



**HAL**  
open science

## Measuring gaseous emissions from sored pig slurry

S. Espagnol, L. Loyon, F. Guiziou, Paul Robin, I. Bossuet, Mélynda Hassouna

► **To cite this version:**

S. Espagnol, L. Loyon, F. Guiziou, Paul Robin, I. Bossuet, et al.. Measuring gaseous emissions from sored pig slurry. The eighth international livestock symposium, Iles VIII, Aug 2008, Iguassu Falls, Brazil. 8 p. hal-00468642

**HAL Id: hal-00468642**

**<https://hal.science/hal-00468642>**

Submitted on 31 Mar 2010

**HAL** is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

# MEASURING GASEOUS EMISSIONS FROM STORED PIG SLURRY

S. Espagnol<sup>1</sup>, L. Loyon<sup>2</sup>, F. Guiziou<sup>2</sup>, P. Robin<sup>3</sup>, I. Bossuet<sup>1</sup>, M. Hassouna<sup>3</sup>

## ABSTRACT

The study tested the use of dynamic floating chambers to measure emissions factors of ammonia (NH<sub>3</sub>), nitrous oxide (N<sub>2</sub>O) methane (CH<sub>4</sub>) and carbon dioxide (CO<sub>2</sub>) from stored pig slurry and measured the variations of the emissions in time and space. In 2006, dynamic floating chambers were used for the continuous measurement of gaseous emissions from two experimental tanks filled with fattening pig slurry stored for two summer months and in a pit filled repeatedly with mixed slurry between October and March.

To check the influence of air speed on gaseous emissions, each tank was fitted with a chamber : one operating with an air speed at the surface of the slurry of 0.01 m/s, the other with a speed of 1 m/s. To ascertain the spatial variability of the emissions, two identical chambers were used for the pit : one was regularly displaced across the surface of the slurry ; the other was fixed throughout the storage period. The measurements obtained were compared with the nitrogen and carbon input-output mass balances of the slurry.

The results show that the measured gaseous emissions explain from 4 to 38% of the total nitrogen losses and from 61 to 285% of the total carbon losses. The use of such dynamic floating chambers is not an appropriate method to evaluate the gaseous emission factors from slurry storage. The kinetics of the emissions underline the importance of measurement periods and their duration to measure emission factors.

**KEYWORDS.** Ammonia, nitrous oxide, methane, gaseous emissions, dynamic flux chamber, methodology, slurry storage.

## INTRODUCTION

The actual emission factors used in France for assessing records of emissions come from foreign data originating from livestock enterprises which differ in their configuration from French ones. However, Gac et al. (2007) show the effect of the systems and practices of breeders on gaseous emissions. To deal with the diversity of the French systems and make possible the acquisition of the relevant emission factors, ITAVI, Cemagref, INRA, CITEPA and ACTA are working to perfect a simplified method to measure gaseous emissions from slurry storage under rearing conditions.

This study has as objectives (i) to test the validity of dynamic floating chambers to measure emission factors from slurry storage, a widely-used method for this kind of emission which has the advantage of being simple to apply in animal rearing, (ii) to characterise the dynamic of gaseous emissions (NH<sub>3</sub>, N<sub>2</sub>O, CH<sub>4</sub> and CO<sub>2</sub>) during the storage of slurry for several months in a slurry pit between two spreading periods with successive feedings to measure the variations in time and space of the gaseous emissions. The aim is to establish the main methodological elements needed in order to estimate emissions factor from pig slurry storage with periodic measurements.

