Research article

Evaluation of Dust Generation from Animal Farm Activities

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Abstract Dust generated in feedlots from roads, animal activity in pens, and equipment can have detrimental effects on air quality for animals, workers and surrounding communities. Controlling dust in cattle feedlots requires an understand of the key sources and processes needed to better manage dust generation and associated activities. There is growing recognition internationally that dust sources from the agricultural sector may contribute to regional sources with both local and area wide effects on the population, animals and other biota in the environment. Monitoring of fine 10 micron-sized particulate matter (PM_{10} air particulate matter) over the last decade shows that agricultural activities can contribute to regional dust generation from diffuse sources such as from farms and feedlots. The basic features and processes of manure generation at feedlots and storage with water are dried to become a source of dust but other subtle phenomena associated with interaction of conditions and constituents are being identified. In the Central Plains of the United States antibiotic residues and antibiotic-resistant bacteria absorbed on particles have been observed. By understanding the processes of dust generation from feedlots as diffuse sources, it should be possible to identify risks to the population, animals and other biota in the environment. Sustainable production systems rely on keeping soil in place and in good health, efficient use of water, minimizing nutrient loss and maintaining or enhancing biodiversity. This is primarily achieved through management of the pasture base (native, naturalized and sown) in a highly variable and changing climate. This review provides a summary of the significant advances in dust suppression technologies and strategies to suppress dust generated from farms. It also identifies that emerging issues including the dispersion of antibiotics, antibiotic-resistant genes and human-pathogenic bacteria on dust particles from feedlots require managing.

Keywords dust generation, animal feedlots, sustainable, management

INTRODUCTION

Dust generated in feedlots from roads, animal activity in pens, and equipment is recognised as having detrimental effects on air quality for animals, workers and surrounding communities (Galvin et al., 2005). For satisfactory suppression and control of dust in cattle feedlots it is necessary to understand the key sources and processes to give better management of dust generation and associated activities. In Australia, National guidelines were adopted in 1992 for beef cattle feedlots but the regulations vary from state to state (ARMCANZ, 2003).

The scale of feedlot dust generation is related to their number; for example, in Australia there are over 400, with a nominal estimate of over 1,000,000 cattle fluctuating with drought conditions (Jones et al., 2017). The cost of feedlot dust generation was estimated to be more than AUD5 billion nationally per annum (Jones et al., 2017). Management techniques typically centre on regular pen cleaning, watering of roads, and use of in-pen sprinklers during peak times of dust-generating behaviour. Whilst National guidelines identify basic requirements for managing feedlots, they don't indicate all interactive factors that are associated with feedlot management (Galvin et al., 2005). In addition, there is growing recognition of dust sources from the agricultural sector which may contribute to regional sources with both local and area wide effects on the population, animals and other biota in the environment.

Particulate matter (PM) is categorized according to various diameters or sizes based on the physical property of airborne material (NEPC, 2002). The measurement of ambient 24-hr average air concentrations of air particulates may cover the following categories: (i) Total suspended particulates (TSP, <50 μm in diameter); (ii) PM_{10} suspended particulates (<10 μm in diameter); (iii) $PM_{2.5}$ suspended particulates (<2.5 μm in diameter, "respirable"); and (iv) Particle identification in the TSP fraction of the dust. No data on typical dust fall levels for Australian beef cattle feedlots was confirmed (Jones et al. 2017) and no guidelines exist for dust fallout. However, the Queensland recommended guideline for fallout dust is 120 mg/m^2/day for nuisance soiling of property and is adopted from the NSW guideline (DEHP, 2013).

Monitoring of fine air particulate matter (<10 μm in diameter or PM_{10} suspended particulates) over the last decade shows that agricultural activities can contribute to regional dust generation from diffuse sources such as from farms and feedlots (NPI, 2001). Whilst manure needs to be dried to become a source, there are subtle phenomena associated with interaction of conditions and constituents that are being identified (Wilson et al., 2002). In the Central Plains of the United States, antibiotic residues and antibiotic-resistant bacteria absorbed on particles are identified as hazardous and may be dispersed by wind (McEachran et al., 2015).

