Publishable Summary for 21GRD10 quantiAGREMI
On farm quantification of ammonia and greenhouse gas emissions from livestock production

Overview

Many current food production practices still result in air, water and soil pollution, contributing to biodiversity loss, climate change and poor air quality. Increasing global food demand drives ruminant livestock numbers, rapid land use change and nitrogen (N) fertilizer use, accelerating greenhouse gas (GHG) emissions. The aim of this research is to provide a SI-traceable field measurement infrastructure for accurate determination of animal houses emissions as well as nitrogen footprints. Mitigation measures can therefore be assessed to reduce emissions and improve inventories.

Need

The EU agricultural sector contributes to 93 % of ammonia (NH_3) and 48 % of methane (CH_4) emissions in Europe and dominates Europe's anthropogenic N_2O emissions (72 %). While NH_3 is an important contributor to particulate matter, with adverse health effects estimated to cause 4.2 million premature deaths worldwide per year (2016), CH_4 and N_2O are potent GHG. The Farm to Fork strategy is a central part of the European Green Deal for a climate neutral Union in 2050. The strategy aims to reduce the GHG emissions from agriculture and food value chain to 55 % compared to 1990 levels by 2030. Additionally, innovative CH_4 mitigation strategies are required to be explored under the "EU strategy to reduce CH_4 emissions". It is essential to develop a coordinated European metrology infrastructure to improve and reduce the uncertainty of emission data GHG and reactive N from agriculture, in order to understand the processes governing emissions, assess the efficiency and reliability of developed reduction strategies and to provide reliable evidence for policy makers who set emission targets. In addition, there is a requirement from the United Nations Framework Convention on Climate Change (UNFCCC) and the United Nations Food and Agriculture Organization (FAO) to reduce the environmental and climate footprint from agriculture.

Objectives

The overall objective of the project is to enable a more reliable quantification of livestock emissions and allow policy makers assessing and establishing efficient mitigations strategies.

The specific objectives of the project are:

1. To develop, building upon existing techniques, traceable techniques for quantifying NH_3 and CH_4 emissions from selected livestock housings with a target uncertainty of 10 % (CH_4) and 20% (NH_3) for mechanically ventilated and 30 % (CH_4) and 40 % (NH_3) for naturally ventilated housing. In addition, to define target applications (e.g. animal category, housing systems) according to stakeholder needs.
2. To develop and characterise CO_2, NH_3 and CH_4 emission monitoring techniques, considering atmospheric conditions, for enhanced spatial and temporal coverage.
3. To identify, using emissions data from objective 2, key-indicators (e.g. milk urea content and manure storage) and to improve emission models (e.g. based on feeding, climate conditions) for increasing the representativeness of the emission estimations and determine their uncertainty. In addition, to

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develop farm-monitoring systems for evaluating the efficiency of reduction measures and provide management tools to farmers for ensuring reduction performance.

4. To reduce the uncertainty associated with up-scaling GHG emissions and nitrogen loss from soils by improving model parameterisation (e.g. relative contributions of nitrification and denitrification to N_2O emission) using field-deployable spectroscopic techniques to determine N_2O isotopic species for different production pathways. In addition, to improve methods for quantifying NH_3 deposition from livestock housing and tracing nitrogen isotopes (e.g.^{15}N) in managed soils.
5. To facilitate the dissemination and uptake of the technology and measurement infrastructure developed in the project by (i) contributing to emissions inventory reports under the UNFCCC, (ii) providing guidelines to the measurement supply chain (researchers, commercial measuring institutes), expert groups (VERA, COST Action LivAGE) and standardisation developing organisations (CEN TC264) on techniques/modelling approaches to facilitate the establishment of decision matrices and the promotion of mitigation measures by policy makers, and (iii) providing farmers access to reliable methods for identifying efficient mitigation strategies and provide quantitative GHG emissions at farm level.

