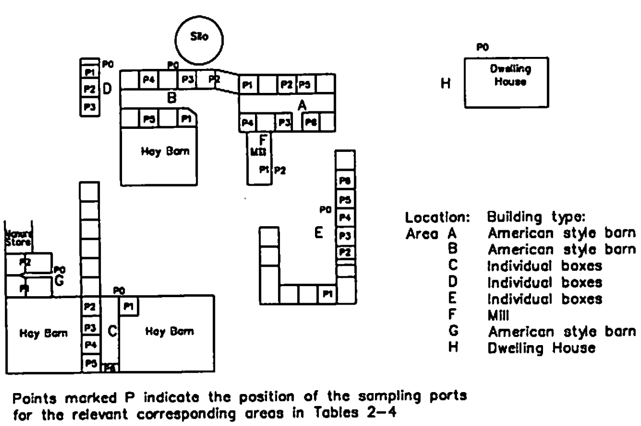

Fig. 2. Layout at the Co. Kildare commercial racing stables, showing location of the sampling points.

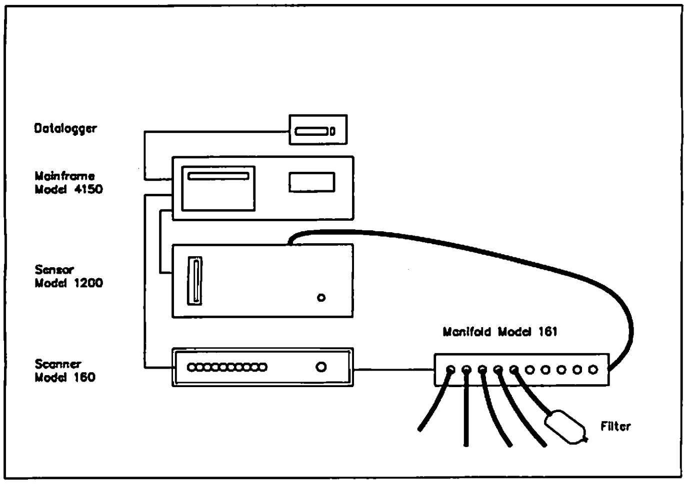

Fig. 3. Hiac/Royco particle counting system.

aerodynamic diameter of greater than 0.5 µm. The model was selected to cope with the large volume of dust in the horse stable environment. The low flow rate allowed the counting of large particle numbers and avoided the possible problem of multiple imaging. The counter was controlled by a mainframe (Hiac Royco Model 4150, Pacific Scientific, Menlo Park, CA). The mainframe also controlled a scanner (Hiac Royco Model 160, Pacific Scientific, Menlo Park, CA) which allowed air samples to flow through a manifold (Hiac Royco Model 161, Pacific Scientific, Menlo Park, CA). Up to ten different sample ports were available using the manifold and the scanner. Data produced throughout the project were recorded on a data logger (Tracker Model 1350, Data Track Technology Ltd., New Milton, Hampshire, UK). Figure 3 shows a diagram of the dust particle counting system used in this survey. Air samples were obtained using 12mm plasticized vinyl tubing with a high purity inert internal liner of Hytrel polyester. This tubing was located above the horses head within the stable environment and also outside the stable near the inlet openings. Tubing lengths of less than 12.5 m were used throughout the tests, consequently tubing particle loss was considered to be minor. Zweers (1983) stated that "losses in 150 ft (46 m) of 3/8" (9.5 mm) flexible tubing at 1.0 CFM (28 L/min) air flow rate were shown to be 4.2% at 0.5 µm and much greater, 25% as would be expected, in the 3 - 5 µm range". The same author stressed that sensor-to-sensor particle count variation was far greater than tube-to-tube variation due to length losses, a view also shared by West (1985). The tubing was placed above the head of the horse near the centre of the stable. For practical reasons it was not possible to place the tubing within the breathing zone of the horse.

The air sample was purged for one minute between each port. This was known as the stabilisation delay time. The areas sampled were monitored every hour for one minute for a duration of one week before the apparatus was moved to a new location, except for the week beginning 1991-11-29 when sampling was done twice each hour.

Respirable dust was measured in the range of 0.5 to 10.0 µm.

