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► **To cite this version:**

Paul Robin, Gérard Amand, Claude Aubert, Nadège Babela, Aude Brachet, et al.. A LOW-COST DATABASE AND SOFTWARE FOR THE MEASUREMENT OF AMMONIA AND GREENHOUSE GAS EMISSIONS OF ANIMAL HOUSES. Emissions of gas and dust from livestock, IFIP - Institut du Porc, 2013. hal-01461138

**HAL Id: hal-01461138**

**<https://hal.science/hal-01461138>**

Submitted on 7 Feb 2017

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## **A LOW-COST DATABASE AND SOFTWARE FOR THE MEASUREMENT OF AMMONIA AND GREENHOUSE GAS EMISSIONS OF ANIMAL HOUSES**

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**ABSTRACT:** Measuring the emissions of thousands of animal houses is needed to obtain representative emission factors and relevant categories of animal farms for emission inventories. This scale is also necessary to develop a comprehensive understanding of all factors that influence ammonia and greenhouse gas emissions at the farm scale. A robust and low-cost method was developed in France to measure emissions from poultry, bovine and swine houses. A database and associated software is presented here that helps to apply this method to a large number of houses, while protecting the data when the database is used by different companies or institutions. It is based on freeware: an Ubuntu system, OpenOffice for testing equations, PostgreSQL and PgAdmin for database management with “user-only” or “project-only” restricted access to data, and C++ with CodeBlocks and wxWidgets for the calculation and interface modules developed. As for typical Ubuntu software, all messages in the interfaces developed can be translated into several languages using PoEdit. All systems, software and data can be stored on a bootable USB flash drive or SD card with at least two partitions, one for the system (FAT32) compressed into a squashfs file, and one for the modified files (EXT2). The data are divided into three categories: national references (e.g. manure composition), farm references (e.g. specific house characteristics), and observations (e.g. gas concentrations). Training is recommended to begin using the software more quickly. Further development is required to adapt this tool to monitor the results of mitigation strategies and improve their efficiency.

**Keywords:** database, NH<sub>3</sub>, GHG, emission, measurement, inventory, low-cost method

**INTRODUCTION:** As stated in IPCC 2006 Guidelines, "the best way to determine emission factors is to conduct non-invasive or non-disturbing measurements of emissions in actual systems representative of those in use in the country" (IPCC, 2006). Emission factors depend greatly on livestock and manure management practices: in the case of N<sub>2</sub>O emissions, IPCC (2006) proposes values ranging from less than 0.001 to above 0.1 kg N<sub>2</sub>O-N (kg N excreted)<sup>-1</sup>. The high uncertainty (factor 2 for N<sub>2</sub>O, IPCC 2006) shows that the variability within any one category remains high. Measuring the emissions of thousands of animal houses is a strategic issue for improving emission inventories and mitigation strategies. It will improve the choice of relevant categories of animal farms, animal numbers and emission factors associated with each category. Identifying and understanding the differences between categories will improve the knowledge of practices that reduce ammonia (NH<sub>3</sub>) and greenhouse gas (GHG) emissions at the farm scale. Monitoring emissions in a large number of

animal houses over years will help reveal emission reductions independent of animal numbers.

A robust and low-cost method was developed in France to measure emissions in animal houses. The measuring principle is non-disturbing. It can be applied in mechanically or naturally ventilated houses for NH<sub>3</sub> or GHG emissions and was adapted for bovine (Hassouna et al., 2010), poultry (Ponchant et al., 2009) and swine (Guinand et al., 2011) houses. This method could be applied to a large number of animal houses if a standard software offered the ability to store farm data and use it to calculate emissions in a homogeneous manner. The objective of this paper is to propose an initial set of software, including a database for observations and programs to calculate emissions, for the management of NH<sub>3</sub> and GHG emission data in a large number of animal houses.

