Results from testing of SyreN for reduced ammonia emission following land application of pig slurry

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June 2019
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1. Introduction

This document presents the results from testing of the SyreN technology for reduced ammonia emission following land application of pig slurry.

The document is based mainly on the DANETV Test report, "SyreN - Reduced emissions following land application of animal slurry" made by Martin N. Hansen (Hansen, 2011). However, data on weather conditions, soil analyses and slurry analyses delivered by the test responsible at Aarhus University, Tavs Nyord, have been added (Nyord, 2019).

Martin N. Hansen who was author of the DANETV test report on SyreN was at that time employed in AgroTech. Martin N. Hansen is now (June 2019) employed in SEGES. AgroTech is now (June 2019) part of Danish Technological Institute.

1.1. Name of product and vendor

SyreN is developed by BioCover A/S, Veerts Skovvej 6, Veerst, DK-6600 Vejen, Denmark. Website: www.biocover.dk. Contact person of BioCover is Morten Toft. Email: mt@biocover.dk. Phone: +45 29 63 49 36.

1.2. Name of test institute

SyreN has been tested at Aarhus University, Research Centre Foulum Blichers Allé 20, PO Box 50, 8830 Tjele, Denmark. Test responsible was Tavs Nyord, Email: tavs.nyord@eng.au.dk.

Review of the SyreN technology´s effect on ammonia emission was done by Danish Environmental Protection Agency´s technical advisory board for environmental technologies for agricultural production.

2. Description of the technology

The basic idea of the SyreN slurry application system is to add sulphuric acid to pig slurry during land application. In a liquid, ammonium will be in equilibrium with ammonia in its aqueous and gaseous forms as follows: NH_4^+ (aq) <—> NH_3 (aq) <—> NH_3 (gas). If pH is reduced the equilibrium is displaced to the left. By adding sulphuric acid to slurry pH is decreased and ammonia emission is reduced.

SyreN is an add-on system to be installed on existing slurry application machinery, which normally consisting of a tractor and a slurry tanker. There are three main parts of the SyreN technology:

1. Front tanks for storage of sulphuric acid and additives during land application

2. Terminal software for regulation of dosage of sulphuric acid and iron sulphate to slurry tanker
3. Pumps for addition of sulphuric acid and additives to the slurry tanker.

Figure 1 shows a photo of the SyreN technology installed on a tractor with a slurry tanker.

Figure 1. The SyreN technology includes three tanks installed on the front of the tractor. 1: Tank for iron sulphate. 2: Here the tank for sulphuric acid shall be placed. 3: Tank for water for cleaning the system.

Table 1 gives an overview of the main parts of the SyreN system.

Table 1. Overview of the main parts of the SyreN system (Hansen, 2011).

System part	Purpose
Front tanks	Storage system for sulphuric acid and additives during land application
Terminal software	Regulation of dosage of sulphuric acid and additives to slurry tanker
Pumps	Addition of sulphuric acid and additives to slurry tanker
Slurry tanker	Transport and land application of acidified animal slurry

3. Test design

The SyreN slurry application system was tested in full-scale on fields under normal operational conditions. The test was designed so that it was possible to determine ammonia emission following the use of the SyreN system compared to a reference slurry application system.

The primary performance parameter is loss of NH_3-N in percent of applied NH_4-N.

3.1. Test site

The SyreN slurry application system was tested at the fields of Aarhus University, Research Centre Foulum, Blichers Allé 20, 8830 Tjele, Denmark. Responsible for planning, measuring, and quantification of ammonia emission was Tavs Nyord.

The SyreN system was tested using pig slurry applied to a winter wheat field. The test involved measurements from three slurry application scenarios, see Table 2.

Table 2. Three slurry application scenarios were tested (Hansen, 2011)

Scenario no.	Description
1	Application of un-treated pig slurry using trailing hoses (reference scenario).
2	Open slot injection of un-treated pig slurry.
3	Addition of sulphuric acid to pig slurry and land application using trailing hoses.

3.2. Test methods

<u>Ammonia emission</u>
The emission of ammonia from the animal slurry applied to agricultural land by the SyreN technology was quantified by a test design based on the micrometeorological mass balance technique. The technique is described in detail by Denmead (1983), Ryden et al. (1984), Leuning *et al.* (1985); Sherlock *et al.* (1989), Huijsmans et al. (2001), but will be described briefly below.