---

<sup>1</sup> IFIP, La Motte au vicomte, F-35650 Le Rheu, France

<sup>2</sup> Cemagref, Environmental Management and Biological Treatment of Wastes Research Unit, 17, avenue de Cucillé, CS 64427, F- 35044 Rennes Cedex, France

<sup>3</sup> INRA, UMR 1069, Sol Agro et hydrosystèmes Spatialisation, F-35000 Rennes, France

## MATERIALS AND METHODS

### Experimental design

In order to test the influence of air speed in the dynamic floating chambers, two experimental uncovered tanks were used. The high density polyethylene tanks were cylinders of a capacity of 13.2 m<sup>3</sup> (2.9 m diameter) standing on the soil. Slurry issued from the fattening period of pigs on slatted floors was homogenised, sampled and transferred into the two tanks (2 x 10.5 m<sup>3</sup>) and stored outside for two months during June and July 2006. At the end of storage the volume of slurry in each tank was measured and mixed with a pump (KSB, 220V, 8m<sup>3</sup>/h), and sampled.

To determine the kinetics of emissions, their spatial variability and the emission factors, a uncovered cylindrical above-ground slurry pit with a capacity of 300 m<sup>3</sup> (11.4 m diameter) was used. This was first emptied and cleaned out, and slowly filled through the base with five successive batches of pig slurry (fattening and post-weaning) spread over the period from mid-September 2006 to March 2007. Each addition of slurry was measured and sampled. Two dynamic floating chambers operating with an air speed of 0.01 m/s were placed on the surface of the slurry, one fixed in the middle of the pit (FA) for the whole storage period, and the other moved regularly (FB). At the end of storage the slurry in the pit was mixed with a pump (LJM, 15kW, 360 m<sup>3</sup>/h), then emptied in six fractions. The volume taken out in each fraction was measured and sampled. The volume of sludge still present at the bottom of the pit after the six extractions was also measured and sampled.

The slurry and sludge samples were analysed for density, dry matter, pH, total carbon and nitrogen, ammoniacal nitrogen, phosphorus and potassium. The volume and composition of all the feedings and emptyings of the experimental tanks and the pit made it possible to work out a nitrogen, carbon, phosphorus and potassium input-output mass balances of the slurry. The balances of non-volatile elements (P and K) were used to check the sampling of effluents.

### Measurements of gaseous emissions of stored slurry

For the experimental tanks, the measurements of gaseous emissions were made continuously during two periods (39 days in total) spread over 54 days of storage. For the pit, they were made continuously over the course of six measurement periods (88 days in total) spread over the 193 days of storage.

For both types of storage the floating PVC volatilisation chambers (Peu, 1999), made up of a polystyrene base (1.2 m square), were used. Their volume was 0.046 m<sup>3</sup>. They were placed on the surface of the slurry, creating an air circulation on a surface of 0.114 m<sup>2</sup>.

For the experimental tanks, two air circulation speeds were applied on the slurry surface in the floating chambers : the chamber of the tank 1 (C1) was modified to obtain an air speed of 1 m/s on the slurry surface covered; and the chamber of the tank 2 (C2) applied an air speed of about 0.01 m/s. C1 was fed with compressed air and the outlet flow was 75 L/min. The outlet flow from C2 was 15 L/min. A valve situated after the air intake maintained the interior of the chamber at atmospheric pressure. For the pit, both chambers (FA and FB) operated like C2.

The gas concentrations were measured by photoacoustic infrared absorption spectrometry using a gas analyser (INNOVA 1312) coupled to a sampler dosimeter (INNOVA 1303) capable of sampling air from 6 different places. The air samples were taken successively and automatically every 1 min 30 s for 15 min at the floating chamber's outlets and outside. The gases analysed were NH<sub>3</sub>, N<sub>2</sub>O, CO<sub>2</sub>, CH<sub>4</sub> and H<sub>2</sub>O. The Teflon sampling tubes, 25 m long from the sampling point to the analyser, were heated and insulated over their whole length to avoid condensation.

During storage the weather conditions (temperature and relative humidity of the air, wind speed and precipitation) were measured with a Campbell weather station situated 2 m above the soil in an open space. Air temperature and humidity within the dynamic floating chambers C2, FA and FB were measured continuously using TESTO 177-H1 data loggers. The air temperatures and humidity were used to calculate the bulk density of the air used in the calculation of gas concentration gradients.