## 1. MATERIAL AND METHODS:

**1.1. Measuring principle:** The method's principle is based on the general law of convective transfer through an opening (eq. 1) and on two hypothesis: (i) most carbon (C) is lost as CO<sub>2</sub> (eq. 3), (ii) variations in NH<sub>3</sub> and GHG emissions follow variations in CO<sub>2</sub> emission:

$$\text{emission} = \text{ventilation} \times (\text{concentration inside} - \text{concentration outside}) \quad [\text{eq. 1}]$$

$$\text{therefore: } \frac{\text{emission CO}_2}{\text{emission NH}_3} = \frac{\text{concentration CO}_2 \text{ inside} - \text{concentration CO}_2 \text{ outside}}{\text{concentration NH}_3 \text{ inside} - \text{concentration NH}_3 \text{ outside}} \quad [\text{eq. 2}]$$

when most carbon is lost as CO<sub>2</sub> through animal respiration, CO<sub>2</sub> emission can be estimated by:  $\text{emission CO}_2 = (\text{input C} - \text{output C}) \times \frac{44}{12}$  [eq. 3]

On each farm, gas observations inside and outside the animal houses are supplemented with climate observations and a farmer questionnaire. The mass balance of C is estimated using national references or specific observations of feed, animals, manure and litter. When the ratio of concentration gradients used in eq. 2 is stable during a period in which C loss can be estimated, the emission of NH<sub>3</sub>, GHG or water can be estimated with eq. 2. The value of CO<sub>2</sub> emission in eq. 2 is then replaced by the value estimated with eq. 3.

Uncertainties in emission estimates are mostly due to (i) the representativity of national references and feed information used to calculate the mass balance of C and (ii) the temporal representativity of one gas observation to the period when it is applied. The former can be reduced by performing expensive mass balance surveys, including mass and concentration measurements of animals, feeds and manure. The latter can be reduced by repeating the measurements or performing expensive continuous gas and climate monitoring inside and outside the houses.

In France, the variability in the ratio of concentration gradients used in eq. 2 is high: from less than 10 to above 10000 when considering NH<sub>3</sub>, CH<sub>4</sub> and N<sub>2</sub>O gradients in swine, poultry or dairy cattle houses. This indicates that emissions can vary by a factor of 1000 for a given animal's respiration. Therefore, despite simplifications and uncertainties, we consider that this low-cost method can help identify emission categories relevant to national diversity.

**1.2. Factors explaining emission variability:** In most countries with a tradition of animal farming, there is a high diversity of livestock and manure management practices and existing databases. The following factors influence emissions and can be used to improve the definition of farm categories; some are directly included in the proposed database. Emission of nitrogenous species ( $\text{NH}_3$ ,  $\text{N}_2\text{O}$ , and  $\text{N}_2$ ) depends on the nitrogen content of the feed and animal production. Changes in stocking density modify  $\text{NH}_3$  and GHG emissions. Emissions from manure vary with dilution of excretion by water or litter addition. Emissions depend on air temperature and manure dry matter content. Other factors can be identified by linking this database to other existing databases on a farm basis. The farm's crop area and herd size influence farmer practices: in France both can vary within a large range (Agreste, 2011). The number of animal species combined on one farm is higher on small farms, while genetic diversity is smallest on the largest animal farms: this diversity influences feed conversion ratio, efficiency of local resources and manure management. Animal feed can be produced on the farm or imported. In poultry confined-feeding operations, manure is mostly solid, while it is liquid in most swine systems (CITEPA, 2012). Solid manure is more easily exported than liquid manure. On farms where most feed is imported and manure is liquid, decreased efficiency of nitrogen recycling and higher nitrogen losses are observed at the farm scale.

The complex influence of these factors is linked to the various time and spatial scales of the concerned processes. This complexity is also due to positive or negative biological feed-back that interacts with farmer management practices and the climate. Associating many factors with emission values observed on a large number of animal farms can help improve national emission categories. Comparing categories can help identify low-cost practices that currently reduce emissions. Transferring these practices to farms can reduce the cost of mitigation strategies compared to large-scale investments.