By understanding the processes of dust generation from feedlots as diffuse sources, it should be possible to identify if uncontrolled processes are risks to the population, animals and other biota in the environment that may be causing undescribed effects. The significance of this step is in being able to properly describe any risks associated with dust generation that may be shown to be detrimental to the population, animals and other biota in the environment. Sustainable production systems rely on keeping soil in place and in good health, efficient use of water, minimising nutrient loss and maintaining or enhancing biodiversity. This is primarily achieved through management of the pasture base (native, naturalised and sown) in a highly variable and changing climate.

This review provides a summary of the significant advances in dust suppression technologies incorporating strategies to detect when dust-load is problematic, available technologies and strategies to suppress pen and road dust, animal health impacts, occupational health and safety impacts, air quality impacts on surrounding neighbours, recommendations to limit exposure of dust to animals, workers and neighbours. The review also identifies emerging issues including the dispersion of antibiotics and related compounds on dust particles from feedlots.

OBJECTIVE

The objectives of this paper are: (i) to review and summarize advances in control of dust from animal feedlot activities that can impact on air quality impacts on surrounding areas; and (ii) identify emerging issues including the dispersion of antibiotics on dust particles from feedlots.

METHODOLOGY

Published papers, reports and other sources including internet and suppliers of dust collection equipment were collated, reviewed and summarized.

Monitoring data for PM_{10} air particulates (covering the period 2003 – 2012 at 8 sites) and for fall out dust (covering the period 2009 – 2011 at 24 sites), were collected on the Darling Downs, the main grain-growing area in Australia, 30-50 km west of Toowoomba, Queensland (Noller and Zheng, 2013). Collection of PM_{10} (Standards Australia 2003a) followed the National Environment Protection (Ambient Air Quality) Measure (Air NEPM) standards, the uniform standards for ambient air quality in Australia (NEPC, 2002). Fall out dust monitoring was undertaken using dust deposition gauges described by the Australian dust sampling method (Standards Australia, 2003b). The extracted data was placed in EXCEL spread sheets. The PM_{10} and dust deposition data was set out in a statistical format giving the mean, seventy-five and ninety-five percentile values.

Monitoring data for fall out dust from a large cattle feedlot study site located on the Darling Downs (Galvin et al., 2005) was examined to compare with the data described above. The fall out dust data were converted from units of g/m^2/month to mg/m^2/day.

RESULTS AND DISCUSSION

The dusty conditions of feedlots have been found to result from fine dry material being dispersed by wind and mechanical action (Galvin et al., 2005). Studies on feedlot dust sources have shown that the largest contributor of dust was manure (Huang et al., 2013). Apart from its physical nature manure is a valuable agricultural resource. This value is even though it contains high numbers of microorganisms, that include a large variety of organisms capable of causing disease in animals and farm workers (Milinovich and Klieve, 2011). Dust from road traffic could also be a major source of dust at drier locations like Texas (Wanjura et al., 2004). Dust from roads can be finer than that generated by material handling due to the repeated pulverizing of road materials into smaller fragments and the resultant creation of fine particles which can easily become airborne (Cox and Isley, 2012). The production of fine particles at feedlots has been shown to arise from cattle hooves causing dry manure to be pulverized (Jones et al., 2017). In general, dust emitted from an emission source consists of a range of particle sizes that is dependent on the source characteristics.

The introduction of the National Pollutant Inventory (NPI) handbook for beef cattle feedlots in Australia in 1999 resulted in some feedlots reporting emissions of particulate matter $<PM_{10}$ (NPI, 2001). Emission rates for feedlots based on US data for feedlots were demonstrated to overestimate the actual emissions from US feedlots (Galvin et al., 2005). However limited dust monitoring data has been available in Australia and elsewhere to the current time.

Dust generation is a recognized issue for many Australian and other feedlots because it has the potential to impact on the health and safety of livestock, employees and the surrounding community. Significant advances are required in dust suppression technologies incorporating strategies (Jones et al., 2017): (i) To detect when dust-load is problematic, (ii) To improve available technologies and strategies to suppress pen and road dust, (iii) Deal with animal health impacts, occupational health and safety impacts, (iv) Air quality impacts on surrounding neighbours and (v) Make recommendations to limit exposure of dust to animals, workers and neighbours feedlots. The review of the issues regarding dust generation by Meat and Livestock Australia (Jones et al., 2017) gave the following key findings: (i) There is growing recognition of dust sources from the agricultural sector which may contribute to regional sources with both local and area wide effects on the population, animals and other biota in the environment; (ii) Monitoring of fine dust (PM_{10} suspended particulates) over the last decade shows that agricultural activities can contribute to regional dust generation from diffuse sources such as from farms and feedlots; and (iii) Whilst manure needs to be dried to become a source, there are subtle phenomena associated with interaction of conditions and constituents that are being identified.

