Barbara Amon, Vitaliy Kryvoruchko, Thomas Amon and Josef Boxberger, Vienna

Effects of Covering Dairy Cow Slurry during Storage on CH_4-, NH_3-, N_2O-Emissions

The Division of Agricultural Engineering of the Department of Sustainable Agricultural Systems of the University of Natural Resources and Applied Life Sciences in Vienna quantifies emissions with the goal of mitigating emissions from animal husbandry. The project presented here is about the effect of covers during slurry storage. It is part of the EU-project "MIDAIR" (Greenhouse Gas Mitigation for Organic and Conventional Dairy Production).

Dr. Barbara Amon, and Dr. Vitaliy Kryvoruchko are research assistants, ao.Univ.Prof. Dr. Thomas Amon is head of the working group "Environmental and animal husbandry engineering", and o.Univ.Prof. Dr. Josef Boxberger is head of the Division of Agricultural Engineering of the Department of Sustainable Agricultural Systems, University of Natural Resources and Applied Life Sciences, Peter-Jordan Strasse 82, A-1190 Vienna, Austria; e-mail: *barbara.amon@boku.ac.at*

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Keywords

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Literature

Literature references can be called up under LT 05420 via internet http://www.landwirtschaftsverlag.com/landtech/local/literatur.htm.

Ammonia (NH_3), nitrous oxide (N_2O), and methane (CH_4) are emitted during slurry storage. Covering slurry stores is recommended as a measure to reduce ammonia volatilisation and odour emissions. Stored dairy cow slurry may form a natural surface crust if the dry matter content is high enough. Alternatively, an artificial crust may be established using materials such as straw or leca pebbles [1].

Slurry contains considerable amounts of easily degradable carbon that serves as a nutrient source to microbes. During slurry storage a continuous degradation of organic matter can be observed. Degradation intensity is strongly dependent on slurry dry matter content [2]. As conditions in the slurry are anaerobic, degradation of organic matter must always occur with anaerobic pathways. This means, that CH_4 and CO_2 are formed as end products.

Some studies have observed that the presence of a surface crust may reduce methane emissions [3, 4], indicating that methane is oxidised within the crust environment. For an environmentally friendly manure management, slurry dry matter and carbon content should be reduced at an early stage. [5].

Nitrous oxide (N_2O) is produced through nitrification and denitrification. Data on N_2O emissions from manure stores comprise a high range of uncertainty. [4] measured emissions of up to 25 mg N_2O-N m^{-2} h^{-1}, while [6] cite field and lab scale measurements that range from 0.2 to 5.4 mg N_2O-N m^{-2} h^{-1}. According to [4], N_2O emissions increase when the natural surface cover desiccates.

Experiments described in this paper aimed at quantifying the influence of different levels of covering slurry stores on NH_3, N_2O, and CH_4 emissions during storage of untreated and anaerobically digested dairy cattle slurry.

Materials and Methods

Measurement of gaseous emissions during slurry storage

Emission measurements were carried out in Gross Enzersdorf, Lower Austria near the city of Vienna. Mean air temperature is 9.8 °C, mean precipitation is 547 mm per year, mean relative humidity is 75 %. Dairy cow slurry was stored in five pilot scale slurry tanks, which were 2.5 m deep and had a diameter of 2.5 m. The tanks were made from concrete and buried in the ground. Emissions of NH_3, N_2O, and CH_4 were quantified by moving the large open dynamic chamber designed by ILT over a slurry tank and collecting the emissions [7] (*Fig. 1*). Due to variability in emissions it was necessary to have frequent sampling. Emissions of each variant were measured at least twice a week for at least eight hours.

Slurry temperature was continuously measured at two heights in each slurry tank. At the beginning of the experiments, slurries were sampled weekly. Later the sampling frequency was reduced to every two weeks. Slurry was analysed for: dry matter, ash, pH value, NH_4-N, total N, and total C. Concentrations of NH_3, N_2O, and CH_4 were quantified by high resolution FTIR spectroscopy [8].