Table I: Respirable dust levels (counts/mL) at the University College Dublin (U.C.D.) stables in County Dublin

Port No.	Location	$\bar{x}$ mean	s.d. (+/-)	Range	
During the week 91-01-30 (see Fig. 1)					n = 120
0	Inside aisle	75.0	53.8	2.9-250.6	
1	Box No. 2	76.2	53.3	2.9-251.3	
2	Box No. 3	75.8	53.2	3.0-250.3	
3	Outside air	74.9	56.5	2.6-273.6	
4	Box No. 1	75.0	52.2	2.8-246.1	
During the week 91-08-22					n=164
0	Inside aisle	23.0	31.7	2.3-120.8	
1	Box No. 3	23.0	32.0	2.4-134.2	
2	Box No. 2	23.5	31.9	2.4-130.2	
3	Outside air	23.2	32.3	2.1-138.7	
4	Box No. 4	23.3	31.7	2.5-123.1	

Table II: Respirable dust levels (counts/mL) at the commercial racing stables in County Kildare

Port No.	Location	$\bar{x}$ mean	s.d. (+/-)	Range	
During the week 91-10-25 (see Fig. 2 area A)					n=164-169
0	Outside air	51.6	52.1	0.7-194.7	
1	Box No. 1	54.4	54.3	1.0-201.1	
2	Box No. 3	53.7	53.3	0.8-196.3	
3	Box No. 8	54.0	53.9	0.9-195.1	
4	Box No. 10	53.3	53.1	0.9-196.4	
5	Box No. 4	53.3	53.1	0.7-195.3	
6	Box No. 7	54.1	53.7	0.7-194.5	
During the week 91-11-01 (see Fig. 2 area B)					n=161-167
0	Outside air	16.4	32.2	0.4-288.8	
1	Box No. 1	12.3	17.8	0.5-131.9	
2	Box No. 9&10	14.1	23.6	0.6-230.4	
3	Box No. 8	12.3	22.6	0.6-186.0	
4	Box No. 6	14.8	28.2	0.5-264.9	
5	Box No. 3	12.9	21.9	0.7-224.9	
During the week 91-12-06 (see Fig. 2 area G)					n=166-168
0	Outside air	83.5	59.6	9.0-305.0	
1	Box No. 1&2	83.3	58.0	8.9-289.1	
2	Box No. 3&4	83.2	56.2	9.1-276.8	

Table III: Respirable dust levels (counts/mL) at the commercial racing stables in County Kildare

Port No.	Location	$\bar{x}$ mean	s.d. (+/-)	Range	
During the week 91-11-08 (see Fig. 2 area C)					n=157-168
0	Outside air	13.1	12.2	0.7-71.9	
1	Box No. 1	13.0	12.3	0.9-79.3	
2	Box No. 2	13.1	11.3	0.8-67.4	
3	Box No. 3	13.1	11.4	0.9-69.0	
4	Box No. 4	12.9	10.8	0.8-62.8	
5	Box No. 5	13.0	10.3	1.3-53.8	
6	Box No. 6	12.0	9.8	1.3-49.0	
During the week 91-11-15 (see Fig. 2 area D)					n=164-165
0	Outside air	29.3	34.5	1.5-247.0	
1	Box No. 1	27.4	29.5	1.4-193.8	
2	Box No. 2	28.0	31.0	1.5-210.0	
3	Box No. 3	28.2	31.2	1.5-200.0	
During the week 91-11-22 (see Fig. 2 area E)					n=165-167
0	Outside air	17.4	20.3	0.4-158.4	
1	Box No. 9	16.3	19.7	0.6-184.0	
2	Box No. 6	15.6	14.8	0.5- 94.5	
3	Box No. 5	15.9	15.2	0.4-113.6	
4	Box No. 4	16.2	16.4	0.8-145.2	
5	Box No. 3	16.3	17.8	0.8-176.0	
6	Box No. 2	15.4	15.9	0.6-148.1	

RESULTS AND DISCUSSION

Dust levels recorded at the different locations are given in Tables I to IV and show the extent of the variation in the stable respirable dust levels at both locations in Co. Dublin and Co. Kildare. The ranges of respirable aerosol levels presented show that low (0.4 counts/mL) and high levels (305 counts/mL) of respirable aerosols existed at the same stable location. These results also show that there was little difference in the respirable dust levels between different stables within each group of stables.

Figures 4 and 5 show the variation within a 24-hour period both inside and outside the stable location for Co. Dublin and Co. Kildare, respectively. The respirable dust levels in the outside air also showed large fluctuations. The pattern of these fluctuations was similar to that of the inside-stable respirable dust levels. High levels of dust were recorded at about 0800h to 0900h during which time cleaning activity was carried out. High levels of stable dust were also recorded at times when little activity was expected, which may be accounted for by high corresponding levels of dust in the outside air. To attempt to allocate an origin to the ambient dust would lead to a lot of uncertainty and supposition. It has been shown that air inlets could be recontaminated from other barn exhaust air (Maghirang et al. 1991). Proximity to a roadway, wind direction, or chimney output may all influence the quality of the ambient air. It is also clear that the stables themselves produce dust. For example, in Table II all sampling ports of each stable box tested recorded average dust levels higher than that of the outside air. The other tables show that the outside dust level was very similar to, if not higher than, the inside stable dust levels. Figures 4 and 5 show how the outside dust levels vary similarly to the inside dust levels. Because of the positioning of the sampling location of the outside air, it was not possible to distinguish whether these samples represented air entering the stables or air exiting the stables due to wind-assisted ventilation.

