GREENHOUSE GAS EMISSIONS FROM STORED SLURRY WITH AND WITHOUT DIFFERENT COVERS

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1 INTRODUCTION

Total greenhouse gas (GHG) emissions from stored manure corresponded to 13% of overall GHG emissions from Swedish agriculture in 2006 according to calculations using standard values for a cool climate. Knowledge about greenhouse gas (GHG) emissions from the Swedish agricultural sector is deficient, as data based on actual measurements are limited. The IPCC Guidelines (IPCC, 2006) state that at mean air temperatures below 10°C, the default methane conversion factor (MCF) is 17% for slurry handling (housing and storage) when there is no natural crust during storage, and 10% when a natural crust cover is formed. In addition to temperature and crust formation, factors such as feed and animal characteristics at the measurement site (Külling *et al.*, 2002), manure characteristics, length of storage, time between indoor and outdoor storage, amount left in the storage facility (methanogenic inoculum) (Massé *et al.*, 2008) and timing of storage/application also affect methane (CH_4) emissions from slurry handling (IPCC, 2006), while agitation of slurry seems to have negligible impact (VanderZaag *et al.*, 2009). IPCC encourages countries to use factors based on local studies. In order to obtain accurate data for official reporting of Swedish GHG emissions from slurry and to evaluate the effects of measures to reduce ammonia (NH_3) emissions from manure on GHG emissions, it is important to measure GHG emissions under Swedish conditions.

The overall aim of the project was to identify effective measures to reduce GHG emissions (methane (CH_4), nitrous oxide (N_2O)) and NH_3 emissions from slurry. The main objective of this study was to quantify these GHG emissions from cattle and pig slurry, with or without measures to reduce NH_3 emissions during storage (*i.e.* using covers). A further objective was to evaluate the IPCC default emission factors with respect to the results obtained.

2 MATERIALS AND METHODS

2.1 Conditions in full-scale slurry storage in different regions of Sweden

Storage conditions, e.g. slurry temperature, were measured for slurry in three different regions of Sweden during 1.5 years. The farms were located in Halland county in south-west Sweden (57°1.3´N, 13°3.3´E), Uppland county in eastern Sweden (60°0.9´N, 17°59.3´E) and Jämtland county at the northern boundary of agriculture in Sweden (62°57.6´N, 14°23.4´E). Temperature loggers encased in watertight boxes and attached by a chain to a buoy were placed at 0.5 m and 1.5 m below the surface of the stored slurry and the temperature was logged every 3 hours. The farmers were also asked to record slurry level in the tank and slurry handling operations.

2.2 GHG emissions from stored slurry during a full year

Methodology was developed for measuring GHGs from slurry stored under conditions comparable to full-scale storage (Rodhe *et al.*, 2009). A pilot-scale plant with nine containers (height 1.5 m, diameter 1.92 m) was constructed where the conditions were similar to full-scale storage as regards slurry temperature, climate and filling/emptying routines, Figure 1. The containers were half-buried in the ground and had a base area of 2.0 m^2. Three closing roofs were constructed so that three containers could be closed simultaneously during gas sampling.

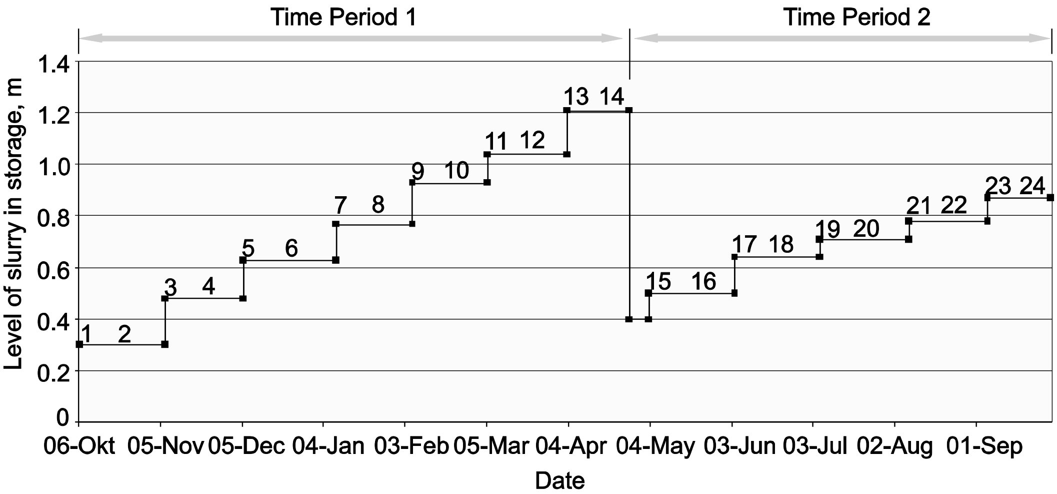

FIGURE 1 **Level of slurry in storage container during one of the experimental years and gas sampling occasions numbered (1 to 24).** The storage year is divided into two periods for summarising winter/summer emissions and for calculating the methane conversion factor (MCF). (Rodhe *et al.*, 2009).

Cattle and pig slurries were tested. The cattle slurry consisted of 5.9% dry matter (DM), and 3.6 kg total-N and 2.0 kg NH_4-N per ton at the first filling when the slurry was taken from the main store on-farm, and on average 8.1% DM, 4.7 kg total-N and 2.2 kg NH_4-N for fillings 2 to 12, when slurry was taken from the pumping pit on the farm. The pig slurry consisted of 8.0% DM, and 4.3 kg total-N and 2.4 kg NH_4-N per ton at the first filling, taken from the main store on-farm, and on average 7.5% DM, 5.4 kg total-N and 2.9 kg NH_4-N for fillings 2 to 12.

