Nutrient Cycling in Agroecosystems **51:** 59–63, 1998.

Research note

Direct Ground Injection of livestock waste slurry to avoid ammonia emission

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Key words: animal waste, injection, ammonia emission

Abstract

The aim of the project was to improve the slurry injection techniques for injecting animal waste slurries into the soil under Norwegian conditions. A new slurry application technique for grassland was therefore developed, by adapting well known methods of injecting a fluid into a solid or porous material. The injection nozzles had a diameter of 13 mm, and the liquid pressure in the nozzles was between five and eight bar, which was sufficient for the slurry to be injected 5 to 10 cm into the ground. The depth of the injection depended on the soil type and on the slurry pressure. Ammonia emission was reduced as compared with application through ordinary broadcasting, and with band spreading. The emission was also reduced if water was added to the slurry, or if the slurry solids were separated from the liquid before application.

Introduction

A consequence of modern agriculture is that more livestock wastes are applied to grassland or land that will not be ploughed (ECETOC, 1994). Therefore, odour emission and ammonia losses have become two main environmental problems. When livestock waste slurry is spread on the surface of soils, the emissions are affected by temperature, soil properties, application technique, slurry manure characteristics and type of animals (Pain, 1991). Soil properties such as the infiltration capacity, the cation exchange capacity, the pH-value, and the buffer capacity have a significant effect on NH_3 losses when slurry is applied (Amberger,1987; Holtzer et al., 1988; 1990; Stevens et al., 1988).

Losses can be reduced when the water content in slurry is increased. Water added to the slurry in the proportion 3:1, reduced NH_3 losses by 44 - 91% as compared to untreated slurry (Huijsmans and Bussink, 1990). Sommer and Olesen (1991) found increasing ammonia emission as the dry matter content of the slurry increased. Morken (1992) found that ammonia emissions from separated slurry were less than from untreated slurry.

When spreading slurry, it is important to obtain immediate contact between soil and slurry, and injection has resulted in low NH_3 losses (Hall and Ryden, 1986; Hoff et al., 1981; Holtzer et al., 1988; Huijsmans and Bussink, 1990).

Investigations by Morken (1988, 1990) and others using band spreading showed that this technique is not satisfactory in terms of ammonia volatilization. An injection technique where slurry was placed in open slits, reduced ammonia loss after spreading by 80 to 90% (Huismans and Bussink, 1990). However, trials under Norwegian conditions (not published) confirm that this technique is not suitable for soils with more than 20% clay content, stony soils, and in hilly terrain (Frost, 1994).

In this paper a new technique for injecting slurry into soils, Direct Ground Injection, DGI[1], is presented, and the effect on NH_3volatilization is presented.

Material and methods

The DGI concept and equipment used

The DGI concept involves a pump to pressurize the slurry (5-8 bars), which is then distributed to nozzles. The nozzles jet out the slurry in pulses forceful enough

[1] Direct Ground Injection technique is patented by the company Moi A/S, and DGI® is a registered trade mark of the same company.