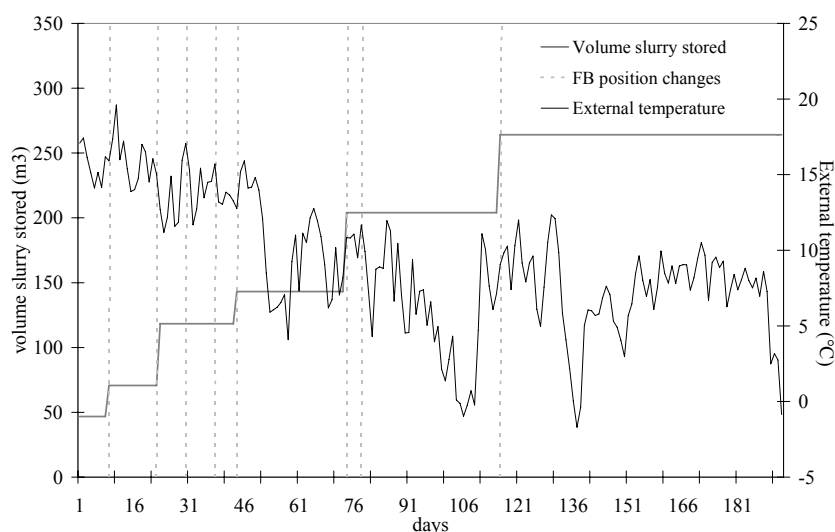
Hourly mean gaseous emissions (gN/h and gC/h) were calculated by multiplying the flows through the chambers by the differences in gas concentration. Between the measurement periods the emissions were interpolated linearly. The measurements of gaseous emissions, corresponding to 0.114 m<sup>2</sup> covered by chambers, were extrapolated to the storage areas of the tanks and the pit.

Wind speed at the surface of pit slurry were monitored every 10 min by two cup anemometers (type INT 10) placed on the side of each floating chamber FA and FB.

## RESULTS

### Slurry storage conditions

During storage in experimental tanks, the external hourly temperatures varied between 9.0°C and 34.0°C with a mean of 19.3°C. During the 5 months of the pit storage, external hourly temperatures varied between -3.0°C and 28.0°C with a mean of 9.3°C : the mean daily external temperatures are shown in figure 1. The temperatures in the floating chambers generally followed the external temperatures with a slightly higher mean of 21.5°C for C1 and 9.6°C for FA and FB.



**Figure 1. Variation in daily external temperature and the daily wind speed during storage in the pit**

During the experimental tanks storage, external wind speed measured at the weather station varied between 0.03 and 4.7 m/s (hourly means) with a mean of 1.7 m/s. It is assumed to be identical at the slurry surface of the tanks located near the edge of the tank. During storage in the pit, the wind speeds at the surface of the slurry, measured with the anemometers, varied between 0.01 and 4.0 m/s with a mean of 0.8 m/s.

### Total nitrogen, carbon and water losses during storage

The composition of the slurry stored in the experimental tanks (table 1) and in the pit correspond to pig slurries of French Husbandries listed by Levasseur (2005).

**Table 1. Composition of the slurry stored in experimental tanks and in the pit**

	Density (kg/l)	DM (%)	pH	NTK (g/kg)	NH <sub>4</sub> <sup>+</sup> (g/kg)	P <sub>2</sub> O <sub>5</sub> (g/kg)	K <sub>2</sub> O (g/kg)	C tot (g/kg)
Slurry E start Tank 1	1.05	6.5	7.2	5.1	3.9	2.3	4.2	27.8
Slurry E end Tank 1	1.01	6.6	6.9	5.4	4.2	2.6	4.8	28
Slurry E start Tank 2	1.05	6.5	7.3	5.0	3.8	2.5	4.1	25.9
Slurry E end Tank 2	1.01	6.4	6.9	5.3	4.2	2.5	4.7	25.9
Slurry E addition 1 pit	1.04	4.7	8.0	3.7	2.5	2.0	3.2	15.5
Slurry PS addition 2 pit	1.04	4.3	7.6	2.5	1.3	1.6	1.8	16.5
Slurry E addition 3 pit	1.03	4.8	7.9	3.2	2	1.9	2.6	12.4
Slurry PS addition 4 pit	1.02	2.2	7.9	2.0	1.3	0.7	2.5	7.2
Slurry E addition 5 pit	1.04	5.2	8.0	4.5	3.1	2.3	3.2	15.5
Slurry E addition 6 pit	1.06	4.7	8.0	4.2	2.7	2.2	3.3	15.6
Slurry mean added to the pit *	1.04	4.6	7.9	3.6	2.4	1.9	2.9	14.3

