EIP-AGRI Focus Group
Reducing livestock emissions from cattle farming

Mini-paper – *Measuring and monitoring methods to assess emissions from cattle barns and to evaluate and improve mitigation options*

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Introduction

Cattle production, with the dairy and beef cattle categories as their main components, is an important source of ammonia, methane and nitrous oxide emissions in Europe. A substantial part of these emissions emanates from animals housings. Available information on emissions from cattle barns and the effect of mitigation options is compared to other animal categories very limited for a number of reasons:

- Cattle are almost exclusively housed in naturally ventilated (NV) barns. It has been widely acknowledged that the quantification of emissions from naturally ventilated (NV) buildings is a more complicated and challenging task compared to mechanically ventilated buildings. Emissions are calculated as the product of the gas concentration in ventilated barn air and the air flow rate of the barn. There are substantial methodological difficulties to accurately determine airflow rates in NV barns.
- So far an undisputed reference field method for emission measurement cannot be identified from the variety of available methodological approaches. As a result, information on emissions from NV buildings is scarce and subject to discussion on measurement accuracy.
- Currently used research methods to determine air flow rates are mainly based on the mass balance principle (using tracer gases like CO_2/SF_6) and at a more experimental level on velocity measurements. Both approaches require a considerable effort in terms of measurement expertise, equipment and labour to yield reliable results.
- Scale and layout of NV cattle building vary considerably across Europe. This variability complicates the elaboration of standardized measurement protocols for emissions and the evaluation of mitigation options Europe wide.
- With the current state of art it is not possible for cattle farmers to routinely monitor at affordable costs the effects of mitigations options on barn emissions. This restricts the contribution of farmers' experience and expertise in developing mitigation options.

Despite the progress that has been made over last years, as exemplified in the VERA test protocols for evaluating emissions and mitigation options for housings and management systems (VERA, 2011), the lack of reliable and practical measurement methods for emissions from cattle barns has impeded the development and implementation of mitigation options. First results from measurements campaigns that comply with the setup of

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the VERA test protocol indicate that the random measurement error in case of ammonia emission from dairy housing systems amounts approx. 15-25% (expressed as standard error of the overall mean ammonia emission of 4 barns measured in intervals distributed over 1 year; Ogink et al., 2014). This means that the ability to statistically distinguish emission factors (mean ammonia emission, per year and animal unit) between different cattle housing systems is limited to differences of at least 40% and more. This lack of distinctive power undermines the evaluation of many relevant mitigation options with reduction efficiencies below 40%.

To comply with national and regional targets (NEC and Natura 2000) there is, European wide, a need to improve measurement methods, this includes:

1. Improvement of measurement methods to assign emission factors to mitigation options that can be used by regulators and policy makers, and accurate methods for research purposes to develop and optimize mitigation options.
2. The development of low-cost monitoring strategies that can be widely applied at farm level to support management decisions to lower emissions, and offer tools for verification of emission abatement.

This paper identifies possible solutions and perspectives in both directions.

Needs and perspectives: measurement methods for emission factors

Developed methods mainly focus on direct measurements at full barn level, with the main aim to establish emission data. However measurement methods applied at source scale to evaluate floor and pit emissions, as well as approaches based on measuring critical parameters in the process of ammonia/methane emission can be useful as well.

Current constraints in full barn measurements may be overcome by the following incentives:

- Development of a limited number of NV research cattle facilities equipped with a solid reference method, in which newly developed measurement methods and equipment can be optimized and validated.
- Development of measurement systems for direct measurement of ventilation rates.
- Development of ventilation rate prediction models based on 'smart' direct measurements.
- Improvements in barn emission modelling: both ammonia and methane.
- Improvements in the tracer gas ratio method as the most promising method to become a reference for measuring gas emissions from NV livestock houses (Ogink et al., 2013).
- Improvement of methods for characterising and quantifying error sources of measured emissions (Calvet et al., 2013).

Current measurement methods at emission source scale could be further improved, and new approaches developed. They can be applied in comparative control-case measurements for the development of mitigation options, offering the flexibility of testing different mitigation options within one experimental facility, being lower in costs than full barn emission measurements. For this purpose the following aspects have to be addressed:

- Improvement and standardization of flux chamber equipment for local emission sources and operation methods.
- Practical methods to quantify emissions from manure pits, especially in case of barn storage under slatted floors

A better understanding of critical parameters in floor and pit characteristics (for example pH, floor puddle volume, floor drainage capacity, air exchange pit, air velocity etc.) and their impact on barn emission could result in far more effective evaluation methods than currently provided by measuring full barn emissions. This requires:

- Improvement of the understanding of critical emission parameters.
- Measurement methods capable of quantifying critical parameters, like urine draining capacity of floors and air exchange rate from the headspace of manure pits in the barn.
- Development of emission models that connect parameter measurements to full barn emission.

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Needs and perspectives: tools for on-farm monitoring

The development of reliable farm emission monitoring tools at cost levels that are affordable to farmers enables several applications that may contribute to reduce emissions:

- The feedback from monitoring tools could guide farmers in feed and barn management decisions that lower emissions.
- Monitoring tools would directly enable the contribution of farmers' experience and expertise in developing new and optimizing existing mitigation options that can be applied at a generic scale.
- Farm monitoring tools could support regulators to on-farm verify the working of licensed mitigation requirements.
- Improved verification options may lead to the acceptance of mitigation options that are otherwise difficult to confirm in practice, as is very often the case in mitigation options related to feed and ventilation management.
- Reliable farm monitoring of emissions enable future regulatory systems in which farmers and regulators agree on target emission thresholds that are verified by farm monitoring, and leave the farmer a preferred choice out of all available management and housing layout options.

How far away are farm emission monitoring tools from application in practice? Farm monitoring tools should be able to determine the gas concentration in ventilated barn air and the barn air flow rate. The main challenge to overcome is the development of a robust, accurate and cost affordable sensor system for NH_3-concentrations in the ventilation air. Its application in NV barn requires sensor accuracies at very low concentrations close to the background concentration of ambient air. The determination of air flow rate can be based on the CO_2 mass balance method which requires the measurement CO_2 concentrations in the barn combined with the use of accurate CO_2-prediction models based on available farm variables. In principle the CO_2 mass balance approach enables the measurement of any emission as long as the involved gas concentrations and CO_2 concentrations are representatively sampled and measured, and CO_2 production can be accurately predicted.

Recent years new NH_3-sensors have been developed for farm application. Some of them look promising, as indicated by first series of laboratory tests (Melse et al., 2016). In current research this sensor is tested under practical conditions in both MV and NV buildings of different animal categories, including dairy barns. This research will include the development of a prototype barn sampling system to enable representative measurements of concentrations of $NH_3/CH_4/CO_2$. Such combined measurement data together with farm data to predict CO_2 production, enable the monitoring of both NH3 and CH4 barn emissions. Current developments could lead to the development of a first generation of practical systems to be applied in NV barn in a couple of years. This would open new perspectives, as outlined before, for both farmers and other stakeholders to reduce emissions from cattle production.

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