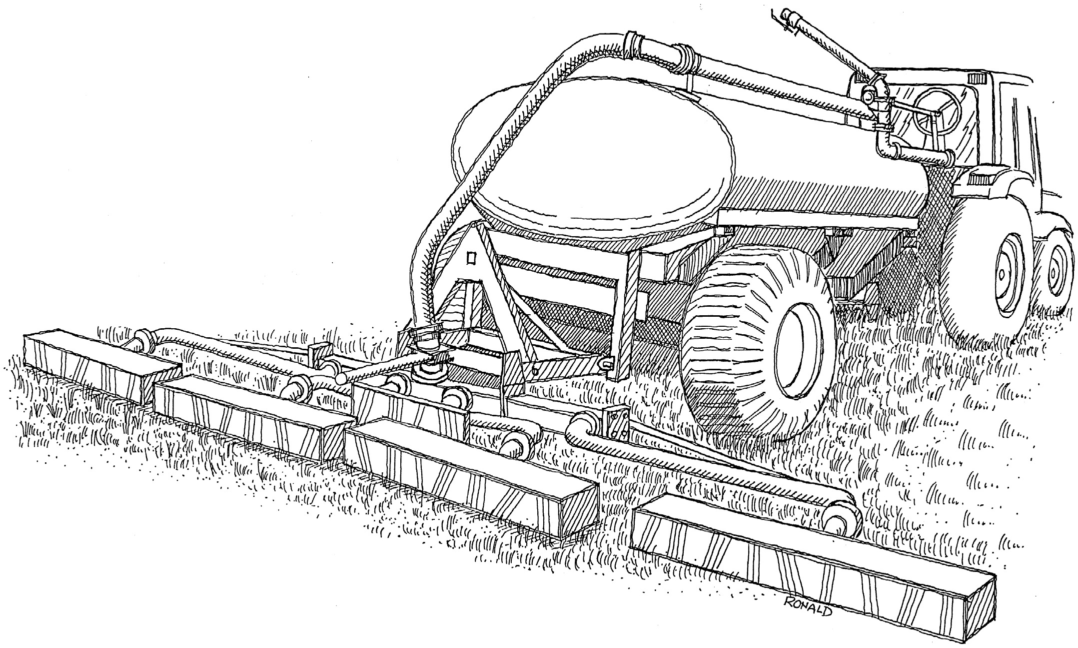

Figure 1. Drawing of the direct ground injection equipment mounted on a tanker. Working width is 6m, and each section is 1.5 m.

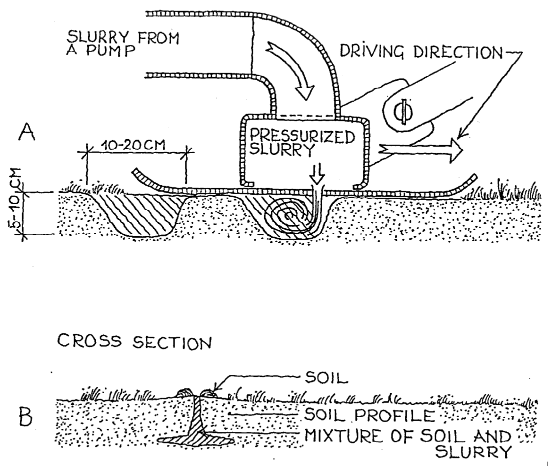

Figure 2. The principle of the direct ground injection method. A. Slurry is pressurized by a pump. The slurry then jets out under a ski and into the ground. B. As the depth of the trench increases, the manure flow slows down, and a build-up of pressure takes place. This results in an upward force on the top layer, and this produces horizontal cavities at a depth of 5-10 cm, depending on the soil type.

to inject the slurry into the ground in elongated, discontinuous cavities (Figure 1, Figure 2). The nozzles are located on skis that slide on top of the soil. There is no device that enters the soil because the slurry itself is doing the penetration.

It is obvious that the strength of the pulses from the nozzle determine the depth of the injection. The slurry leaves the DGI nozzles at a speed of 20-30 m s^{-1}. The depth to which slurry is injected can be manipulated by altering the working pressure of the DGI. Two types of DGI have been used. Type 1 had a distribution chamber located separately from the nozzles. Slurry came from the pump to the distribution chamber which consisted of an inner cylinder with six holes distributed along its periphery. The inner cylinder, driven by a hydraulic motor, could rotate inside an outer cylinder with six outlets (internal outlet diameter 63 mm). Slurry flowing through the inner cylinder, was distributed through hoses to nozzles on discs that slid on top of the soil. These discs ensured that slurry went into the soil and not onto the surface.

The type 2 DGI (Figures 1 and 2) consisted of distribution section (rectangular hollow beam) instead of a cylinder and six discs. These sections passed above the soil surface, running on skis (one ski per nozzle), and rotating knives ensured that the nozzles were not blocked.

Determination of ammonia emissions

Ammonia emissions were estimated using the method introduced by Svensson (1993). Ammonia emission can be parameterized in the expression $(C_{eq}\text{-}C_a)K_{z,a}$, where

$$C_{eq} = \text{ammonia equilibrium concentration in the air,}$$
$$C_a = \text{ambient ammonia concentration,}$$
$$K_{z,a} = \text{mass transfer coefficient between the air and the soil.}$$

C_{eq} is obtained from ammonia concentration measurements in a stirred dynamic chamber. C_a and $K_{z,a}$ can be measured directly in the field. All three terms are determined by applying the passive sampler technique. We had two sampling periods of approximately 3 hours each the day of spreading, and one 6 hour period on the next two days.

Field experiments

In the 1994 experiment, the DGI (type 1) was compared to broadcast spreading. The experiment was conducted using separated dairy cattle at Ås (South-East Norway) spread in September. Only slurry with small particles could be used and therefore it was separated with a Reime separator (auger-type separator) (Morken and Fjelldal, 1991).

A set-up with two chambers per plot (15x15 m^2) were used. This experiment was conducted on grassland and the soil type was sandy clay loam.

In an experiment carried out in spring 1995 (Jæren, South-West Norway), the DGI (type 2) was used, comparing this technique with broadcasting and band-spreading. Diluted and undiluted slurry was used for the comparison. Three replications of each technique were used, and the experiment was carried out on grassland.

A third experiment was carried out in fall 1995 at Ås. In this experiment undiluted and diluted slurries were applied with the use of the DGI (type 2). The experiment was carried out on grassland.