\* : weighted by the mass of the slurry in each addition

The mass balances of the slurries determine the total nitrogen, carbon and water losses which occurred during the storage periods. The error associated with the weighing, sampling and physico-chemical analyses, needed for the balance, is evaluated with the help of the mass balance of the non-volatile elements (P<sub>2</sub>O<sub>5</sub> and K<sub>2</sub>O). The very week mass balance obtained (table 2) allow to validate the sampling of the slurries.

For tanks 1 and 2 and the pit respectively, the mass balances indicate nitrogen losses of 7%, 9% and 9% of the stored nitrogen (the initial addition and successive additions for the pit) and carbon losses of 12%, 14% and 10% of the stored carbon. The water losses represent 15%, 14% and 8% of the water stored, taking account of precipitation.

**Table 2. Slurry Mass balances of tanks 1 and 2 and the pit between the start and the end of storage**

	Mass (kg)	Volume (m <sup>3</sup> )	DM (kg)	Water (kg)	C tot (kg)	NTK (kg)	P <sub>2</sub> O <sub>5</sub> (kg)	K <sub>2</sub> O (kg)
Tank 1 start	10847	10.4	700	10148	301	55.0	25.4	45.2
Rainfall during the 2 months	247	0.2	-	247	-	-	-	-
Tank 1 end	9434	9.3	623	8812	264	50.7	24.4	44.9
Tank 1 losses	1660	1.3	77	1583	37	4.3	1.0	0.3
% losses Tank 1	15%	12%	11%	15%	12%	8%	4%	1%
Tank 2 start	11054	10.6	719	10336	286	55.7	27.8	45.3
Rainfall during the 2 months	247	0.2	-	247	-	-	-	-
Tank 2 end	9515	9.4	604	8911	247	50.5	23.5	44.4
Tank 2 losses	1786	1.4	115	1672	39	5.2	4.3	0.9
% losses Tank	16%	13%	16%	16%	14%	9%	14%	2%
Total Pit fillings 1 to 6	254361	265	11529	242832	3626	920	487	746
Rainfall during the 5 months	64221	64	-	64221	-	-	-	-
Total Pit emptyings 1 to 6	252321	261	7483	244837	2676	713	390	622
Pit sediment	40670	43	1891	38779	600	124	101	99
Pit losses	25591	25	2155	23437	350	83	-4	25
% losses Pit	8%	8%	19%	8%	10%	9%	-1%	3%

### Gaseous emissions (NH<sub>3</sub>, N<sub>2</sub>O, CH<sub>4</sub>, CO<sub>2</sub>, H<sub>2</sub>O) measured with the floating chambers

For the experimental tanks, the nitrogen gaseous emissions measured represent, for tank 1 (C1 : 1 m/s) and tank 2 (C2 :0.01 m/s) respectively, 1.64 kg and 0.99 kg of NH<sub>3</sub>-N and 13 g and 3 g of N<sub>2</sub>O-N (i.e. in total, 3.0% and 1.8% respectively of the initial stored nitrogen). The tanks carbon emissions measured were 3.2 kg and 4.3 kg of CH<sub>4</sub>-C and 19.5 kg and 23.9 kg of CO<sub>2</sub>-C (i.e. 7.5% and 9.8% respectively of the initial stored carbon) (Table 3) The tanks water emissions measured were, for tanks 1 and 2 respectively, 1415 kg and 232 kg of H<sub>2</sub>O The carbon emissions measured from tank 2 were 34% (CH<sub>4</sub>) and 23% (CO<sub>2</sub>) higher than those from tank 1. Conversely, the emissions of NH<sub>3</sub>, N<sub>2</sub>O and H<sub>2</sub>O were 40%, 77% and 84% lower respectively. Statistical analysis (Student's test, P <= 0.05) indicated that the emissions of NH<sub>3</sub>, N<sub>2</sub>O, CH<sub>4</sub> and H<sub>2</sub>O measured from tanks 1 and 2 were significantly different. This was not the case with CO<sub>2</sub> emissions.

