

## STUDY OF NH<sub>3</sub> EMISSIONS DURING SLURRY STORAGE IN SMALL-SCALE TANKS

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### ABSTRACT

The main objective of this work is to quantify the effects of slurry store characteristics and weather conditions on the concentration of total N and total ammoniacal-N in stored slurry.

Two consecutive experiments were carried out to measure changes during slurry storage; first with pig slurry and then cattle slurry. At each site, three treatments from each slurry were prepared: whole slurry and the same slurry diluted with water to 75% and 50% of its original concentration. Each was replicated three times in tanks of 1m diameter x 0.8 m high. Meteorological data was recorded at each site in order to calculate evaporation rates from the slurries and to relate the wind speed measured over the surface of the tanks to that at 2 and 5 m height. Temperature probes were installed in three slurry tanks at 10 and 30 cm depths (representing each slurry dilution from one source) to help to calculate mineralization rates.

### INTRODUCTION

The Integrated Pollution Prevention and Control Directive (IPPC) requires action to be taken to reduce ammonia (NH<sub>3</sub>) emissions.

Agriculture is a major source of diffuse pollution and some of this pollution occurs following the application of livestock manures and slurries to land. But substantial amounts of nitrogen may be lost as NH<sub>3</sub> from slurry storage. Misselbrook et al., (2000) estimated that manure storage was responsible for about 9% of total NH<sub>3</sub>-N emissions in the UK, with cattle manure storage emissions alone, estimated at 16.6 kt year<sup>-1</sup> and pig manure storage 3.4 kt year<sup>-1</sup>.

The volatilization of NH<sub>3</sub> during storage depends on surface area and the local conditions that affect mass transfer (e.g. wind speed at the surface, total ammoniacal-N (TAN) concentration, pH, surface properties and temperature).

The main objective of this work is to quantify the effects of slurry store characteristics and weather conditions on the concentration of total N and TAN in stored slurry in order to produce a simple predictive model that can be applied to slurry stored on commercial farms.

### MATERIAL AND METHODS

The experiment consisted of two periods of slurry storage in small tanks for 15 weeks. The first was with pig slurry (22/05/2003-29/08/2003), and then cattle slurry (6/10/03-15/01/04), but only the results for pig slurry are reported in this paper.

The experiments were conducted at three different sites in England, IGER (South West), ADAS (West Midlands) and SRI (South East), to compare the impact of weather conditions on changes of nutrient concentrations in stored slurries.

The slurries were stored in small tanks of 0.6 m<sup>3</sup> capacity and diameters of 1.0 and 0.9 m at

the top, and base and 0.8 m height. Each tank was filled 0.4 m below the rim of the tank (0.3 m<sup>3</sup>) to allow for increase in volume due to winter rainfall. The slurry for each experiment was obtained from two different farms, the sources are denominated Slurry 1 and Slurry 2. They were delivered to all sites within three days. Three dilutions were prepared for each slurry type, undiluted (100% slurry), diluted with water to 75% and 50% of its original concentrations. There were three replicates for each slurry dilution. Therefore 18 tanks were used for each site and experiment.

Wind speed and rainfall were monitored at all three sites throughout the experiments, together with measurements to calculate evaporation. The monitoring equipment included a rain gauge, global radiation sensor, 12 temperature probes installed in the slurry tanks at depths of 10 and 30 cm (representing each slurry dilution from one source), a sensor for measuring air temperature, three anemometers (2 m and 5 m above ground, and one floating on the slurry surface) and a relative humidity sensor. The slurry depths were also measured manually each week and observations of crust development were recorded.

During the pig slurry experiments at SRI, a pair of 4Hz sonic anemometers was deployed at the liquid surface and at 5 m height. These provided high-resolution 3D measurements of wind characteristics, from which turbulence intensity was calculated.

Slurry samples were collected at the start and the end of each storage experiments and analysed for: pH, total solids (TS), volatile solids, total nitrogen (TN), as Kjeldahl-N, TAN and electrical conductivity (CE). Organic N (ON) was defined as  $ON = TN - TAN$ .

