REFERENCE PROCEDURES FOR THE MEASUREMENT OF GASEOUS EMISSIONS FROM LIVESTOCK HOUSES AND STORES OF ANIMAL MANURE

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ABSTRACT: In the ten years before the EMILI 2012 symposium, gaseous losses from animal farms became increasingly important in the media. The paradox of this tendency was the great number of publications, scientific or not, even though the emissions of most animal farms had never been measured. Therefore, the development of reference tools to measure greenhouse gas and ammonia emissions was important. Such tools allow recognition and remuneration of the best practices and equipment. Accordingly, ADEME funded an international project associating several research and development organizations involved with the animal production chain. The project proposed an initial set of 18 procedures to measure ammonia and greenhouse gas emissions from animal houses and manure stores. These were adapted to the diversity of animal farms found throughout the world. Some methods were compared during a "building" and a "liquid manure" experiment. Results showed a high difference among methods (ca. 80%), much higher than the estimated uncertainty. Associating independent emission measurements, together with a mass balance of the system, is necessary for the reliability of further results. However, previously published references lack uncertainty estimates of measurements that conform to GUM 2008. In the coming years, this is one of the major concerns for measuring emission factors. Uncertainty estimates should depend on the measurand (temporal: hourly, per batch, yearly; spatial: animal, house, national) and include the uncertainties associated with system representativity and temporal interpolation.

Keywords: measuring method, NH_3, GHG, dust, uncertainty

INTRODUCTION: Gaseous losses on animal farms are receiving increasing importance in the media. The paradox of this tendency is the great number of publications, scientific or not, even though the emissions of most of the animal farms were never measured. Therefore, IPCC guidelines for emission inventories are based on many references (IPCC, 2006), but the uncertainty in emission factors remains high: 50% in France (CITEPA, 2012). Therefore, development of measurement tools for greenhouse gas and ammonia emissions is important. The quantification of emissions also enables recognition and remuneration of the environmental performance of animal farms. Thus, farmers will be encouraged to adapt their practices. The tools could offer realistic reduction objectives without waiting until negative effects are so high that expensive regulation becomes inevitable. Accordingly, ADEME funded an international project associating several research and development organizations involved in the animal production chain.

The project's objective was to propose an initial set of reference procedures for measuring ammonia and greenhouse gas emissions from animal houses and manure stores. These were adapted to the diversity of animal farms found throughout the world.

1. MATERIAL AND METHODS: The project was based on the experience of the partners in measuring of gaseous emissions on animal farms and exchanges between them. It comprised three phases: reviewing existing methods, describing some methods in detail, and evaluating the ability to apply the methods in various countries. During the second phase, different measuring methods were compared in two experiments, one with liquid manure storage and one in a poultry house.

The storage experiment occurred at the IFIP experimental station in Romillé, France. Two tanks were used that contain approximately 10 m^3 of slurry produced during a standard batch of growing-finishing pigs. One tank was covered with a greenhouse equipped with a calibrated fan, allowing accurate ventilation measurement around the tank. The other tank was equipped with a dynamic chamber, and measurements were compared with emissions measured with a tracing gas. The mass balance of water, carbon and nitrogen was also measured.

The housing experiment occurred in a commercial house equipped with natural ventilation automatically regulated with motorized curtains and temperature sensors. The broilers were reared from 20 November 2008 to 19 January 2009. Air temperature and humidity were measured from 15 November to 21 January. Gas concentration measurements started 29 November and ended 18 January. Ventilation was measured indirectly using two tracing methods: one using assumptions on heat production of animals and manure, the other based on a measured flux of SF_6 injected homogeneously into the house for 20 days between 29 November and 27 December. The mass balance of the batch was also measured. A simplified method suited to batch emissions based on intermittent measurements of the ratio of concentration gradients between inside and outside the house was also applied and compared to the emissions calculated with ventilation measurements. An indirect method based on reverse modelling was also applied from 11-18 December and compared to previous hourly emission measurements based on heat production or SF_6 tracing. Dust concentrations and particle-size distributions were also measured inside and outside the house.

