The effect of application technique and climate conditions on ammonia emissions from cattle slurry

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Introduction

The agricultural sector accounts for 98% of ammonia (NH_3) emissions in Ireland, with the cattle industry accounting for approximately 78% and 73% of total agricultural emissions in 1991 and 2010, respectively (Hyde *et al.* 2003). Under the National Emissions Ceilings Directive (Council Decision 2001/81/EC), Ireland is limited to produce 116,000t of NH_3 come 2010. Emissions are currently just below this target at 113,000 Kt (Hyde *et al.* 2003). The vast majority of Irish cattle slurry is spread using a splashplate application, where the slurry is pressurised against a plate and is spread in a thin uniform layer on the ground. Hyde *et al.* (2003) estimated that the land-spreading of cattle slurry in any one-year can typically account for 40% of total national NH_3 emissions. Therefore, a method of slurry application that reduces NH_3 emissions will impact substantially on Ireland's emission levels.

The trailing shoe is used to apply slurry in narrow bands on the soil surface and under a crop canopy. The bands are approximately 5cm wide and this leads to a 79% reduction in the area that is covered by the slurry compared with the splashplate. This reduced slurry area has the potential to decrease NH_3 emissions.

There are numerous factors which can affect the rate and total emissions of NH_3 from slurry, such as the slurry its self with regards to dry matter (DM), and total ammonium-nitrogen content (TAN). Slurry with a high proportion TAN has the ability to emit more NH_3 than slurry with a low amount of TAN present. Various weather conditions can have an effect on the rate of NH_3 emissions with factors such as wind speed, solar radiation, precipitation, and soil and air temperatures. Soil conditions such as moisture content can also have an effect, where by a dry soil will lead to greater infiltration of the slurry and therefore a lower NH_3 emission (Sommer & Hutchings 2001).

The objective was to assess the effect of both application techniques and climatic drivers on NH_3 emissions from cattle slurry applied to grassland under Irish conditions.

Materials and Methods

On two dates during 2006 (12/7) and 2007 (14/5,) cattle slurry (DM- 83.1 & 76 g kg^{-1}; TAN- 1.71&1.42 kg t^{-1}) was applied at 30 m^3 ha^{-1} to grassland plots (see Table 2 for climatic conditions). These plots were a pseudo-circular in shape and 30 m in diameter. The plots were created by spreading a 30 m long, 6 m wide strip. To each side of this a 24 m strip was spread with a further two strips 18 m long to each side of the 24 m strips. The four plots were 23 m apart and positioned in a line which was perpendicular to the prevailing wind. Each plot had been mown off to a height of 5 cm two to three days before spreading.

The trailing shoe and splashplate methods were used to apply the slurry. There were two plots per treatment located on grassland at Johnstown Castle, Co. Wexford Ireland.

The NH_3-N emissions were measured using a micrometeorological mass balance technique. Masts (4) were located in the centre of each area to which the slurry had been applied and two masts were positioned upwind from the four plots. Passive flux samplers commonly known as shuttles were placed on the four masts in the centres of the plots at 0.2, 0.4, 0.8, 1.2, 2.2 and 3.3 m above ground level (see Leuning et al. 1985 for shuttle details). The upwind masts had samplers at 0.2, 0.8, 2.2 and 3.3 m above ground level. The shuttles were changed during the seven day measurement period at approx 1, 3, 6, 24, 48 96 and 168 hours following the slurry application. The shuttle's interior lattice were washed with acetone to remove trace ammonium, and subsequently coated with 3% oxalic acid and allowed to dry completely. All joints and orifices were sealed and the shuttles were placed in a nitrogen free cold room prior to exposure.

As air flowed through the shuttle, the NH_3 was converted into ammonium (NH_4) under acidic conditions. The samplers were washed out with 30 ml of deionised water for one minute, the NH_4 -N concentration of the solution was then determined photometrically. On each occasion an emission of NH_3 was calculated from each plot. The Students t-test was used to determine the significance of treatment effects.

Results and Discussion

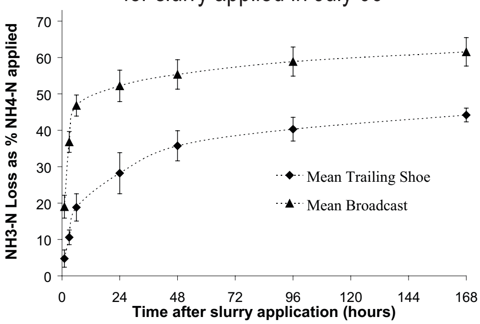
On the two spreading dates in July 2006 and May 2007 there were significant reductions (Table 1.) in the emission of NH_3-N as a percentage of NH_4-N applied from the trailing shoe compared to the splashplate application methods.

Table1. NH_3 loss as a percentage of the total NH_4-N applied by splashplate (SP) or trailing shoe (TS)

Spreading Date	SP	TS	% Reduction	P Value
12/7/2006	61.54	44.20	28.18	0.036
14/5/2007	73.05	43.72	40.15	0.024

There was a difference in the weather conditions observed over the two spreading dates. On average during measurement period of the July spreading, temperature and solar radiation were higher, while in the May spreading, wind speed, precipitation and relative humidity were higher. These different weather conditions affected the amount (Fig.1 & 2) and rate (Fig.3 & 4) at which the NH_3 was volatilised from the slurry.