Progress beyond the state of the art and results

Development of techniques for the quantification of NH_3 and CH_4 emissions from selected livestock housings with a target uncertainty of 10 % (CH_4) to 20 % (NH_3) for mechanically ventilated and 30 % (CH_4) to 40 % (NH_3) for naturally ventilated housing and for target applications such as animal category and housing systems.

Objectives 1 will contribute to a more reliable quantification of GHG and NH_3 emissions from agriculture by improving existing and developing new measurement methods, characterising metrologically the emission measurements and providing complete uncertainty budgets. This will enable SI-traceable emission estimations. SI-traceable estimations and their uncertainty will contribute to the accuracy improvement of the inventories, thereby ensuring a better implementation check of the National Emission Ceilings Directive (NEC 2001/81/EC) and the UNECE 1999 Gothenburg Protocol (revised in 2012), which set national emission reduction commitments. For this purpose, the results of EMPIR ENV55 MetNH3 will be used. That project aimed to achieve metrological traceability for ammonia measurements in ambient conditions by developing improved dried and wet reference gas mixtures (RGMs) by static and dynamic gravimetric generation methods of NH_3 amount fractions, as well as by developing laser-based optical transfer standards. The protocol for the intercomparison of wet and dry ammonia RGMs in the nmol/mol range in synthetic air has been developed and the planning has been defined. The campaign will be held from the end of April 2024 by sending the references to LNE. Laboratory work will be done until May 2024, with the final report planned for November 2024. The transfer from high-accuracy standards to field applicable methods was also established by employment of characterised exposure chambers and field sites for validation and comparison experiments.

Data on measurement ranges, conditions and required amount fractions have been collected. Estimation of ventilation rates is still pending. Linearity and repeatability of CH_4 and CO_2 measurements with a commercial CRDS analyser has been evaluated on data collected in an experimental dairy housing over several years (2015 – 2020). Also, linearity and repeatability of a commercial CRDS analyser for NH_3 has been tested in relevant concentration range using wet reference gas from the reference gas generator.
Target applications for emission measurement techniques for enhanced spatial and temporal coverage have been defined.

Development and characterisation of CO_2, NH_3 and CH_4 emission monitoring techniques, considering atmospheric conditions, for enhanced spatial and temporal coverage.

Objective 2 will allow the development of new CO_2, NH_3 and CH_4 emission monitoring techniques and their characterisation. The development of these new sensors is still on going. Three TRL 6 OEM modules have been developed and qualified in the laboratory under ammonia exposure. Mobile measurements of a dairy farm were performed successfully. A more precise calibration set-up for this instrument is under development at VSL. Senseair K96 multi-gas NDIR sensor has been optimized and extensive laboratory characterization has been performed. The K96 sensor has been integrated in a field deployable sensor system including data logging and wireless communication capabilities. GASERA has designed and manufactured the first prototype of a laser-based analyser for measuring CH_4, NH_3, N_2O and H_2O simultaneously with a single analyser unit. The spectral analysis is developed, and the system will be validated in co-operation with PTB.

The measurement protocols for laboratory testing of sensors have been developed and the collection of data from partners will start soon. It is shared with Objective 3.

Identification of key-indicators (e.g. milk urea content and manure storage) and improvement of emission models (e.g. based on feeding, climate conditions) for increasing the representativeness of the emission estimations and their uncertainty evaluation. Development of farm-monitoring systems for the evaluation of the reduction measures efficiency in order to provide management tools to farmers for ensuring reduction performance.

Objective 3 will allow step-by-step validation measurements in the laboratory and under real housing conditions to identify suitable sensors and to evaluate them with regard to their suitability and field of application (animal category, housing system, manure storage). There is now no clear solution for farmers and policy makers to measure GHG and reactive N emissions, and thus to develop a mitigation policy. This project will allow the sensors implementation, while a survey policy at the European scale will be developed.