2. RESULTS AND DISCUSSION:

2.1. Methods described: The following methods were described within the project (see http://www4.inra.fr/animal_emissions_eng/Results) for further details:

1. measuring the mass balance deficit of manure storage;
2. measuring emissions of ammonia (NH_3), nitrous oxide (N_2O), methane (CH_4) and carbon dioxide (CO_2) of liquid manure storage with a dynamic chamber;
3. measuring the emissions of NH_3, N_2O, CH_4 and CO_2 of liquid manure storage with a tracing gas (SF_6);
4. measuring emissions from the mass balance deficit of carbon for pig housing;
5. measuring emissions from the mass balance deficit of carbon for meat poultry housing;
6. measuring emissions from the mass balance deficit of carbon of laying hen housing;
7. measuring emissions from the mass balance deficit of carbon of dairy cow housing;

8. calculating gas emissions using continuous measurements and a model calibrated with intermittent measurements of concentrations for animal housings;
9. calculating ammonia emissions using continuous measurements and a model calibrated with intermittent measurements of emissions for liquid manure storage;
10. measuring ventilation with an anemometer in housings with mechanical ventilation;
11. measuring ventilation with a CO_2 budget in animal housings regardless of ventilation type;
12. measuring ventilation with the heat balance of the animal house;
13. measuring ventilation with SF_6 in the animal house;
14. measuring emissions by using ventilation measurements in the animal house;
15. measuring ammonia emissions using the inversion of a stochastic Lagrangian model;
16. measuring ammonia emissions using the inversion of a Gaussian model;
17. generating a selected ammonia concentration and measuring it using bubbling;
18. calculating the uncertainty in gaseous emission measurements from animal housings or manure storage.

Methods 1, 2, 3, 9 and 18 were applied in the liquid-manure storage experiment and methods 5, 11, 12, 13, 14, 15, and 16 were applied in the housing experiment.

2.2. Method comparison: Both experiments, with liquid manure storage and broiler housing, showed high differences between methods. Comparison with mass balance results required interpolation in the case of continuous measurements (Figure 1). For the batch, nitrogen loss was 771 kg N (N loss = 27% N feed). Measured ammonia emissions were 11% (method 5) or 16% (method 12) of N feed. Denitrification could explain the gap due to observed N_2O emission. Uncertainty was estimated for NH_3 emissions from liquid manure (methods 9 and 18) and was usually below 10%. This could not explain the high gap between emission measurements and the mass budget (observed NH_3 emission less than 50% of nitrogen loss, without significant N_2O emission).

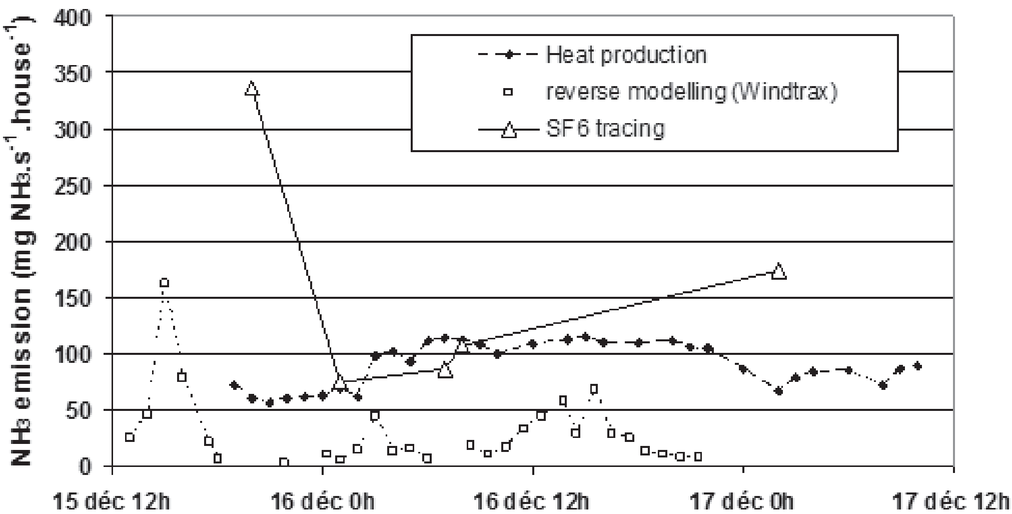

Figure 1. Ammonia (NH_3) emission observed with 3 methods during a broiler batch in a naturally ventilated house in France.

CONCLUSIONS: This project showed that comparing methods, comparing emissions to mass budgets, and repeating measurements should be performed to assess the repeatability and representativity of emission measurements for housing and manure storage. Emission estimates, based on the regular measurement of gas concentrations inside and outside the houses, constitute one of the rare low-cost methods that can be used regardless of whether animal houses are naturally or mechanically ventilated.

The estimation of uncertainty associated with measurements seems a major omission in previously published references. Complete use of GUM 2008 will be a major issue in the coming years for measuring emission factors. Uncertainties due to air heterogeneity, gas interferences, or calibration are rather simple to associate with continuous measurements. It becomes less straightforward when measurements are intrusive (chamber), when it is necessary to evaluate uncertainties due to representativeness of spatial sampling or temporal interpolation (e.g. intermittent measurements with high climate influence) or to include the effect of variability due to animals, weather, or farmer practices.

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