Results and discussion

Ammonia losses from the separated slurry, 2% dry matter content, used in the 1994 experiment were reduced by 62% using DGI during the first 5 hours as compared to broadcasting (Table 1). Differences in ammonia emission rates were, however, decreasing after 24 h. Separation of slurry has in itself shown

Table 1. Ammonia loss from separated slurry applied through Direct Ground Injection and through broadcast spreading to soil Experiment 1). Type 1 of DGI was used.

Application techique	Ammonia loss during (g NH_3 t^{-1} slurry and h^{-1})			
	0 - 3h	3 - 6h	22 - 28h	46 - 52h
Direct Ground Injection	25	23	7	4
Experimental spreader	70	55	13	5
Reduction, %	64	58	45	17

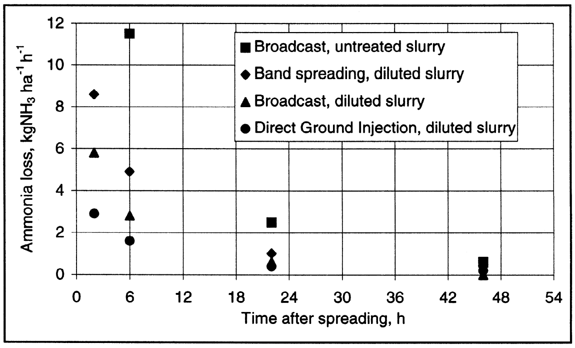

Figure 3. Ammonia emission after spreading of cattle slurry with various application techniques at Jæren, spring 1995.

a great reduction of ammonia losses application it to grassland (Morken, 1992).

Comparing different application techniques (Figure 3), using diluted and undiluted slurries (10 and 4.5% dry matter), broadcast spreading of slurry resulted in the highest loss rates. Water addition to the slurry reduced the loss rate and there were only small differences between broadcast and band spreading. The DGI technique gave the lowest loss rates. The reduction of the loss rates when water was added to the slurry is similar to the results that Sommer and Olesen (1991), and Morken (1992) obtained.

In the Ås experiment, 1995, diluted slurry and undiluted cattle slurry were applied with the DGI technique only (4.2% and 8.3% dry matter). Ammonia emission was decreased with less than 53% as compared to the emission from application of undiluted slurry (Figure 4). One can conclude that when one uses this technique, the dry matter content of the slurry is less important than with broadcast spreading, as NH_3 emissions are generally lower with the DGI technique.

The three experiments show that when the DGI method was used, very low NH_3 emissions after

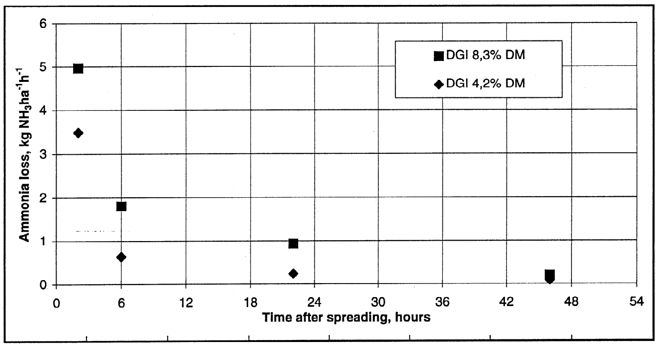

Figure 4. Ammonia emission after application of undiluted and diluted cattle slurry with Direct Ground Injection at Ås, fall 1995.

spreading of cattle waste slurry on grassland could be achieved.

Other experiences

The strength of the pulses from the nozzles determines the depth of injection, and this is in turn determined by the internal pressure in the nozzles. Since the slurry jets from the nozzles in pulses, the injected liquid does not form a continuous cavity, and DGI can therefore be used in hilly terrain. Since there is no mechanical device entering the soil, stones in soil are not a problem, neither for machine maintenance nor for the agricultural practice. There is no definite upper limit to the application rate, but it should be below 80 m^3 ha^{-1} to avoid slurry on the top of the soil. The system works best when the application rate is under 45 m^3 ha^{-1}.

We have not had problems with blockages of the nozzles in type 2, and therefore assume that this system works with slurries with dry matter content below 12-13%. The capacity of a DGI machine with a 6 m working width is approximately 2 m^3 min^{-1}.

However, DGI can be difficult to use on extremely cohesive clay soils and on loam soils because the slurry has problems entering the soil. This is found through developmental work, and has not been performed as experiments.

Acknowledgements

We would like to recognize Moi A/S for their commissioning of the project and supporting us both financially and technically. We would also like to thank the Department of Agricultural Engineering, Agricultural University of Norway, for having assisted us and contributed to the development of the DGI. Finally, we would like to thank the Norwegian Research Council for financial support.

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