Mitigation of Nitrogen and Greenhouse Gas Emissions from the Manure Management Chain – a Review

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Introduction:

To reduce losses of nitrogen (N) and greenhouse gases (GHG) emissions from animal excretions and to increase subsequently the manure-nutrient use efficiencies, a variety of manure management technologies have been developed. Some of these have also been implemented in practice in EU member states (EU-27).

Here, we present a review of recent literature with the aim 1) to estimate mitigation efficiencies of the most widely used technologies for reducing NH_3 and GHG emissions from manure collection, treatment, storage and land application stages, 2) to access side-effects of specific technologies within or among stages, and 3) to define the most effective measures for reducing those emissions and then increasing manure-nutrient use efficiencies.

Materials and methods

In this review, approximately 200 scientific articles have been studied, covering laboratory-, pilot- or field-based studies and also several review papers. In our study, treatment technologies prior to slurry storage such as mechanical (or -chemical) separation, acidification and anaerobic digestion were included. For slurry stored, formation of natural surface crust and covers, and for storage of solid manure, management practices in terms of turning, static, covering and compacting manure heap were taken into account. In field application, application technologies include splash-plate spreading, band spreading (i.e., trailing shoe and trailing hose) and injection of slurry, and solid manure application with or without incorporation into fields. Beside of the impact of each practice on NH_3 and GHG emissions, subsequent influences on N use efficiency (expressed as N fertilizer replacement value [NFRV] or N recovery efficiency by the crop [RE]) and manure nutrient recovery in the soil were reviewed.

Results

Separation efficiencies (i.e., the mass of a substance in separated solid fraction as percentage of the total mass of a substance in raw slurry before separation) greatly vary between separation technologies. The separation efficiency of dry matter (DM) (26%) and N (8%) by pressurized filtration (e.g., screw press and press auger) are lower than other separation technologies such as centrifugation (61% for DM; 27% for N). Compared to raw slurry, liquid fractions (LFs) have the potential to increase NH_3

emission factors (% of total N) during open storage by 1.1-1.7 times, as result of failure of natural crust formation and the high ratio of total ammoniacal N/total N. When LFs are applied via band spreading, however, the NH_3 emission factors (10-20% of total N) can be lower than raw slurry, because LFs infiltrate into soil more quickly due to lower viscosity. Subsequently, the NFRV and RE of N in LFs are larger than raw slurry over the first year after field application. DM-rich solid fractions (SFs) are suitable for composting partly because of increased C/N ratio after separation. About 45-75% of total C and 30-70% of total N are possibly lost during composting, especially during frequent turning. When composts are applied into the field, NH_3 and CO_2 emission are small because most of mineral C and N have been lost already or have been transformed into immobilized fractions during composting. Anaerobically digested (AD), fermented slurry with high pH vale and high ammoniacal N content may lead to high NH_3 emissions during open storage and on-farm application via broadcast and banding, compared to raw slurry storage and application.

The NH_3 and CO_2 emissions during separation and AD can be avoided by mitigation measures. For slurry (i.e., raw slurry, LFs and fermented slurry) storage, covering slurry surface (using chopped straw, wood lid, clay granules and plastic film) and acidification of slurry (pH <6) can reduce NH_3 emission factors by 65-99%, with respect to slurry without mitigation measures. Acidification also significantly decrease CH_4 emission due to the inhibition of methanogenesis. As for solid manure, compacted and covered heaps have less than 40 and 25% of total C and N losses. Abatement effectiveness of NH_3 emissions from the later stage in manure management chain can be significant via appropriate application technologies. As opposite to surface spreading of slurry, NH_3 emission are able to be mitigated by 45-65% via band spreading, and by 75-95% via injection of slurry into solid, but with large variations due to differences between animal slurry types, climate condition and vegetation. Lower nutrient losses during storage and field application increase the amounts of nutrients available for crop uptake.

Covering slurry solely via natural surface crust, chopped straw or clay granules is able to increase N_2O emissions particularly during summer. Compacting and covering heaps may stimulate anaerobic condition of solid manure heap, leading to higher CH_4 emissions. Injection of slurry into deep soil is more likely to increase N_2O emissions than band-spreading or the rapid and shallow injection of slurry.

Conclusion:

A certain farming practice is able to transfer either positive or negative impacts on use and losses of manure-nutrient into later stages of the system. In most cases, these side effects generated by a certain practice can be effectively prevented by combined mitigation measures. Interactions of manure management practices need to be studied further from the manure management chain point of view. Packages of mitigation measures are required to successfully reach the overall environmental and agronomic goals.