A hierarchy of hazard control was recommended to minimize or eliminate exposure to hazards from feedlot dusts (Jones et al., 2017). The hazard controls in the hierarchy, in order of decreasing effectiveness described by Jones et al. (2017), are: Elimination, the most effective means of hazard control such as sealing of feedlot roads to eliminate dust generation by traffic; Substitution that may involve replacement with something that does not produce a hazard, e.g preparing feed rations offsite to eliminate feed-related dust; Engineering and other physical controls that do not eliminate hazards but isolate workers and livestock from hazards by using barriers placed between personnel and hazards; Administrative controls that change the way people work; and Personal protective equipment for farm workers such as gloves, respirators, hard hats, safety glasses, high visibility clothing and safety footwear.

Plots of Darling Downs monitoring data for air particulates (PM_{10}) and dust fall are shown in Figs. 1 and 2 and the summary data is given in Table 1. Comparison of the Australian National Environment Protection (Ambient Air Quality) Measure (Air NEPM) standard (NEPC, 2002) for PM_{10} (50 μg/m^3 for an averaging period of 1 month) with the data in Table 1 shows there were no exceedances of PM_{10} with the guideline (Fig. 1), excepting for one site (6) during 3-4 November 2011 that had the maximum value (71 μg/m^3) out of PM_{10} monitoring data for all 8 sites. The fallout monitoring data (Fig. 2) is compared against the level of 120 μg/m^2/day for soiling that is adopted in Queensland (DEHP, 2013); the exceedances of this level were historical and not the most recent for the monitoring period up to 2012.

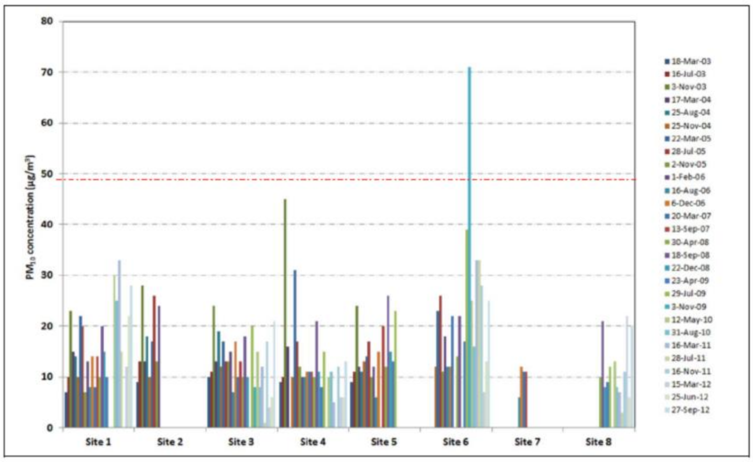

Fig. 1 PM$_{10}$ (µg/m^3) monitoring record during 2003 – 2012 at Darling Downs

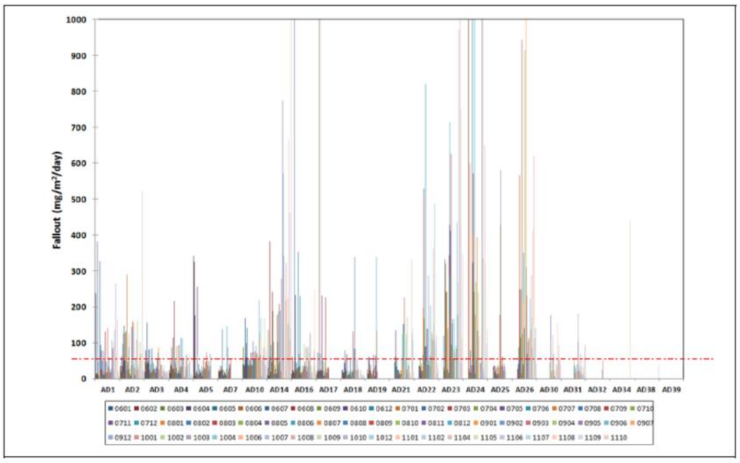

Fig. 2 Dust fallout (mg/m^2/day) monitoring record during 2006 – 2011 at Darling Downs

