A Test-Bench for Infrared Photoacoustic Analyzers Used to Measure Gas Emissions from Animal Houses and Manure Storage

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Summary: Animal production is recognized as a major source of ammonia and greenhouse gases despite the high uncertainty associates to current estimates. Mitigation strategies are proposed to decrease the emissions. International standards exist for the national emission inventories or for the composition analysis of manure or soils but not for the measuring methods and associated uncertainty of the emissions of animal production. This limits considerably the quality control and the certification of existing reductions. One of the key measurements is the concentration increase of ammonia or greenhouse gas due to the animal production. Many research teams in the world have chosen Infrared photoacoustic spectroscopy analyzers (PAS; e. g. INNOVA® 1312 or 1412) to measure selectively the concentrations of ammonia and greenhouse gases. Network activity between them is difficult because different PAS can give different concentrations because of differences in configuration or maintenance: the chosen filters can compensate for different cross interferences, different concentrations used for calibration can induce differences in measurements, a significant drift in calibration can appear due to the infrared source or the microphones or changes following the use in highly contaminated environments. Therefore, INRA and IFIP, with the financial support of ADEME, developed a test bench that can be used to compare different PAS, to check the calibration drift during a project, to evaluate the effect of not compensated interferences when using a PAS in a new animal production system. Equipment and software allow the rapid preparation of gas mixtures with ammonia, nitrous oxide, methane, carbon dioxide at different concentration levels diluted in dinitrogen. The uncertainty of the concentrations in the mixture is evaluated based on the uncertainties of the flow meters and the gas bottles. The concentrations measured by the PAS are compared in real time with the concentrations of the gas mixtures.

Introduction

World Regions with intensive animal production have to focus on environmental impacts of livestock because of social, political, health stakes. The environmental impacts of intensive livestock production concern all the environment compartments (air, water and soil). For instance, animal production is recognized as a major source of ammonia and greenhouse gases and therefore significantly contributes to the global warming and acidification. Nevertheless national inventories are not accurate because of the difficulties associated to the assessments of emission factors. One of the key of emissions measurements is the concentration increase of ammonia (NH_3) or greenhouse gases (CH_4, N_2O) due to the animal production. Many research teams in the world have chosen infrared photoacoustic spectroscopy analyzers (PAS; e. g. INNOVA® 1312 or 1412) to measure selectively the concentrations of ammonia and greenhouse gases [1 – 4]. Network activity between them is difficult because different PAS can give different concentrations because of differences in configuration or maintenance: the chosen filters can compensate for different cross interferences, different concentrations used for calibration can induce differences in measurements, a significant drift in calibration can appear due to the infrared source or the microphones or changes following the use in highly contaminated environments. Therefore, INRA and IFIP, with the financial support of ADEME, developed a test bench that can be used to compare different PAS analysers (INNOVA®).

Material and methods

The aim of the developed test bed is to generate gas mixtures with chosen NH_3, CH_4, N_2O and CO_2 concentrations. 4 bottles of pure gases at diluted concentrations (400 ppm NH_3, 3000 ppm for CH_4, 100 ppm N_2O and 50000 ppm for CO_2) are connected to mass flow controllers (Bronkhorst® F-201CV-500-RAD-11-V with numerical control; Fig. 1). The initial concentrations of the bottles have been assessed considering the concentration ranges in the final gas mixture. The concentrations is the N_2O, CH_4 and CO_2 bottles are certified. Their small volume allows a storage in the room at 20℃.

N_2 is used for dilution and to provide the total required output flow for the analyser (minimum 1.8 L/min). A Nafion Tube, connected to the N_2 line, is used to humidify the gas mixture. In order to avoid high pressure at the inlet of the analyser, at the exhaust of the test bed one tube is connected to the inlet of the analyser and another one is opened to the outside. Two flow meters were added between the two output lines (PTFE tubes) of the test bed in order to control the output flow (at 3 L/min when the analyzer doesn't pump).

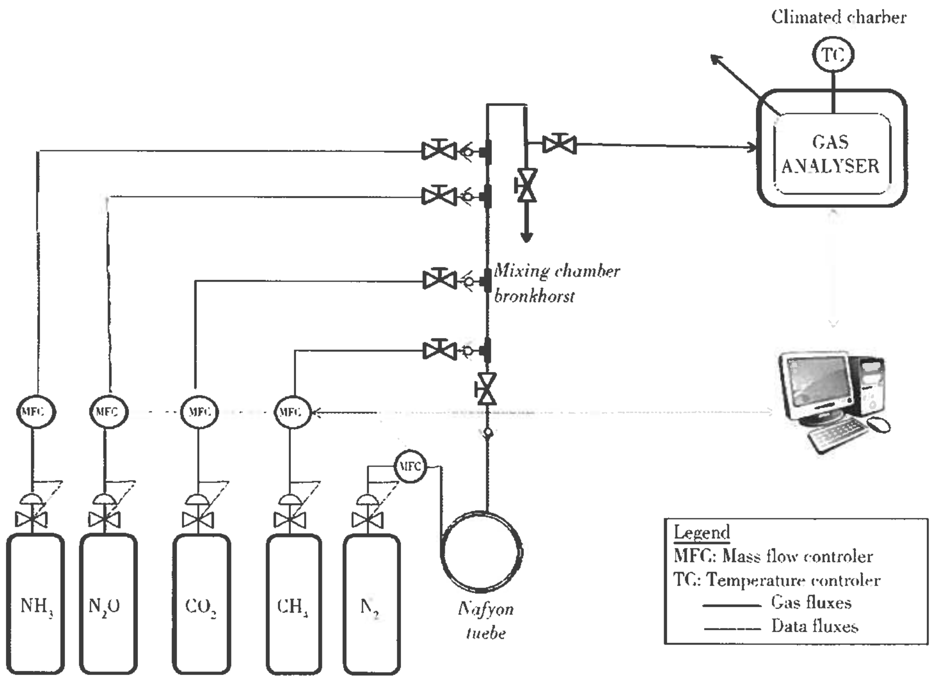

Fig. 1 The test bed is composed of mass flow controllers and gas bottles(CH_4, CO_2, NH_3 and N_2O) at diluted concentrations. N_2 is used as vector and dilution gas.