**Table 3. Gaseous emissions measured from the tanks and the pit**

		Period (number of days)	N_NH <sub>3</sub>	N_N <sub>2</sub> O	C_CH <sub>4</sub>	C_CO <sub>2</sub>	H <sub>2</sub> O
Total emissions (kg)	Tank 1 C1	Total (54d)	1.64	0.013	3.2	19.5	1 415
	Tank 2 C2	Total (54d)	0.99	0.003	4.3	23.8	232
	Pit FA	Total (193d)	5.2	0.089	655	344	2 970
	Pit FB	Total (193d)	3.6	0.043	357	190	3 499
Mean daily emissions (g/m <sup>2</sup> /d for NH <sub>3</sub> and g/m <sup>3</sup> /d for N <sub>2</sub> O, CH <sub>4</sub> and CO <sub>2</sub> )	Pit FA	Measurement (88d)	0.23	0.0014	21.96	14.47	
		46,8 m <sup>3</sup> (8d)	0.36	0.0015	18.87	21.42	
		70,7 m <sup>3</sup> (7d)	0.21	0.0026	23.18	30.76	
		118,3 m <sup>3</sup> (21d)	0.21	0.0009	21.64	13.91	
		143,2 m <sup>3</sup> (16d)	0.38	0.0021	40.35	19.94	
		204 m <sup>3</sup> (14d)	0.26	0.0013	18.71	8.90	
		264,1 m <sup>3</sup> (22d)	0.10	0.0011	12.85	7.56	
	Pit FB	Measurement (88d)	0.21	0.0014	13.5	8.9	
		46,8 m <sup>3</sup> (8d)	0.47	0.0034	11.00	14.35	
		70,7 m <sup>3</sup> (7d)	0.31	0.0019	12.72	18.87	
		118,3 m <sup>3</sup> (21d)	0.28	0.0014	21.49	13.17	
		143,2 m <sup>3</sup> (16d)	0.18	0.0011	18.93	8.64	
		204 m <sup>3</sup> (14d)	0.14	0.0009	8.41	3.57	
		264,1 m <sup>3</sup> (22d)	0.08	0.0009	6.79	3.58	

For the pit, the nitrogen gaseous emissions measured with FA (fixed position) and FB (variable position) respectively, represent 5.2 kg and 3.6 kg of NH<sub>3</sub>-N and 89 g and 43 g of N<sub>2</sub>O-N (i.e.

0.6% and 0.4% of the stored nitrogen respectively) and the measured carbon emissions were 655 kg and 357 kg of CH<sub>4</sub>-C and 344 kg and 190 kg of CO<sub>2</sub>-C (i.e. 27.6% and 15.1% of the stored carbon respectively). The emissions measured with FA were 83% higher for CH<sub>4</sub>, 81% for CO<sub>2</sub>, 104% for N<sub>2</sub>O and 42% for NH<sub>3</sub> than those measured with FB. The tendency is noticed for the all storage period.

For the different storage modalities, the measured nitrogen emissions were almost entirely (about 99%) in the form of NH<sub>3</sub>. The carbon emissions were mainly (about 85%) in the form of CO<sub>2</sub> from the experimental tanks and mainly (65%) in the form of CH<sub>4</sub> for the pit.