## **2. RESULTS AND DISCUSSION:**

**2.1. Database and datasheet design:** A database for a large number of houses and datasheets for single houses were implemented with the same rules (Figure 1). The data come from three source types: national references (e.g. manure composition), farm references (e.g. specific house characteristics), and observations (e.g. gas concentrations). All sources can be used for mass balance estimates. Mixing observations and national references (e.g. observed concentrations in manure with references for mass values) can increase uncertainty in emissions. The conservation of phosphorus and potassium should be checked before using farm data to calculate the mass balance of N or C. When water consumption is observed, the water deficit can confirm the water emission.

**2.2. Software development:** The software was implemented using open source freeware. PostgreSQL and PgAdmin were installed on an Ubuntu operating system, with “user-only” or “project-only” restricted access to data. C++ software for data input and calculations were implemented with CodeBlocks and wxWidgets. All messages of the developed interfaces can be translated into different languages using PoEdit. A bootable USB flash drive contains all the software. It uses a system compressed into a squashfs file and a modifiable partition (EXT2) to store current work.

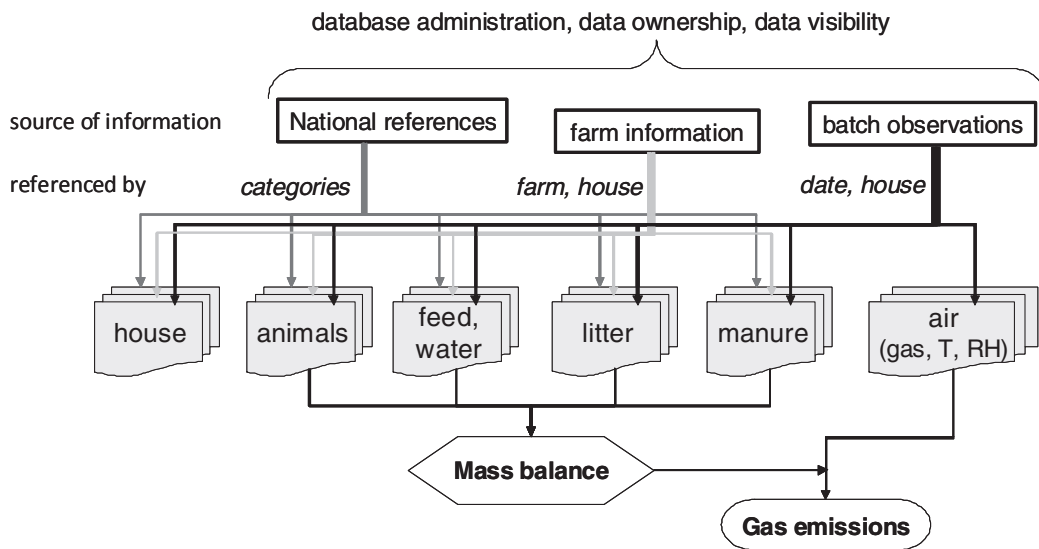


Figure 1. Source and flow-chart of the database/datasheet information.

**CONCLUSION:** Software and a database were developed to provide tools for monitoring emissions in a large number of animal houses. It was developed on a bootable USB flash drive using open source freeware. It combines OpenOffice datasheets for flexible use with a small number of farms with a PostgreSQL database with C++ input and calculation programs for standard application to a large number of farms. Training is recommended to begin using the software more quickly. Further development is required to adapt this tool to reduce the costs of mitigation strategies on the basis of observed efficient practices.

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**ACKNOWLEDGEMENTS:** Acknowledgements to INRA (RMT allocation), CASDAR, PITE program for funding this project (2007-2012) and to the Public Agricultural Schools (EPLEA) of Brittany and the farmers for collaborating in farm surveys.