## RESULTS AND DISCUSSION

Slurry depth decreased in all slurries and at all sites (Table 2) due to evaporation of water in the dry summer weather. The evaporation of water from slurry was similar to that calculated from open water using the Penman equation from meteorological data. The length of storage had a greater influence than the slurry source on change of depth. The decrease in depth presented a linear trend against time.

The volume (V) of slurries in tanks (Table 2) was calculated as would be done for a truncated cone. The volume is directly related to the depth (D) data. The tanks at ADAS and IGER lost 50% of initial volume while the tanks at SRI lost around 80% the initial volume.

*Table 1. Mean losses of N from all sites and dilutions (%)*

Source	TN	ON	TAN
Slurry 1	36	54	8
Slurry 2	69	84	32
Both slurries	53	71	19

Surface area/volume ratios (Table 2) roughly doubled at ADAS and IGER by the end of the experiment, but roughly quadrupled at SRI, because of more evaporation there. During the experiments, two different trends were seen: for the first half of the experiment, the ratio was similar for all sites, sources and dilutions, but in the second half, the surface area ratio increased, due to evaporation of water from the slurries. The surface area/volume ratio fits an exponential function, which increases proportionally when the depth decreases.

Table 2. Changes in pig slurry composition during storage

ADAS											
Sample	Source	Dilution	pH	TS	TN	TAN	ON	CE	D	V	SA/V
Original	Slurry 1	100%	6.8	5.59	0.93	0.71	0.22	16.87	0.38	0.28	2.8
		75%	6.8	3.08	0.48	0.36	0.12	10.07	0.38	0.28	2.8
		50%	6.9	3.14	0.34	0.25	0.09	7.48	0.38	0.28	2.8
	Slurry 2	100%	7.8	5.33	1.14	0.74	0.40	22.37	0.39	0.28	2.7
		75%	7.9	2.67	0.96	0.41	0.54	13.27	0.39	0.28	2.7
		50%	7.9	1.37	0.39	0.27	0.12	9.45	0.39	0.28	2.7
End	Slurry 1	100%	6.5	11.42	0.86	0.62	0.24	15.03	0.17	0.12	6.0
		75%	6.9	2.55	0.24	0.08	0.16	7.71	0.18	0.13	5.6
		50%	7.0	2.92	0.13	0.03	0.10	5.14	0.17	0.12	5.9
	Slurry 2	100%	7.0	7.48	0.49	0.26	0.23	18.03	0.20	0.14	5.2
		75%	7.5	3.35	0.15	0.04	0.11	9.12	0.19	0.14	5.3
		50%	7.7	2.18	0.08	0.02	0.06	6.64	0.17	0.12	5.9
IGER											
Sample	Source	Dilution	pH	TS	TN	TAN	ON	CE	D	V	SA/V
Original	Slurry 1	100%	6.9	8.06	0.96	0.68	0.28	17.03	0.35	0.25	3.1
		75%	6.8	7.69	0.80	0.51	0.28	13.60	0.35	0.24	3.2
		50%	7.0	6.50	0.66	0.44	0.22	12.03	0.34	0.24	3.2
	Slurry 2	100%	7.6	6.84	1.14	0.90	0.24	23.57	0.34	0.25	3.1
		75%	7.6	6.40	0.94	0.73	0.21	19.57	0.33	0.25	3.0
		50%	7.8	3.86	0.64	0.47	0.16	13.87	0.34	0.25	3.1
End	Slurry 1	100%	6.5	8.90	1.02	0.70	0.32	24.87	0.19	0.12	5.8
		75%	6.7	7.23	0.50	0.26	0.25	18.37	0.18	0.12	6.2
		50%	6.8	4.96	0.35	0.16	0.19	10.46	0.17	0.11	6.5
	Slurry 2	100%	6.8	7.13	0.51	0.26	0.24	18.73	0.18	0.13	5.6
		75%	7.1	5.40	0.27	0.11	0.16	13.20	0.17	0.12	5.9
		50%	7.2	2.91	0.15	0.04	0.11	9.39	0.16	0.12	6.1
SRI											
Sample	Source	Dilution	pH	TS	TN	TAN	ON	CE	D	V	SA/V
Original	Slurry 1	100%	7.5	12.61	1.26	0.76	0.51	12.73	0.39	0.29	2.7
		75%	7.3	7.40	0.87	0.56	0.32	10.56	0.39	0.29	2.7
		50%	7.5	4.51	0.60	0.39	0.22	8.11	0.39	0.29	2.7
	Slurry 2	100%	8.1	8.29	1.32	1.01	0.33	18.57	0.39	0.29	2.7
		75%	8.0	4.78	0.97	0.74	0.25	15.83	0.39	0.29	2.7
		50%	8.2	3.89	0.68	0.52	0.16	11.93	0.39	0.29	2.7
End	Slurry 1	100%	6.5	7.27	0.81	0.45	0.22	33.85	0.13	0.07	10.6
		75%	6.4	7.37	0.62	0.22	0.22	27.04	0.10	0.06	11.7
		50%	6.9	5.33	0.24	0.03	0.15	9.60	0.08	0.06	11.5
	Slurry 2	100%	7.0	7.89	0.62	0.21	0.22	31.48	0.11	0.08	9.5
		75%	6.9	5.28	0.31	0.10	0.18	23.41	0.09	0.06	12.9
		50%	7.8	4.80	0.19	0.01	0.16	14.04	0.08	0.07	10.8

