AMMONIA EMISSIONS FROM WOODCHIP PADS USED FOR OUT-WINTERING CATTLE

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1 INTRODUCTION

There has been an increased interest in recent years in the UK in the use of out-wintering pads as a low cost over-wintering system for cattle (Smith et al., 2006), following the adoption of such systems in New Zealand and Ireland (Hickey et al., 2002; Stewart et al., 2002). In addition to being low cost, woodchip pads may also provide lower potential for ammonia (NH_3) emission when compared with cattle housing, as urine (the primary source of NH_3 emissions) is likely to quickly drain into the woodchip matrix and be less susceptible to volatilisation. Ammonia emission from cattle housing and concrete yards accounts for approximately 25% of the total annual NH_3 emission from UK agriculture (Webb and Misselbrook, 2004). There are international pressures to reduce NH_3 emissions to the atmosphere, because of its negative environmental effects through eutrophication and acidification and potential human health effects deriving from particulate formation (Erisman et al., 2008), therefore it is important that robust emission factors are developed for alternative management strategies so that national impact scenarios can be used to inform policy development.

The aims of this study were to assess the magnitude of NH_3 emissions from out-wintering pads used by cattle, for comparison with existing data on indoor housing systems, and to assess the impact of a range of management factors, including woodchip size, stocking density and feeding management (on- or off-pad feeding). Ammonia emission measurements were made from pilot-scale and commercial farm-scale out-wintering pads as part of a larger project including measurements of effluent quality and potential agronomic benefit of spent woodchips, which are reported elsewhere in these proceedings (Dumont et al., 2010a; 2010b). This paper presents the NH_3 emission results from the first year measurements of a two-year study.

2 MATERIALS AND METHODS

2.1 Pilot-scale studies

Four pilot-scale woodchip pads (each 10 x 10 m) were established at North Wyke Research in Autumn 2008. Each pad was fronted by a concrete area with a feeding barrier (Figure 1), such that the cattle could either be fed off the woodchip pad (i.e. standing on the concrete area while feeding) or on the pad (with feed placed on the concrete area and the feeding barrier between the pad and concrete area). Factors studied were woodchip size (7.5 cm; 2-3 cm; 1-2 cm; and sawdust), feeding management (on or off the pad) and area allowance (11.8 and 18.6 m^2 per head). A total of 4 measurement periods were conducted, each of 6-7 weeks, with treatments allocated to pads based on a Graeco-Latin Square design. Beef cattle (Friesian-Charolais steers) used in the study were weighed at the beginning and end of each period. Meteorological data were monitored at the site.

2.2 Commercial farm sites

Three commercial farms using woodchip pads for out-wintering cattle were selected as being suitable for NH_3 emission measurements, located in Powys, Leicestershire and Shropshire. The pad in Powys was 1085 m^2 and used for c. 31 organic beef finishers. The pad in Leicestershire was 1370 m^2 and used for up to 100 beef cattle. The pad in Shropshire was 600 m^2 and used for out-wintering c. 400 cows and heifers prior to calving and subsequently for young stock. Meteorological data were monitored at the site.