Fig. 2 gives the overall picture of historical exceedances of fall dust; however, some of the large exceedances for fall out monitoring data were related to bird and frog activity and a long dry dusty period associated with drought (Noller and Zheng, 2013). The data set for all fall out dust monitoring (Table 1) shows that the mean and 75th percentile did not exceed the level of 120 mg/m^2/day, while the 95th percentile did. When the data set for fall out dust monitoring values <120 mg/m^2/day (Table 1) were examined, the mean of 38 mg/m^2/day was a representative background level for the farming activity on the Darling Downs during 2006-2011.

Table 1 Background levels of PM$_{10}$ air particulates and dust deposition at Darling Downs

Category	Time frame	Mean	75th Percentile	95th Percentile
PM$_{10}$ air particulate (µg/m^3)	2003-2012	14	17	26
Dust deposition all monitoring (mg/m^2/day)	2006-2011	103	89	365
Dust deposition <120mg/m^2/day only (mg/m^2/day)		38	52	93

Source and explanation: Data from Noller and Zheng (2013)

Table 2 shows the range of fall out dust was 107 - 923 mg/m^2/day for the beef cattle feedlot study at the Darling Downs (2003-2004) with the highest dust deposition being near roads in and around the feedlot (Galvin et al. 2005). Comparison of the dust deposition monitoring data in Tables 1 and 2 shows that the dust deposition for all monitoring mean was 103 mg/m^2/day (Table 1) and was almost the same as 107 mg/m^2/day at the dust deposition at intermediate sites located on edges of feedlot pen (Table 2). In addition, dust deposition near roads in and around feedlot (923 mg/m^2/day) and dust deposition at background sites (417 mg/m^2/day) (Table 2) exceeded the 95th percentile for dust deposition all monitoring (365 mg/m^2/day) given in Table 1. Dust deposition within a feedlot (320 mg/m^2/day) in Table 2 was marginally lower than 365 mg/m^2/day (Table 1), but indicated that the cattle feed lot data (Table 2) was collectively very dusty.

Table 2 Dust deposition at beef cattle feedlot Darling Downs (2003-2004)

Category	Mean
Dust deposition near roads in and around feedlot (mg/m^2/day)	923
Dust deposition at background sites (mg/m^2/day)	417
Dust deposition within a feedlot (mg/m^2/day)	320
Dust deposition at intermediate sites located on edges of feedlot pen areas (mg/m^2/day)	107

Source and explanation: Data from Galvin et al. (2005) converted from g/m^2/month to mg/m^2/day

Table 2 does not include air PM_{10} data for the beef cattle feedlot study at the Darling Downs (2003-2004). The concentration of PM_{10} was measured at the feedlot and ranged from 29 µg/m^3 to 204 µg/m^3 with a mean of 100 µg/m^3 (Galvin et al., 2005) and far exceeded the air NEPM guideline of 50 µg/m^3 (NEPC, 2002) and the mean background levels of PM_{10} air particulates given in Table 1. Thus, the feedlot was demonstrated as emitting PM_{10} particulates. Although total concentrations of dust and PM_{10} can be measured and compared against guidelines, the manure-derived dust could not be distinguished from manure-derived dust (Galvin et al., 2005).

In addition to the organic matter in manure is the management of zoonotic diseases and means to treat and eliminate them remains a critical issue (Milinovich and Klieve, 2011). McEachran et al. (2015) identify that the reported half-lives of tetracycline antibiotics in soil and soil-slurry mixes are sufficiently long for these antibiotics to remain active during aerial transport and after deposition onto soil, water or other surfaces for days to weeks. The measured concentrations antibiotics found in airborne PM and in cattle manure by McEachran et al. (2015) were also similar to those inside large-scale swine production facilities. The use of antibiotics and other related substances for maintaining animal health and growth require further understanding. Dust issues are relevant to other species of domestic animal production apart from beef cattle.

CONCLUSION

This review has provided a summary of the significant advances in dust suppression technologies. The review also identifies emerging issues including the management of manure and dispersion of antibiotics and related compounds on dust particles. Thus, by understanding the processes of dust generation from feedlots as diffuse sources, it should be possible to identify if uncontrolled processes are risks to the population, animals and other biota in the environment that may be causing undescribed effects.

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