Table 1: Cumulated CH_4-, NH_3-, N_2O-, and greenhouse gas emissions measured in winter and in summer experiment

treatment	winter experiment				summer experiment			
	CH_4	NH_3	N_2O	GHG[a]	CH_4	NH_3	N_2O	GHG[a]
	[g m^{-3}]			[kg CO_2eq.m^{-3}]	[g m^{-3}]			[kg CO_2eq.m^{-3}]
untreated_crust	164[a]	72.5[a]	44.0[a]	17.1	3591[a]	110[a]	48.7[a]	90.5
untreated_cover	142[b]	52.2[b]	38.2[c]	14.8	2999[b]	60.0[b]	58.6[b]	81.1
biogas	111[c]	62.0[c]	40.1[b]	14.8	1154[c]	222[c]	72.4[c]	46.7
biogas_straw	114[c]	49.6[b]	39.9[b]	14.8	1192[c]	126[a]	75.7[d]	48.5
biogas_straw_cover	81.1[d]	48.7[b]	40.7[b]	14.3	1021[d]	78.1[d]	61.4[b]	40.5

[a] Global warming potential (GWP) N_2O = 310; GWP CH_4 = 21 [10]
Different superscripts indicate significant differences at $p < 0.05$

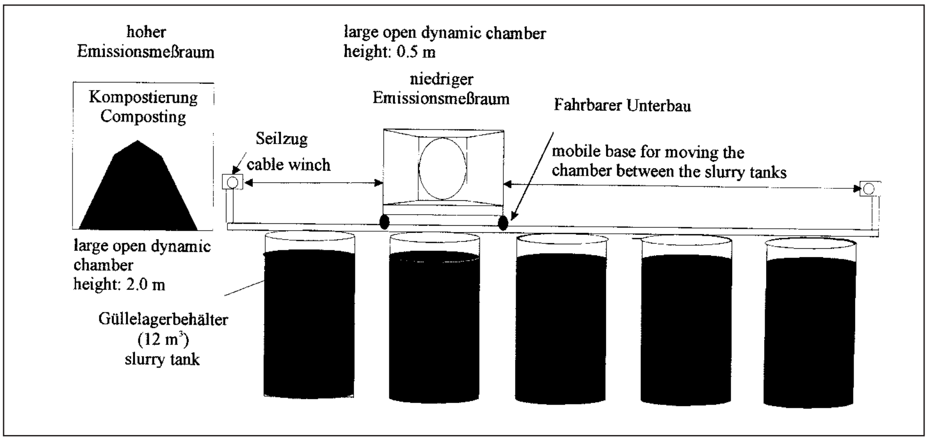

Fig. 1: Design of the experimental facility for quantifying emissions from manure storage; side view [11]

Experiments

The following treatments were included in the experiments: untreated slurry with natural surface crust (untr_crust), untreated slurry with natural surface crust and wooden cover (untr_cover), anaerobically digested slurry without any cover (biogas), anaerobically digested slurry with a layer of chopped straw (biogas_straw), and anaerobically digested slurry with a layer of chopped straw and a wooden cover (biogas_straw_cover).

In February 2002, measurements started with the quantification of emissions from dairy cattle slurry under cool winter conditions. Emissions were continuously quantified for 100 days. In June 2002, emission measurements continued with the assessment of emissions from dairy cattle slurry under warm, summer conditions. Summer experiments lasted 140 days.

Dairy cow slurry was received from two typical Austrian dairy farms. Farm 1 keeps 33 dairy cows in a slurry based loose house. Milk yield is 8,600 kg per year. The dairy cows` diet consists of forage maize silage, grass silage and hay. In addition, concentrate is fed via a transponder system. Farm 2 supplied anaerobically digested dairy cow slurry. 30 dairy cows are kept in a tied stall. Milk yield is 6,000 kg per cow and year. Dairy cow slurry is anaerobically digested in a fully mixed, continuously stirred concrete digester without addition of other organic substrates. The digester is operated at a mesophile fermentation temperature. Hydraulic residence time is 30 - 40 days.