The micrometeorological mass balance technique involves a measuring mast situated centrally in each experimental plot, and a background measuring mast located outside the plots for measurement of the background NH_3 levels. The theoretical profile shape (Z_{inst}) method, described by Wilson *et al.*,1983; Sherlock et al., 1989; Gordon et al., 1988 was used for the measurements which involved that both the both the centrally located mast and the background mast were fitted with two measuring units mounted at a fixed distance above soil surface. The fixed distance (Z) is depending on height and roughness of crop and the size of the experimental plot. The actual Z value was calculated as suggested by Wilson et al. (1983) and Sherlock et al. (1983).

<u>Composition and dosage of pig slurry</u>

Samples of the animal slurry used in the experiments were taken while the slurry was land applied. The slurry application rate was calculated by weighing the amount of animal slurry applied to the experimental plots and by measuring the area of the experimental plots onto which the slurry was applied. The amount of slurry applied was measured by weighing the manure application device before and after manure application on each plot. The area of land applied manure was calculated by measuring the area of land applied animal slurry.

<u>Meteorological data</u>

The ammonia emission from land applied slurry is highly depending on the meteorological conditions during and following land application. Hourly data for wind speed, temperature, incident solar radiation, atmospheric humidity and precipitation were therefore continually measured during the measurement period by a meteorological station situated less than 1 km from the experiment site.

The experimental plots were situated at least 100 m apart, and more than 300 m away from ammonia emitting sources like animal houses and manure storage facilities. As a free wind-profile is required the experimental plots were situated as far away from wind breaks like houses and trees as possible and no closer than 10 times the height of the wind break.

3.3. Test equipment

<u>Ammonia sampling systems</u>

Passive flux samplers were used as ammonia traps (see picture in Figure 1). By this system the ammonia holding air passively passes through the internal of the passive flux samplers. The internal of the passive flux samplers was coated before the sampler were attached to the measuring masts by an acid solution (Leuning *et al.*, 1985).

The passive flux samplers consist of an outer cylinder fitted with mounting pivots and fins to keep the device aligned with the wind and a detachable venturi shield which holds a thin orifice plate (see Figure 2). When passive flux samplers are used for trapping of ammonia, the determination of a wind profile is not required.

Figure 2. Picture of a passive flux sampler fitted with mounting pivots and fins to keep the device aligned with the wind.

The flux of ammonia was measured continuously 96 hours following slurry application.

3.4. Experimental operation for ammonia measurements

The pig slurry was each experimental test day uniformly applied to two experimental plots (36m x 36m) situated more than 100 m apart. One of the plots was applied ca. 31 tonnes of untreated animal slurry per ha, while the other plot was applied ca. 31 tonnes of acidified slurry per ha. The plots were created by applying the slurry to pre-marked experimental plots. The application was done by three parallel passes of the 12 m wide land applicator system. Slurry applied outside the experimental plots were incorporated into the soil as soon as possible to stop emission of ammonia.

As soon as possible after the slurry was applied to the first half of the plot – which usually was within two minutes after the start of the application, the central mast attached measuring units was placed in the centre of the experimental plot. After placement of the central mast the ammonia measurements were initiated at both background and central masts, halfway through the manure application.

The ammonia emission from the experimental plots were continuously measured for 144 hours (6 days) after manure application. During the first twelve hours – when the rate of NH_3 volatilization was highest – the ammonia traps were replaced three times to avoid oversaturation of the ammonia sampling system. Further replacement took place every morning for the following 3 days and after six days. The amount of ammonia volatilized during each interval was calculated by the amount of ammonia trapped by the ammonia traps.

3.5. Operational conditions

The ammonia reduction effect of the SyreN system is depending on the quantity of sulphuric acid added to the animal slurry. The amount of acid added and its effect on slurry pH was measured each experimental day. Used amounts can be seen in table 3.

Table 3. Day of experiment, type of slurry and amount of sulphuric acid used by SyreN in the test (Hansen, 2011).