The mass flow controllers are controlled with a Labview program(Fig. 2) that allows choosing and measuring the mass flows corresponding to various concentration levels in the gas mixture. A FlowView software sold by Bronkhorst® is also used to check the communication with the computer. Two analysers can sample simultaneously the mixture.

The program is also used to visualize and record the concentrations levels in the gas mixture, the concentrations measured by the analysers, the calibration data, the concentration uncertainties(gas mixture, analyzer). The raw signal(mV) from the microphones is also collected as it can be used to develop specific calibration equations, different from those incorporated in the analyser.

Results

The possible concentrations levels that can be obtained in the gas mixture are presented in Table 1. The lower concentrations levels varied in function of the nitrogen flow. The minimum concentration levels can be reached with a high nitrogen flow(12 L/min). With the minimum nitrogen flow, the maximum concentration levels can be reached.

For each gas the uncertainty on the concentration in the mixture is evaluated based on uncertainty on mass flow controller and in the gas bottle.

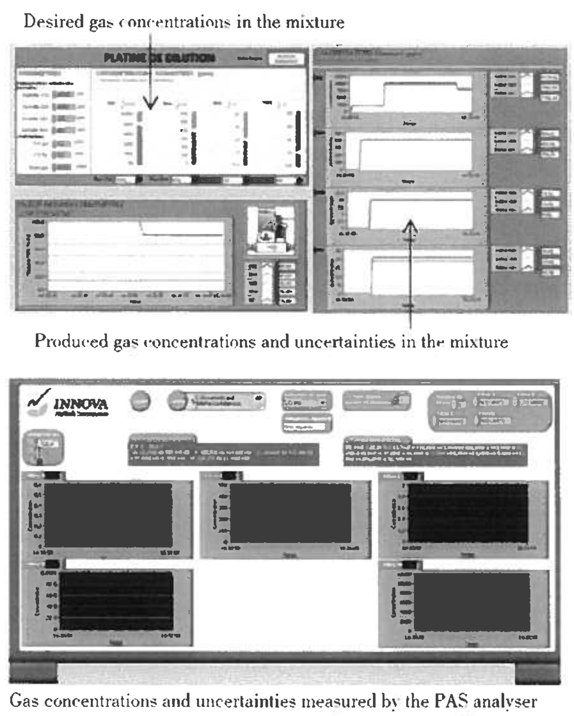

Fig. 2 Man-machine interfaces used to control the mass flow controllers and recorded data from the mass flow controllers, the gas concentrations in the mixture, the gas concentrations and the raw signals given by the PAS analyser

Table 1 Concentration ranges in the gas mixture as a function of the total output flow

Gas	Output flow >3L/min	Output flow at 3L/min	
	Concentration Min	Concentration Min	Concentration Max
CO_2 (ppm)	50	200	10000
CH_4 (ppm)	3	12	600
N_2O (ppm)	0.1	0.4	20
NH_3 (ppm)	0.4	1.6	80

Discussion

This test bed developed for PAS analyser can be used for many purposes: to compare different measuring devices, to test calibration in different ranges, to detect failures and calibration drift, to evaluate interference (of non-targeted gases) impacts on measured concentrations, to estimate uncertainty on gas concentration measurements. When using PAS analysers on farms, other uncertainty sources must be added to the uncertainty evaluated in laboratory conditions. They can highly contribute to the uncertainty on gas concentrations measurements (e. g. condensation in sampling pipes, spatial heterogeneity).

Conclusion

The development of quality control for gas concentrations measurements relies on the development of tools as the test bed presented in this paper. It can improve the comparison of emission measurements performed within a network of organisms over years. To propose a complete uncertainty estimate and to perform the raw data treatment (by performing the correction of all interferences), the presented test bed should be completed with a system that allows the control of the gas moisture and the production of gases from liquid solutions.

Aknowledgment

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References

1. MATHOT, M., DECRUYENAERE, V., LAMBERT, R., & STILMANT, D. (2007): Emissions de CH_4, N_2O et NH_3 en étables et lors du stockage des engrais de ferme de génisses Blanc Bleu Belge. Paper presented at the 14ème Journées 3R, Paris.
2. NGWABIE, N. M., JEPPSSON, K. H., NIMMERMARK, S., SWENSSON, C., & GUSTAFSSON, G. (2009). Multi-location measurements of greenhouse gases and emission rates of methane and ammonia from a naturally-ventilated barn for dairy cows. *Biosystems Engineering*, 103(1), 68-77.
3. PHILIPPE, F. X., LAITAT, M., NICKS, B., & CABARAUX, J. F. (2012): Ammonia and greenhouse gas emissions during the fattening of pigs kept on two types of straw floor. *Agriculture Ecosystems & Environment*, 150, 45-53.
4. ZHANG, G., STROM, J. S., LI, B., ROM, H. B., MORSING, S., DAHL, P., & WANG, C. (2005): Emission of ammonia and other contaminant gases from naturally ventilated dairy cattle buildings. *Biosystems Engineering*, 92 (3), 355-364. doi: 10.1016/j.biosystemseng.2005.08.002.