Statistical data analysis was carried out with the software package SPSS, version 10.0. Regression curves were fitted to cumulative emissions. Regression equation and coefficient of determination are given in the respective figures. Differences in regression equations were tested with a pair wise comparison of regression parameters by the t-test. Level of significance was set to ≤ 0.05.

Results and Discussion

Table 1 summarises cumulated NH_3, N_2O, CH_4 and GHG emissions. GHG emissions are given in CO_2 equivalents. In the winter experiment, CH_4 emissions from anaerobically digested slurry were significantly lower than from untreated slurry. No significant difference was observed between CH_4 emissions from anaerobically digested slurry with or without a layer of chopped straw on the slurry surface. Covering the slurry tank with a wooden cover reduced CH_4 emissions both from untreated and from anaerobically digested slurry.

Covering the slurry tank with a wooden lid greatly decreased ammonia emissions from untreated slurry. A layer of chopped straw on the surface of anaerobically digested slurry significantly reduced NH_3 emissions. A wooden lid did not result in an additional decrease in NH_3 emissions from anaerobically digested slurry.

Nitrous oxide emissions showed only little differences between treatments. Cumulated GHG emissions were greatest from uncovered untreated slurry. A wooden cover reduced GHG emissions from untreated slurry. GHG emissions from anaerobically digested slurry were lower than from untreated slurry. A combination of chopped straw and a wooden cover resulted in a further reduction of GHG emissions.

Under warm summer conditions, considerably more CH_4 was emitted than under cold winter conditions. Untreated slurry emitted by far more CH_4 than anaerobically digested slurry. As with the winter experiments, a wooden lid resulted in a reduction in CH_4 emissions compared to uncovered untreated slurry. No significant difference was observed between cumulated CH_4 emissions from uncovered and straw covered anaerobically digested slurry. Straw cover and a wooden lid lowered CH_4 emissions.

A natural surface crust was formed on untreated slurry. The wooden cover sheltered the natural surface crust from rain and helped to keep it dry. In a dry surface crust, methane oxidation can take place and a part of the CH_4 that was produced in the anaerobic slurry is oxidised in the surface crust. This was as well observed by [4]. A layer of chopped straw alone did not reduce CH_4 emissions. After rainfall, the straw sinks into the slurry and CH_4 oxidation cannot take place. [9] found similar results in England and so do not recommend slurry stores to be covered by a layer of chopped straw.

Under warm summer conditions, uncovered anaerobically digested slurry showed the by far highest ammonia emissions. Covering anaerobically digested slurry with a layer of chopped straw reduced NH_3 emissions. A further reduction was achieved, when a layer of chopped straw and a wooden lid were applied. Cumulated NH_3 emissions from untreated uncovered slurry were significantly higher than NH_3 emissions from untreated slurry that was covered by a wooden lid.

Under warm summer conditions, covering untreated slurry with a wooden lid increased N_2O emissions. A layer of chopped straw increased net total N_2O emissions from anaerobically digested slurry. Covering anaerobically digested slurry with a layer of chopped straw and a wooden lid reduced N_2O emissions. The results demonstrate that the slurry-atmosphere interface represents an environment that can be different from the bulk slurry phase. At the interface, N_2O formation may be influenced by a multitude of factors, and it is difficult to predict which one will be the most dominant.

Net total GHG emissions from untreated slurry were nearly twice as high as from anaerobically digested slurry. A wooden cover effectively reduced GHG emissions. A layer of chopped straw did not result in lower GHG emissions.

Conclusions

Anaerobic digestion was found to be an effective mitigation option for CH_4 and GHG emissions from slurry stores. A wooden lid placed on the slurry tank reduced CH_4 and NH_3 emissions, whereas NH_3 emissions from uncovered anaerobically digested slurry were high due to the high NH_4-N content and pH value.

In conclusion, it is recommended that slurry tanks, and particularly those used for storage of slurry treated in biogas plants, are equipped with a cover. This will reduce CH_4 release into the atmosphere, as well as NH_3 emissions. Full environmental benefits of anaerobic digestion can only be exploited, if all tanks are covered.

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