Day of experiment	Type of slurry	Type of crop	Supplied acid l t^{-1} slurry	pH of slurry	
				Untreated	Acidified
04.05.2010	Pig slurry	Winter wheat	2.0	7.2	6.1
18.05.2010	Pig slurry	Winter wheat	2.2	7.9	6.7

The measured data on air temperature and precipitation during the ammonia emission study can be seen in table 4.

Table 4. Mean air temperature and precipitation during the measurement of ammonia emission (Nyord, 2019).

Period of experiment	Mean air temperature on the day of slurry application. From time of application to 00:00 (Degree Celsius in 2 meter height)	Mean air temperature in the complete measurement period (Degree Celsius in 2 meter height)	Precipitation on the day of slurry application. From time of application to 00:00 (mm)	Precipitation in the complete measurement period (mm)
4th of May 2010	5.6	6.3	2.2	4.6
18th of May 2010	12.5	12.4	0	3.4

In table 5 the measured data on wind speed and soil temperature during the ammonia emission study are presented.

Table 5. Mean wind speed and soil temperature during the measurement of ammonia emission (Nyord, 2019).

Period of experiment	Mean wind speed measured on the day of slurry application. From time of application to 00:00. (Meter/sec in 10 meter height)	Mean soil temperature in the complete measurement period. (Degree Celsius in 10 cm depth)
4th of May 2010	4.0	8.0
18th of May 2010	3.6	11.6

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In table 6 the results of soil analyses are presented. Soil samples were taken from the fields where the test with pig slurry was undertaken.

Table 6. Results of soil analyses from the fields used for the test of SyreN with pig slurry (Nyord, 2019).

Fields used in test with pig slurry	Texture (g 100 g^{-1})					pH
	<2 µm	2-20 µm	20-200 µm	>200 µm	Organic matter	
No. 1, 2 and 3	4.2	8.9	45.4	32.9	5.1	6.6

3.6. Analytical metods

In table 7 the analytical parameter and corresponding analytical method is described. The ammonia sampling units were transported to the analytic laboratory and analysed for absorbed ammonia within two hours after used. Slurry samples were analysed by Eurofins Steins laboratory, Smedeskovvej 38 8464 Galten. Website: www.eurofins.dk. E-mail: agro@eurofins.dk.

Table 7. Analytical parameter and corresponding method (Hansen, 2011).

Parameter	Unit	Measured by	Analytical method
Ammonia	Mg NH_3 ha^{-1}	The micrometeorological mass balance method	The integrated horizontal flux meth

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Table 8 present the results of the slurry analyses.

Table 8. Results of the analytical analyses of slurry samples (Nyord, 2019).

Date	Treatment	Total N (g/L)	NH4 (g/L)	pH	Dry matter (%)
04-05-2010	SyreN (rep 1)	5.0	4.1	6.1	5.9
04-05-2010	SyreN (rep2)	4.9	4.0	6.1	5.9
04-05-2010	Reference	5.0	4.0	7.1	5.6
18-05-2010	Reference (1)	3.6	2.8	7.8	1.9
18-05-2010	Reference (2)	3.5	2.9	7.8	2.5
18-05-2010	SyreN (rep 1)	3.2	2.9	6.7	2.4
18-05-2010	SyreN (rep 2)	3.2	2.7	6.6	2.8

The emission of ammonia was measured for pig slurry land applied to winter wheat. The emission from animal slurry applied by the SyreN system was compared to the emission of untreated slurry applied by trailing hoses and by shallow injection.

Trailing hose application of slurry was found to give the highest emission of ammonia, while shallow injection of animal slurry was found to give the lowest emission (Table 9). The ammonia emission from trailing hose applied pig slurry added between 1.9 and 2.9 l of sulphuric acid by the SyreN system was found to be 35 percent lower on average than the ammonia emission from trailing hose applied untreated pig slurry.

Table 9. Average ammonia (NH_3) emission from pig slurry following land application by trailing hoses, shallow injection and the SyreN system. The SyreN system was trailing hose application of slurry added between 1.9 and 2.9 l of sulphuric acid per 1000 l of slurry (Hansen, 2011).

Type of slurry	Crop	NH_3-N loss, % of applied NH_4-N		
		Trailing hoses	Shallow injected	SyreN
Pig slurry	Winter wheat	23	11	15

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