Readings from the same location in the Co. Dublin stables were taken on two different occasions, i.e. January and Au-

Table IV: Respirable dust levels (counts/ml) at the commercial racing stables in County Kildare

Port No.	Location	$\bar{x}$ mean	s.d. (+/-)	Range	
During the week 91-11-29. (see Fig. 2 area F)					n=327-329
0	Outside air	69.3	45.2	4.3-148.8	
1	Inside mill	76.6	46.0	5.0-186.2	
During the week 91-12-13 (see Fig.2 area H)					n=165
0	Outside house	36.1	38.0	0.6-128.3	

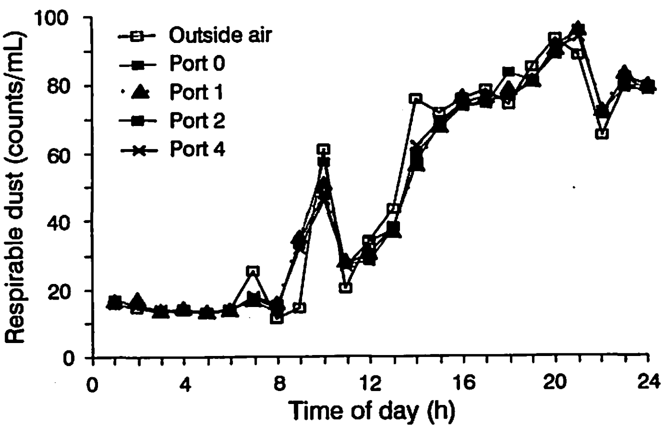

Fig. 4. Respirable dust levels August 23, 1991, University College, Dublin stables.

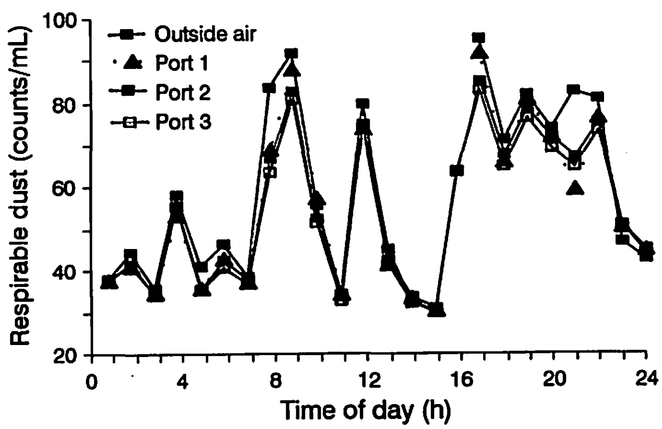

Fig. 5. Respirable dust levels Nov. 20, 1991, Co. Kildare commercial racing stables.

gust (Table I). Large variations in dust levels were recorded between the two tests indicating possible seasonal factors.

The levels of respiratory dust in the outside air also showed variation when monitored at the dwelling house located at a distance of approximately 50m from the nearest stables (Table IV, Area H).

The evidence indicates that the inside stable air cannot be improved through natural ventilation when the outside air contains higher respirable dust levels than the desired levels selected for the inside of the stable. This has been shown to be the case in particular for the racing stables in Co. Kildare where the sampled air recorded a mean of 36.1 counts/mL at a distance of approximately 50 m from the stable complex (Table IV, Area H). Normally it is impractical to achieve the suggested threshold limit values of 33 counts/mL by means of natural ventilation alone when the incoming air exceeds this figure. The difficulties associated with the use of natural ventilation to control the level of respirable dust within the horse stable involve:

1) Variable incoming air quality.
2) Variable ventilation rate (minimum ventilation rate may be insufficient to remove the contaminants).
3) Air flow pattern within the stable can be unsatisfactory and result in drafts or still pockets due to air inlet distribution problems.
4) The clearance route for contaminated air by natural ventilation must of necessity expose the breathing zone of the standing horse.

Clarke (1993) proposed the idea that the horse should be exposed to a minimum of dust throughout its life and also stated that further information was needed to calculate an accurate threshold limit value. To achieve a dust level of less than the T.L.V. of 33 counts/mL at all times or indeed any proposed threshold limit value less than the level of the outside ambient air, further research is required.

A mechanical ventilation system with pre-treatment including a hepa-filter and a designed airflow pattern which ensures that the clean filtered air will at all times be available to the breathing zone of the horse has been under study by the authors of this paper and will be presented in a future paper.

CONCLUSIONS

1) The outside, incoming air quality was shown to be variable (minimum 0.4 - maximum 305 counts/mL).
2) The stable air also showed variable levels of respirable dust (minimum 0.4 - maximum 289 counts/mL).
3) Natural ventilation may not be the most efficient system for controlling respirable dust with respect to the clearance pathway and the quality of the incoming air.

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