Figure 1. The temporal trends in NH_3-N loss as a % of the NH_4-N applied for slurry applied in July 06

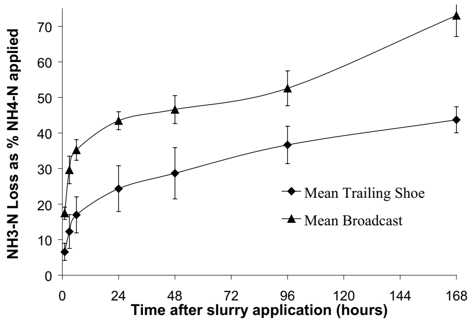


In July 52% of the total NH_3 emitted over the seven days was lost in the first 24 hours when slurry was applied by splash-plate. This was due to low relative humidity, an absence of precipitation and higher air temperatures during this spreading period. By comparison, only 28 % was lost with the trailing shoe application for the same period, representing a

24% reduction in emissions. Previous studies have shown 23-57% reduction in emissions (Smith et al., 2000). On average after the first day, air temperature and solar radiation increased, while wind speed and relative humidity decreased. With no precipitation present the slurry on the splashplate treatment began to form a crust and this reduced the potential of the slurry to emit NH_3. With the slurry from the trailing shoe treatment present in thicker bands and shaded by the crop canopy it did not crust as rapidly. This lead to a higher rate of NH_3 emission compared to the splash-plate treatment (0.08 vs. 0.04 kg $Ha^{-1}h^{-1}$) (Fig.3) over the last five days of the measurement period.

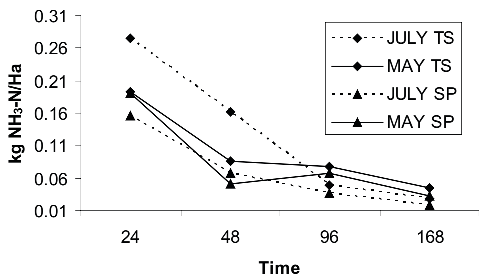
In the splash-plate spreading of May 2006 52% of the NH_3 emitted over the seven days was lost in the first 96 hours (Fig. 2).

Figure 2. The temporal trends in NH_3-N loss as a % of the NH_4-N applied for slurry applied in May 07



This was due to the fact that some precipitation had occurred from hour 8 to 62 after application. Low wind speed, air temperatures and solar radiation were recorded, whilst relative humidity at its highest over that period also. The emission rates of NH_3 for the last three days of the measurement period were greater in 2007 than 2006 for both splash plate and trailing shoe applications (2006-0.03&0.04, 2007-0.05 & 0.06 kg $ha^{-1}h^{-1}$) (Fig.3). Over this time period the weather conditions favoured NH_3 volatilisation with the slurry being moist from the precipitation with an increase in solar radiation, wind speed and a decrease in relative humidity.

Figure 3. The temporal trends in NH_3-N loss rate in kg $ha^{-1}h^{-1}$ from 24-168 h on both spreading dates

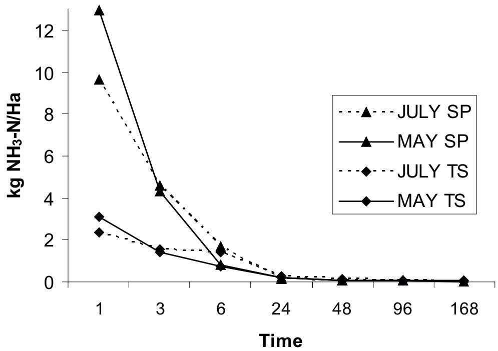


The meteorological conditions in the first hour after application differed on both spreading dates (Table 2). In July 2006 splashplate and trailing shoe NH_3 emissions were 9.7 and 2.4 kg $ha^{-1}h^{-1}$ respectively. While in May 2007 NH_3 emissions were 12.9 and 3.1 kg $ha^{-1}h^{-1}$ for splashplate and trailing shoe (Fig.4), however the TAN content in the slurry was higher in 2006.

Table 2: The weather conditions for the first hour after both applications

Date	mean temperature	wind speed	solar radiation	relative humidity
	0C	ms^{-1}	Jcm^{-2}	%
12/7/2006	14.9	7.65	46.6	92.8
14/5/2007	12.6	7.95	235.3	53.4

Figure 4. The temporal trends in NH_3-N loss rate in kg $ha^{-1}h^{-1}$ for both spreading dates



Conclusion

On the two spreading dates in July 2006 and May 2007 there were significant reductions of 28 and 40% in the emission of NH_3-N as a percentage of NH_4-N applied from the trailing shoe compared to the splashplate application methods. The prevailing weather conditions had an impact on the rates of NH_3 emissions over the two dates. In July 2006 the warm dry sunny weather created a crust on the splashplate plots, which reduced their emissions in last five days of the measurement period. Due to the fact that the slurry from the trailing shoe application was present in thicker bands and sheltered under the crop canopy, the slurry emitted at a higher rate over that same period. In May 2006 lower wind speed, solar radiation, air temperature along with higher precipitation and relative humidity led to a decrease in the emission rates from both splashplate and trailing shoe in hours 36 to 48. After this weather conditions conducive to NH_3 volatilisation returned and the emission rates were higher over the three days of the measuring period in 2007 as compared to 2006. In this study variations in meteorological conditions were found to have a large effect on NH_3 emissions, especially within the first hour. Ammonia emission rates were 33% and 29% greater in 2007 than in 2006 for splash plate and trailing shoe respectively. This was due to the major difference between the relative humidity's and solar radiation measurements on the two spreading dates.

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