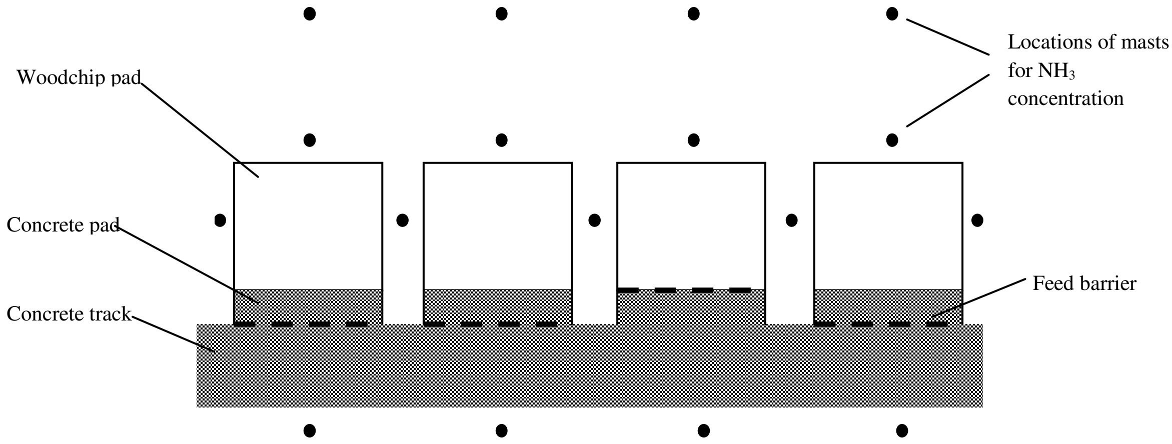

FIGURE 1 **Schematic plan view of the pilot-scale woodchip pads at North Wyke**

2.3 Ammonia emission measurements

Ammonia emissions from all pads were estimated using a short-range dispersion model (ADMS 4.0), as described by Hill et al. (2008). The vertical profile of NH_3 concentration was measured using Willem's badges on masts (up to 4.5 m) at a number of locations around the pads (upwind and downwind), on a number of occasions over the study period. Willems badges were exposed for a 24 h period at the pilot-scale study site and 48 h at the commercial farm sites on each measurement occasion. At the pilot-scale pads, two 24 h measurements were conducted towards the end of each 6-7 week period (i.e. eight NH_3 emission measurement occasions in total). Fewer measurements were conducted at the commercial farm sites in the first year. Where possible, measurement dates were selected with favourable and consistent wind direction (dependant on site), to avoid potential large background sources and, for the pilot-scale pads, to ensure a wind direction at 90^o to the alignment of the pads, enabling emission from each individual pad to be determined. Inputs to the dispersion model included hourly meteorological data for each monitoring period (wind speed, wind direction, air temperature and solar radiation), locations and dimensions of any significant NH_3 sources (including the woodchip pads, slurry lagoons, cattle sheds etc.), a site building configuration, an estimation of surface roughness of the surrounding area and the position and height of each Willems badge monitoring point.

3 RESULTS AND DISCUSSION

In most cases, Willems badge data gave strong negative correlations showing reducing NH_3 concentration with height, allowing most data sets to correlate well with modelled emissions. Preliminary assessment of the NH_3 emissions data at the pilot-scale pads suggest there was no significant impact of woodchip size, stocking density or feeding management. The four pilot-scale pads were therefore treated as a single site and mean emission rate derived for each sampling occasion. Average (mean and median) NH_3 emission rates together with the range in observations are given in Table 1 on a pad surface area basis and a per animal basis. Emission rates from the pilot-scale pads tended to be greater than from the commercial farm sites, possibly because of the smaller size of the pilot-scale pads and greater influence of the feeding area.

TABLE 1 **Ammonia emission rates from the pilot-scale and commercial farm woodchip pads**

	Pilot-scale pads		**Powys**		**Leicestershire**		**Shropshire**	
	g m^{-2} d^{-1} NH_3	g $head^{-1}$ d^{-1} NH_3	g m^{-2} d^{-1} NH_3	g $head^{-1}$ d^{-1} NH_3	g m^{-2} d^{-1} NH_3	g $head^{-1}$ d^{-1} NH_3	g m^{-2} d^{-1} NH_3	g $head^{-1}$ d^{-1} NH_3
Mean	3.69	44.5	1.19	44.2	0.79	31.2	1.89	28.4
Median	2.93	35.7	0.45	16.9	0.48	19.1	1.67	25.2
No. observations	8	8	4	4	3	3	4	4
Standard deviation	2.94	35.0	1.51	56.4	0.57	23.6	0.48	7.2
Minimum	0.16	1.9	0.38	14.2	1.45	58.4	2.60	39.1
Maximum	9.14	102.1	3.46	128.8	0.45	16.2	1.61	24.1

