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TC-O-TOFT Development of system to reduce ammonia emission and leaching of nitrate from slurry application

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Abstract

With the increasing industrialization of agriculture the trend towards ”clusters” of animal production in many countries, the concentration and animal density, has become a problem to the surrounding environment. So far, this has resulted in the EU nitrate directive and the EU National Emission Ceiling, in addition to limiting the amount and emission of nitrogen. In some cluster areas such as Denmark and The Netherlands, national legislations are more advanced and this has given rise to an accelerated implementation of the directives compared with the rest of EU. Consequently, development of new environmental technologies such as the SyreN system discussed in this article.

Keywords

nitrogen, SyreN system

1. Objectives

The national legislation in both above-mentioned countries, specifically addresses soil injection of slurry. Injection of slurry significantly reduces the ammonia emission from slurry, but it is also an expensive method compared to surface application and has drawbacks such as:

- Damage to growing crops
- Operational problems in heavy- and/or undulated grounds, and under dry soil conditions
- Risqué of pollution swapping in the form NH_3 and N_2O
- Increased traffic on fields and compaction of soils

Thus, a project in cooperation with Aarhus University was initiated to prototype a system using acid to control the ammonia emissions without the drawbacks of injection.

2. Results

The SyreN system uses a known technique, lowering the pH of the slurry, known as acidification [1] to reduce the ammonia emission. Concentrated sulphuric acid is used to lower the pH of the slurry during application in the field. The novelty of using acidification in the field is a significant reduction in use of acid compared with storage or barn acidification. This effect is a result of treating only the liquid fraction of the slurry, avoiding consumption of acid by the dry matter. In addition, treatment in the field is flexible and can be adjusted to changing weather conditions, which greatly influences emissions. The dose rate of sulphuric acid can be adjusted to crop need for sulphate fertilizer with good economic results.

A special feature of the SyreN system is using the transport container for sulphuric acid (IBC -Intermediate Bulk Carrier) as an acid tank with the system. This method creates a safe manner to use such system, as there is no refilling / handling of the acid at the user end but only a dry coupler must be used. Furthermore, the IBC is standard approved for public road transportation under the ADR rules. The system is positioned in the front hitch of the tractor, which facilitates loading of the IBC tank, and offsets weight from the slurry tanker to the tractor

2.1. Economy

The trial results from 4 years of tests in Denmark and Germany have revealed that the amount of nitrogen from the reduction in ammonia emission, in combination with a unique way of applying Sulphur as a fertilizer, is profitable. That means that there is a market for the technology with application of all slurries regardless of environmental concerns or not [2]. In the period from 2010 to 2014, + 50 trials with bandspreading have shown an average yield increase of 4% in grass and 2,4 kg/ha-1 in wheat. The economic effect of acidification is influenced by the application technology which is used. Broadcasting of slurry is known to have a very high emission rate and the use of the system in combination with this technology has the highest effect with an average estimated +30 kg nitrogen pr. Ha. [7]. The variation ranges from +10 kg to +60 kg nitrogen / Ha. The combination of bandspreading and acidification is well documented with a VERA test protocol for emissions from fertilizers [3]. It reduces the ammonia emission between 40 – 60%, equivalent of +15 kg nitrogen pr. Ha, based on slurry pH of 6.4. The combination of acidification with open slot injection reduces the effect to an estimated +5 kg pr. Ha. A large number of trials by Aarhus University and Leuphana Universität have compared the effect of open slot injection system to acidification and has largely concluded that the two systems are similar concerning emission and yield increase. Authors have also tried to determine the ideal pH level of the slurry, where the conclusion is that the economical optimal level is pH 6.4, with pH 6.0 having the better emission reduction. Acidification also makes more phosphorus available for plant uptake [1]. The wider working width using acidification compared to injection as well as increased capacity of slurry application makes acidification more profitable than injection.

In addition, different additives can also be added to the slurry from the SyreN additive tank system. Currently iron sulfate is used for reduction of odor from slurry. Manganese sulfate- or nitrate in combination with a low pH in the slurry is used in areas with manganese deficiency as well as all dissolvable micro nutrients can be added to the slurry. Finally, nitrogen inhibitors are used to reduce the nitrification process of the ammonium from slurry. This is especially recommended for maize, beets or all autumn applications, where an increased risk of leaching is present. A research study by SEGES, Denmark [5] – shows an estimated reduction in leaching from nitrogen with an average 6 kg ha-1. from maize and spring crops.

Increasing the use efficiency of organic fertilizer has a significant GHG abating effect. A recent LCA study on acidification during field application has revealed a reduction of 200 kg CO_2 eq pr. Ha [6] under Danish conditions using SyreN with bandspreading technology.

The economics of using acidification with SyreN system have a long range of variable parameters. In order to accommodate user requirements for estimates of profitability, two sets of software have been developed. Alfam model and SyreN Estimater. The core of the software is the Alfam model that is developed by Aarhus University [7]. It aims to estimate the emission from slurry under a given set of climatic conditions in combination with slurry types and application techniques. The software is free to use available at www.biocover.dk. The SyreN Estimater calculations are based on a fixed price pr. m^3 of treated slurry, as most users are custom applicators. To recommend a charge pr. m^3, the Danish custom applicator union [8] has conducted a study among its members (102 units operational in Denmark pr. 2015). As expected, the cost is highly variable depending on number of m^3 slurry offered to the system, where treatment of 20.000 m^3 recommends a price of 0.50 Euro pr. m^3, excluding variable cost for sulphuric acid. For an individual farmer / user, the cost is less, as they typically do not include profits for use of system in their calculations, but rely on the offset of nitrogen cost and / or yield increase to make use of the system in a profitable manner. A farm estimate based

on 1500 Ha swine / dairy farm shows a farm income of 32.000 Euro and 19.000 Euro respectively based on application by a custom applicator [9].