The experiment compared slurry stored: 1) without a cover, 2) with a straw cover, and 3) with a plastic sheet cover. The treatments were organised in a randomised block design with three replicates. Closed chamber methodology and equipment developed for measuring GHG emissions were implemented for one year in order to determine annual GHG emissions for each slurry type (cattle/pig). The GHG emissions (CH_4 and N_2O) were sampled twice per month, with the first samples being taken one day after filling and the others about a fortnight later. Three samples were taken per occasion; the first directly after closing the roof, the next 15 minutes later, and the last 30 minutes after roof closure.

For calculating the MCF, two storage periods were established and are shown for the first year with cattle slurry in Figure 1. Period 1 lasted from 6 October 2006 to 3 May 2007 (210 days) and period 2 from 4 May to 7 October 2007 (157 days) for cattle slurry. For pig slurry, period 1 lasted from 11 October 2007 to 29 April 2008 (213 days) and period 2 from 30 April to 10 October 2008 (152 d). For each period, the MCF was calculated from the sum of methane emissions per average amount of VS added to the containers, divided by B_0 per kg VS (IPCC, 2006; Swedish EPA, 2007) as:

$$MCF = \Sigma CH_4\text{-C}\ (B_0\ VS_{Mean\_in\_storage})^{-1}\ 100 \quad (1)$$

where MCF is the methane conversion factor, %; CH_4-C is the sum of methane-C emissions for the period, kg; B_0 is the maximum methane-producing capacity of the slurry, kg CH_4-C (kg VS)$^{-1}$; and $VS_{Mean\_in\_storage}$ is the average amount of VS added to the container during the storage period, kg. The emission factor for nitrous oxide (N_2O) was then calculated using the equation:

$$EF_{nit} = \Sigma N_2O\text{-N}\ (\text{total-N})^{-1}\ 100 \quad (2)$$

where EF_{nit} is the emission factor for nitrous oxide, %; ΣN_2O-N is the sum of nitrogen (N) lost as nitrous oxide during the period, kg; and total-N is the total amount of N in slurry added to the container during the storage period, kg.

3 RESULTS AND DISCUSSION

3.1 Conditions in full-scale slurry storage in different regions of Sweden

The mean annual temperature in stored slurry was 9.7°C in south-west Sweden (57°1.3´N), 5.6°C in the most northerly agricultural region of the country (62°57.6´N) and an intermediate 8.1°C in Uppland (60°0.9´N). The farm slurry tanks were part-emptied two to three times a year, giving an average storage period for the slurry of about three months. With daily removal of slurry from animal houses with slatted floors, as required by law, the methane from slurry handling in Sweden originates almost solely from storage tanks.

3.2 GHG emissions from stored slurry during a full year

Methane emissions from stored pig and cattle slurry showed a similar pattern, with ~100% higher emissions in the warm period (May-Oct) than in the cold period (Oct-April), and with significantly lower emissions from the stored slurry with a plastic cover during warm periods (Table 1). During winter there were no significant differences in CH_4 emissions between the slurry treatments. For typical Swedish farm conditions, the CH_4 emissions from the uncovered, stored cattle slurry corresponded to 12.4 kg CH_4 per cow and year. The corresponding figure for uncovered, stored pig slurry was 0.31 kg CH_4 per fattening pig.

TABLE 1 **Methane emissions (g CH_4-C per kg VS) and MCF (%) for different periods and mean values for storage of pig and cattle slurry without cover, with straw cover and with plastic cover**

	Slurry	Emissions, g CH_4-C per kg VS			MCF, %		
Time period		**No cover**	**Straw cover**	**Plastic sheet**	**No cover**	**Straw cover**	**Plastic sheet**
1. Oct-April, 213 days	Pig	3.0	4.4	3.0	1.5	2.1	1.3
2. May-Sept, 152 days	Pig	7.6^b	8.8^b	2.0^a	4.2	3.7	1.7
Annual mean	Pig	5.4	5.8	3.0	2.6	2.8	1.5
1. Oct-April, 210 days	Cattle	3.6	2.7	3.4	2.0	1.5	1.9
2. May-Sept, 157 days	Cattle	6.5^b	6.8^b	3.0^a	3.6	3.8	1.7
Annual mean	Cattle	4.8	4.4	3.2	2.7	2.5	1.8

[a, b]Means with different letters within each row and group are significantly different (*P<0.001*)

The N_2O emissions were very low from cattle slurry, at most 0.001 g N_2O-N m^{-2} slurry surface and day, with a few exceptions. In contrast, the N_2O emissions from straw-covered pig slurry during storage in summer were much higher, 35.9 g N_2O m^{-2} $year^{-1}$, corresponding to an EF_{nit} of 0.74% for total-N in slurry.

4 CONCLUSIONS

Under Swedish conditions, an annual methane conversion factor (MCF) of 3% is more relevant than the IPCC default value of 10% for slurry with crust or 17% for slurry without crust. The N_2O emissions from straw-covered slurry vary considerably depending on prevailing conditions promoting nitrification/denitrification. Possible options to reduce GHG emissions from slurry include keeping stored slurry as cold as possible, preferably with a synthetic cover to minimise the release of NH_3 and CH_4, and avoiding the risk of N_2O emissions that can arise with a straw cover.

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