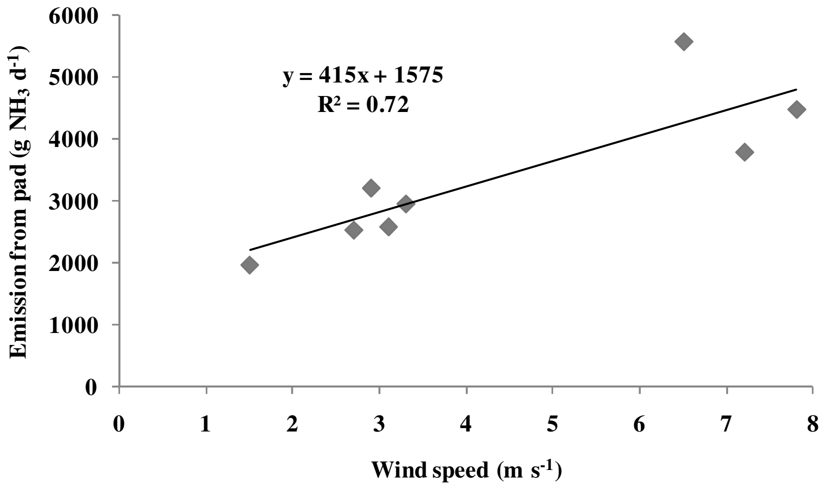

FIGURE 2 **Relationship between ammonia emission from the pilot-scale woodchip pads and wind speed**

Strong, positive linear relationships were established between the NH_3 emission rate from the woodchip pad and ambient wind speed for three of the study sites (North Wyke pilot-scale pads, Powys and Leicestershire), shown in Figure 2 for the pilot-scale pads. This is not surprising as wind speed has been cited as a major factor influencing NH_3 emissions following slurry applications to land (e.g. Misselbrook et al., 2005), with higher wind speeds decreasing the laminar boundary layer across which volatilised NH_3 has to diffuse and increasing the transfer of NH_3 away from the emitting surface. Although expected from theory, no significant relationships were found between NH_3 emission rate and ambient temperature or solar radiation, but this may have been because of confounding factors such as surface crusting at higher temperatures increasing the resistance to NH_3 transfer across the emitting surface.

Expressed on an area basis, the median emission rates (the median being less biased by outliers than the mean) from the data collected so far from the commercial sites (0.45 – 1.67 g m^{-2} d^{-1} NH_3) were lower than those reported by Misselbrook et al. (2006) for beef cattle concrete feeding yards (mean 5.5 g m^{-2} d^{-1} NH_3). However, expressed per animal, emission rates from this study (16.9 – 25.2 g $head^{-1}$ d^{-1} NH_3) were similar to that of 22.0 g $head^{-1}$ d^{-1} NH_3 reported by Misselbrook et al. (2006), reflecting the much larger area allowance per animal for the woodchip pads than concrete feeding yards in the respective studies. The emission rates were also of a similar magnitude to those reported for beef cattle in straw-bedded housing (Misselbrook et al., 2000).

Our hypothesis was that the increased infiltration and absorption of urine by the woodchips would result in lower NH_3 emissions than for concrete yards. The extent to which this occurs will depend on the surface characteristics of the woodchip pad and the subsequent changes over time with the continued presence of cattle. A very absorbent surface layer would retain most of the urine at the surface, from where NH_3 emission may readily occur. In a laboratory study, Misselbrook and Powell (2005) showed the importance of physical characteristics of bedding materials on NH_3 emission from urine deposits, reporting a positive relationship between emission and bedding absorbance capacity, and a negative relationship between emission and bulk density of the packed bedding material.

Finally, emissions from the whole management system must be considered, so a comparison between traditional beef housing systems and out-wintering on woodchip pads must also take into account emissions from subsequent manure storage and application.

4 CONCLUSIONS

At this stage only tentative conclusions can be drawn, as these results represent only the first year of a two-year study. From these preliminary data, initial conclusions are that emission rates from woodchip pads used for out-wintering cattle show considerable variation, are not significantly impacted by woodchip size, stocking density or feeding management and, contrary to our hypothesis, are of a similar magnitude to emissions from cattle on concrete yards. Further analyses of the data from both years of the study are awaited. Further controlled, mechanistic studies may be required to understand the factors influencing NH_3 emissions from excretal depositions to woodchip pads.

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