TS= Total solids, TN= Total Nitrogen, ON= Organic nitrogen, all value are in kg/tank. CE= Conductivity ( $\mu\text{S}/\text{cm}$ ). D= Depth (m), V= Volume ( $\text{m}^3$ ), SA/V= Surface area/volume ratio ( $\text{m}^{-1}$ )

The main changes in N fractions (Table 1) show very large losses in N (mean of 53%), with the losses from Slurry 2 being nearly twice those from Slurry 1. There was more mineralization of organic N and subsequent loss of TAN from Slurry 2. The large losses were partly because of high summer temperature, which accelerated both mineralization and volatilisation, and the relatively shallow depth of slurries, which was initially about 1/5<sup>th</sup> of typical average slurry storage depths.

The initial pH (Table 2) of Slurry 1 was 1 pH unit less than Slurry 2. While the pH of Slurry 1 was constant during storage, the pH of Slurry 2 decreased. This variation in pH was probably due to NH<sub>3</sub> emission, which increases the H<sup>+</sup> concentration in slurry. Slurry pH is also influenced by the production and evolution of CO<sub>2</sub>, the breakdown of volatile fatty acids and temperature. Hence, Slurry 2 is likely to have lost more NH<sub>3</sub> than Slurry 1. This supposition is confirmed by the large loss of nitrogen. So, Slurry 1 had similar total nitrogen, TAN and organic nitrogen amounts at the beginning and at the end of experiment, while all nitrogen types fell in Slurry 2. This was probably because in Slurry 1 the main component was organic, which is difficult to turn over quickly and probably there was a balance between the mineralization of nitrogen and losses of NH<sub>3</sub>. But nitrogen compounds present in Slurry 2 turned over faster. Nitrogen losses increased significantly with slurry dilution.

Conductivity (Table 2) value decreased in tanks with Slurry 2 due to loss of NH<sub>3</sub> but this parameter increased slightly on tanks with Slurry 1 due to evaporation of water.

## CONCLUSIONS

The main conclusions about slurry storage during summer in small tanks are:

- Loss of volume and decrease in depth showed a linear relationship with time.
- The surface area/volume ratio was an exponential function, which increased proportionally when the depth decreased
- The source of slurry had a big influence on the original chemical characteristics and hence on losses during storage, e.g. pH
- The higher pH in one slurry was probably the main reason for greater NH<sub>3</sub> emissions and N losses from one source of slurry
- The site, dilution of slurry and length of storage seem to be important factors in NH<sub>3</sub> emissions and N losses and transformations.
- The N losses were very large in these experiments, because of the weather and shallow storage depths.

## REFERENCES

- Misselbrook, T.H., Van der Weerden, T.J., Pain, B.F., Jarvis, S.C., Chambers, B.J., Smith, K.A., Phillips, V.R., Demmers, T.G.M. 2000. Ammonia emission factors from UK agriculture. *Atmos. Environ.*, 34: 871-880.