2.2. Sulphuric acid as a fertilizer

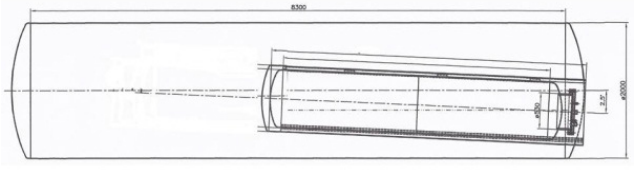
Sulphur deposition in Denmark has dropped from over 300 kg/ha in the early 80ties to just 3.7 kg/ha in 2013 [10]. This has introduced a growing need for sulphate as a fertilizer. From the recent 5 years of operation, we have seen a huge variation in the use of the system depending on local needs; The higher the crop need for sulphur, the better the economics. It is not unusual to see yield increases of ½ ton in rape, as it is hard to find fertilizers that satisfy the high consumption of sulfate. A common way to address the need for sulphur in rape, is to replace expensive fertilizers such as ammonium sulfate NS 21-24 with a combination of sulphuric acid and conventional fertilizers such as Nitrostar NS 28-5. This reduces the purchase price more than 25 Euro / ha and enables increased use of sulfate to reach the recommended target rate.

Sulphur deficiency is also common with grass. Many farmers are using slurry as the only type of fertilizer- or just a low NS supplement is common, resulting in sulphur deficiencies. This kind of problem is automatically solved with SyreN system as the level of sulphate as fertilizer is often the same level for the targeted pH 6.4 used by the system, where 1.5 liter sulphuric acid / Ha is average requirement:

	S-need, kg pr. ha	*Typical amount of slurry, ton pr. ha*	*Needed kg S pr. ton*	*Liter H2SO4 pr. ton slurry*
Winter wheat, clay soil	15	30	0,5	0.9
Spring barley, sandy soil	10	30	0,3	0.6
Winter rape, clay soil	35	30	1,2	2.1
Silage grass, irrigated sandy soil	30	40	0,8	1.3

2.3. Economy in adjustment of N:P rate

The latest addition to the SyreN system (2013) is the ability to inject anhydrous ammonia into the slurry of the slurry tanker. With the extreme pumping capacity available, it is possible to distribute the gas absorption to liquid over a very large area, avoiding overheating and potential problems with heat and pressure building. As the slurry tanker is also a closed container system, 100% absorption of the ammonia is a reality.



Figur 1. Ammonia pressure tank integrated in the slurry tanker

The combined system, now under the name of SyreN+, adjusts the N:P ratio through addition of anhydrous ammonia during the filling of the slurry tanker. The added ammonia is changed to ammonium in the slurry, resulting in a sharp increase in pH value. Only 1 kg / m^3 is needed to increase the pH above 8.0 [11]. During application, sulphuric acid is added at a rate of 1.6 litter / m^3 acid to 1 kg ammonia to offset the pH value increase. This system reduces traffic on the field with one passing.

Avoiding overapplication of phosphorus is the major economic benefit that is attained by adjusting the N:P ratio to a recommended level for crop uptake for both N and P. The reduced use of phosphorus achieves a major economy and environmental benefit. A SyreN Estimater example [9] on 500 Ha rape, showed a net increase of 6.580 Euro using the SyreN+ anhydrous ammonia system compared to using just acid and conventional fertilizer.

Benefits with SyreN+:

- Adjustment of nitrogen contents in slurry – reduced traffic on field
- Surface application or Soil injection
- Reduced purchase price of fertilizer
- All N fertilizer as ammonium – reduced leaching of nitrogen
- Increased effect from nitrogen inhibitor
- Liquid surface application of nutrients – fast plant response
- Ideal system for slurry application in growing crops

The effect create a balanced NPKS nutrient value in slurry, an up to 80% reduction in ammonia emission and binding the nitrogen as ammonium in the soil to, reducing the leaching of nitrogen to aquatic environment. Further, a reduction in CO_2 emission through reduced traffic on fields and in the fertiliser value chain through using industrial raw materials direct at the end user level. The SyreN Estimater software also allows the user to quantify amounts of nutrients to be used and to identify the economy in using the system to optimise the effectiveness of organic fertilisers.

3. Future

The ability to increase and decrease the pH of slurry based fertilizers, gives a unique potential to adjust the nutrient values in slurry. SyreN Crystal is a current project that uses precipitation to reduce / adjust the amount of phosphorus in slurry – whereby excess phosphorus from high animal intensive areas may be economically redistributed to areas of low animal intensity. The slurry tanker is used as a tank for precipitation of phosphorus as MAP or struvite. With a slurry tanker and the SyreN system, there are no additional abilities needed. $MgCl_2$ is injected into the slurry in combination with increasing the pH with anhydrous ammonia. This causes the phosphorus to precipitate. Removing the precipitate material enables adjustment of the N:P ratio. The precipitated material is gathered in a separate tank within the slurry tanker. When enough struvite material is accumulated, the tank is filled with roughly a 1:1:1 ratio of sulphuric acid, struvite and water. This causes the crystals to dissolve and the sulphuric acid is altered to phosphorus acid. Following, the anhydrous ammonia system is used to increase the nitrogen level in the now liquid fertilizer. Ideally, the pH is raised to a 4-6 level increasing the NPKS value to 17-4-0-9. The liquid is filled back into the transport IBC´s and it is now a commercial grade starter fertilizer for maize based on organic P. This process has a potential effect to reduce the consumption of phosphorus in agriculture with 20%. As there are no capital cost for precipitation equipment, it is expected to be a profitable solution.

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