COMPARISON OF MICROMETEOROLOGICAL TECHNIQUES FOR ESTIMATING AMMONIA EMISSION FROM COVERED SLURRY STORAGE AND LANDSPREADING OF CATTLE SLURRY

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The micrometeorological mass-balance integrated horizontal flux (IHF) technique has been commonly employed for measuring ammonia (NH_3) emissions in on-field experiments. However, the inverse-dispersion modeling technique, such as the backward Lagrangian stochastic (bLS) modeling approach, is currently highlighted as offering flexibility in plot design and requiring a minimum number of samplers (Ro et al., 2013). The objective of this study was to make a comparison between the bLS technique with the IHF technique for estimating NH_3 emission from flexible bag storage and following landspreading of dairy cattle slurry. Moreover, considering that NH_3 emission in storage could have been non uniform, the effect on bLS estimates of a single point and multiple downwind concentration measurements was tested, as proposed by Sanz et al. (2010).

In the current study, two experiments were performed in northern Spain: (I) in an outdoor flexible bag storage system and (II) in a plot. In study I, 2,000 m^3 slurry were stored into an impermeable plastic bag and produced biogas was discharged to the atmosphere through 6 chimneys located at the centre of the lagoon. One vertical mast was placed in each side of the storage, which was considered as upwind or downwind depending on main wind direction recorded during the exposure session. Masts supported five passive flux samplers (PFS) coated with oxalic acid (Leuning et al., 1985) and mounted logarithmically at heights of 0.30, 0.48, 1.00, 2.05 and 3.05 m above the soil surface. Furthermore, for single (S) and multiple downwind points (M) testing, two more masts (PFS at 1.00 m height) were placed in each side of the storage. Samplers were replaced every day during 10 measuring days and were immediately transported to the laboratory to be leached with 60 ml of deionised water and analyzed for NH_4^+-N by spectrophotometry. In study II, 145 m^3 slurry from storage were applied to 2 ha land at 323 kg N ha^{-1} by means of a tanker fitted with trailing-hoses. One day after slurry application, the soil was turned with a plough machine. A mast was placed towards downwind of the plot supporting four PFS placed at 0.48, 1.00, 2.05 and 3.05 m height and were changed daily during 3 days before fertilization and 2.5, 9.5, 22.5 h after slurry application. Thereafter, they were changed daily during the following 4 days. For study I and II, a background mast was located 150 m upwind from the storage and fertilized soil. For NH_3 emission determination, the IHF method was used as reference technique. On the other hand, commercial software (Windtrax 2.0, Thunder Beach Scientific, Canada) was used for the determination of NH_3 emission by applying the bLS model. Inputs within measurement periods were average wind speed at heights of 0.30, 0.48, 1.00 and 2.70 m, wind direction at 2.70 m, air temperature, the default surface roughness length for base soils (z_0 = 0.01 m) and NH_3 concentration (μg N m^{-3}). A post-data filtering criteria was performed (friction velocity, $u^* \geq 0.15$ m s^{-1}; Obukhov stability length, $|L| \geq 10$ m) in order to avoid extreme atmospheric stability situations (Ro et al., 2013).

Ammonia emissions estimated by the IHF technique in storage and land (Table 1) were considered low compared to previous studies (VanderZaag et al., 2010; Sanz et al., 2010), indicating that flexible bag storage and slurry application to soil through narrow bands followed by incorporation to soil could have mitigated NH_3 emissions in our research. In study I, NH_3 estimates in M were higher and presented better plot coverage (higher footprints) than in S (Table 1). The differences observed in NH_3 estimates between bLS and IHF techniques were considerably greater in the current experiments than those reported elsewhere by other authors. For instance, Sommer et al. (2005) observed NH_3 estimates from bLS averaged within 16-24% of the IHF estimates in land, whereas Sanz et al. (2010) reported bLS estimates averaging within 5-10% of the IHF estimates after pig slurry application. Our reduced accuracy was attributed to two factors: (I) the low NH_3 emissions observed through both techniques could have lowered the accuracy of the ratio between bLS and IHF estimates and (II) the low footprints observed in the bLS case could indicate that average wind direction within 24 h period did not allow the NH_3 emission plume to be effectively captured by PFS when using Windtrax 2.0, resulting in uncertain emission estimates under changing wind directions.

Table 1. Comparison of mean NH_3 emission from storage (study I), NH_3 emission at peaking time from land (study II) and cumulative NH_3 emissions and footprints by bLS and IHF techniques.

Study	Downwind point	Mean $NH_{3\,bLS}$ ($mg\ N\ m^{-2}\ d^{-1}$)	Mean $NH_{3\,IHF}$ ($mg\ N\ m^{-2}\ d^{-1}$)	Cumulative $NH_{3\,bLS}$ ($mg\ N\ m^{-2}$)	Cumulative $NH_{3\,IHF}$ ($mg\ N\ m^{-2}$)
I	S	0.12 (0.25)†	14.17 (28.76)†	0.93 (9-14 %)*	157.05
	M	0.34 (0.29)†		2.58 (27-36 %)*	
		$NH_{3\,bLS}$ peak ($g\ N\ ha^{-1}\ h^{-1}$)	$NH_{3\,IHF}$ peak ($g\ N\ ha^{-1}\ h^{-1}$)	Cumulative $NH_{3\,bLS}$ ($kg\ N\ ha^{-1}$)	Cumulative $NH_{3\,IHF}$ ($kg\ N\ ha^{-1}$)
II	S	7.26	271.45	0.10 (1-27 %)*	6.77

†Mean (standard deviation). *Footprint (min-max %): fraction of the source area where emissions were "measured" by the sensor.

In conclusion, ammonia emissions from slurry management were lower than expected, possibly due to convergence of NH_3 abatement strategies, in both the storage and fertilization stages, and insufficient plot coverage by PFS. Under non uniform NH_3 emissions, the use of multiple downwind points resulted in more accurate estimates and better plot coverage compared to a single point. Results from the current study indicated that 24 hours average concentration and wind direction values could result in uncertain bLS estimates under changing wind directions.

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