NH_3 sensors has been tested in IMTelecom setup with the following protocol: NH_3 will be generated from cylinders into a 5 L chamber with a flow rate of 10 L/min, with the possibility to add water. LGR analyser is use as a reference. For calibration of the gas bench a Picarro is used as reference instead. Laboratory testing of CO_2 and CH_4 sensors will be held at LNE. The gas mixed from cylinders is diluted with clean pressurized air and fed into a T- and RH-controlled climate chamber.

The conditions for intercomparisons allowing to tests the instruments on the fields will be fixed during the second half of the project.

Reduction of the uncertainty associated with up-scaling GHG emissions and nitrogen loss from soils, by improving model parameterisation (e.g. relative contributions of nitrification and denitrification to N_2O emission) and with the use of field-deployable spectroscopic techniques for defining the N_2O isotopic species for different production pathways. Improvement of methods for NH_3 deposition quantification from livestock housing and tracing nitrogen isotopes (e.g.^{15}N) in managed soils.

Objective 4 will reduce the uncertainty of N_2O inventories from agricultural soils and improve the quantification of NH_3 footprint around livestock buildings through i) evaluating the methodologies used to study the fate of NH_3 released from animal housings and ii) the study of the capability of current field N_2O emission measurements to attribute N_2O emitted from soils to the different microbial N production processes. N_2O emissions from soils have constant emission factors applied, irrespective of soil properties and meteorology, which leads to large uncertainties. In addition, human activities profoundly influence the N-cycle by converting more N into reactive N forms than all of Earth's terrestrial processes combined. Thereby, nitrogen cycles exceed their safe operating space in Europe, by a factor of 3.3 resulting in diffuse N pollution of terrestrial and aquatic ecosystems. The results will be used to determine bias and reduce uncertainty arising from near-field N deposition and parametrisation of different N_2O production processes in biogeochemical models.

The design of N release experiment focused on the identification of the most suitable experimental site for the release experiment. The grassland site Graswang of the TERENO pre-Alpine Observatory was identified as the most suitable site. Also, NH_3 release experiment was carried out in the period June 14th to July 17th 2023. Different techniques including open- and closed-path analysers in eddy-covariance, aerodynamic gradient method, and chamber setups were applied for an inter-comparison of concentration and flux measurements.

Calibration and correction strategy is ongoing. Analyser validation work was initiated and is ongoing. A draft software algorithm for data correction was established and will be finalized with the correction factors. The intercomparison is shared with Objective 2 and it is under preparation.

Outcomes and impact

The project successfully presented the project objectives at the International Metrology Congress (CIM 2023) and the consortium secured the participation of 19 Stakeholders representing a good range of features such as public bodies, large Industrial enterprises, and research organisations. M9 meeting has been held on the 7th of November 2023. The project is on track and all the due tasks have been delivered on time. It has been followed with the first stakeholder meeting, in which the consortium presented the context of the project and the deliverables to the stakeholders. A special session dedicated to the project results has been organised in

conjunction with the Air Quality 2024 Conference in Helsinki, which will be held in May 2024. Seven abstracts have been received for this special session.

The project results will create impact by providing policy-makers with the tools required to develop efficient mitigation measures for emissions. Improved SI-traceable estimations of NH_3 and GHG emissions from agriculture, with a defined uncertainty available will create further impact not only on the scientific community, by enhancing emission data comparability across monitoring studies, but also support national agencies, by improving emission inventories for air pollutants and greenhouse gases

Outcomes for industrial and other user communities

Research outputs, such as improved accuracy of emissions, enhanced spatial and temporal measurements, and reduced model input uncertainties, will be beneficial to farmers, industry, agricultural agencies and national authorities. It will allow users to evaluate, with a higher level of confidence, the measures proposed for reducing emissions (e.g. set of measures for reducing NH_3 included in Directive 2016/2284/EU) and therefore to select and implement the strategies with the highest effectiveness, whilst considering the benefit-to-cost ratio. The impact of this work will reach beyond Europe as the work and the results will be communicated to international agencies such as the WMO and the FAO on how to reduce the environmental and climate footprint of the food system and lead to a global transition towards competitive sustainability from farm to fork.

Outcomes for the metrology and scientific communities

The project aims to characterise metrologically state-of-the-art techniques for estimating emissions from livestock (objective 1), such as natural and artificial tracer gas methods. This characterisation, along with the resulting method comparison, will create impact on the scientific community by offering tools to perform accurate decision matrix analysis of appropriate techniques and/or potential reference. Furthermore, the validation of measurement techniques to estimate the N footprint surrounding livestock buildings including NH_3 deposition, N_2O soil emission fluxes and isotope signatures, will generate data that will improve process descriptions and reduce biogeochemical model uncertainties. These will result in methodologies which will provide a better understanding on nitrogen conversions and fluxes between compartments. Furthermore, this project will enable a European fit-for-purpose metrological infrastructure (partly developed during the EMRP projects ENV55 MetNH3, ENV52 HIGHGAS, IND63 MetAMC and the EMPIR project 16ENV06 SIRS) for direct field applications, and in particular for trace level gases of NH_3 and GHG. It will also enhance the collaboration between different fields/laboratories thus fostering cross-disciplinary tasks and applications (e.g. gas measurement, wind measurement, modelling approach).

Outcomes for relevant standards

This project supports international standardisation technical committees and directive such as CEN/TC264/WG11 and *ad hoc group Stationary Source Emissions — Methods for the Quantification of Diffuse Emissions*, ISO/TC146 (*air quality – ambient air and emissions from stationary sources*) and the Directive 2008/50/EC for air quality. The consortium will disseminate its findings through new or revised guidelines and recommendations with their active participation in several working groups (e.g. CEN/TC264/WG12, ISO/TC158, new WMO-GAW measurement guidelines). Furthermore, the work will especially support the Directive 2008/50/EC for air quality as well as regulation (EC) No 842/2006 by increasing the confidence in the emission/immission measurements and by enabling improved evaluation tools for implemented emission reduction measures.

Longer-term economic, social and environmental impacts

Effective measures and strategies will in turn result in lower socio-economic costs associated with environmental and health issues. For example, avoiding premature deaths associated with NH_3 emissions will translate into benefits > 14800 M€/year in Europe. In the case of measures for reducing NH_3 emissions, the estimated implementation costs range between 80 and 3780 M€. In particular, the project will have a direct impact on the work carried out by expert groups such as VERA (Verification of Environmental Technologies for Agricultural Production), GRA (Global Research Alliance) and the COST LivAGE Action (European Cooperation in Science and Technology - Ammonia and Greenhouse Gases Emissions from Animal Production Buildings). The outputs will facilitate their tasks on harmonisation of measurements and modelling aspects to reduce emissions from livestock buildings, which will additionally support the strategy adopted under the "EU Methane Strategy" and "Farm-to-Fork" as part of the European Green Deal.

List of publications
n/a

This list is also available here: https://www.euramet.org/repository/research-publications-repository-link/

Project start date and duration:		01 November 2022, 36months
Coordinator: Axel Fouqueau, LNE Tel: +33 140433852 E-mail: axel.fouqueau@lne.fr Project website address: https://www.lgcgroup.com/our-programmes/metpart-quantiagremi/		
Internal Beneficiaries: 1. LNE, France 2. CMI, Czechia 3. PTB, Germany 4. TUBITAK, Türkiye 5. VSL, Netherlands 6. VTT, Finland	External Beneficiaries: 7. GASERA, Finland 8. IMTelecom, France 9. INRAE, France 10. KIT, Germany 11. LUKE, Finland 12. Senseair, Sweden 13. TI, Germany 14. TNO, Netherlands 15. WR, Netherlands	Unfunded Beneficiaries: 16. Vaisala, Finland
Associated Partners: 17. Empa, Switzerland, 18. LGC, United Kingdom, 19. METAS, Switzerland, 20. UKCEH, United Kingdom, 21. WBF-Agroscope, Switzerland		