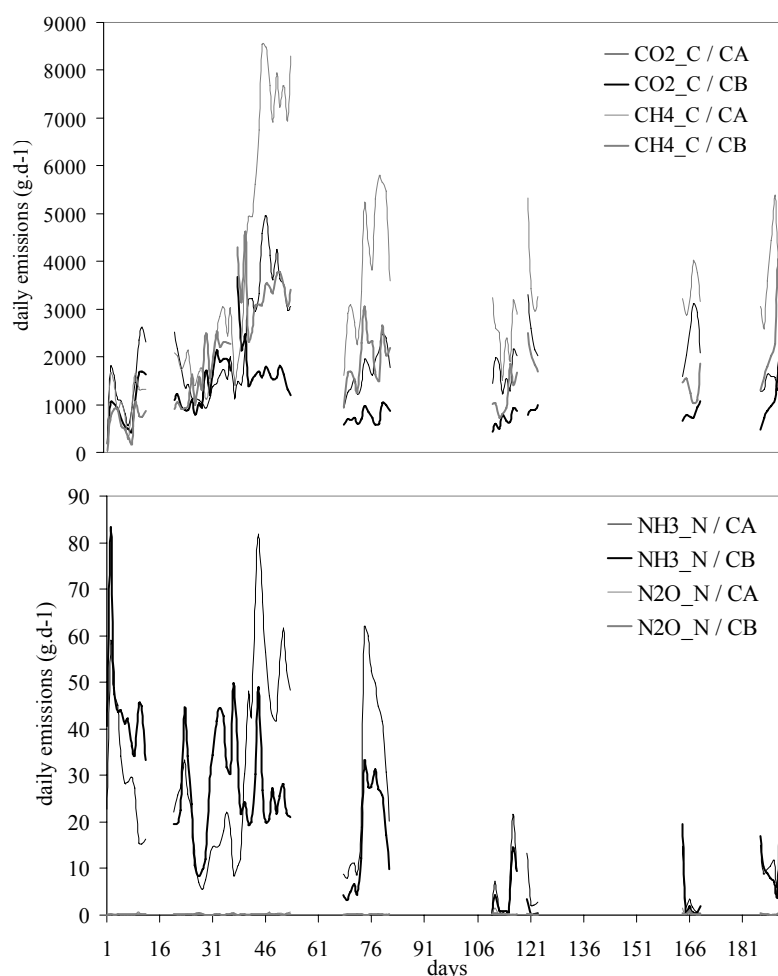
#### Rate of recovery of losses with the gaseous emissions measurements

The nitrogen emissions (NH<sub>3</sub> and N<sub>2</sub>O) of the experimental tanks 1 and 2 and the pit (with FA and FB) measured with the dynamic chambers explain 38%, 19%, 6% and 4% respectively of the losses estimated by the slurry mass balances. Part of the nitrogen emissions was in the form of N<sub>2</sub> gas and was not measured (hence not taken account of in the calculation of the rate of recovery of nitrogen losses). However the storage of slurries in the pit was essentially anaerobic and the N<sub>2</sub> emissions are considered to be negligible.

During slurry storage, carbon losses are known to be mainly in the form of CO<sub>2</sub> and CH<sub>4</sub>. The carbon emissions measured with the chambers explain 61% (C1), 72% (C2), 285% (FA) and 156% (FB) of the carbon losses estimated from the mass balance method. The water emissions measured explain 89% (C1), 14% (C2), 13% (FA) and 15% (FB) of the water losses estimated with slurry mass balances.

#### Variations in the gaseous emissions of the pit slurry

During the 5½ months of pit slurry storage the emissions of CH<sub>4</sub> and CO<sub>2</sub> expressed in g/d of C (figure 2) tend to increase during the first two months of storage when four additions of slurry were made and the pit contents increased from 46.8 m<sup>3</sup> to 143.2 m<sup>3</sup>.



**Figure 2. Variation of daily gaseous carbon and nitrogen emissions of the pit**

The highest emissions occurred towards the end of October, after which they fell during November. Similar changes were found by calculating the mean emissions expressed in  $\text{g}\cdot\text{m}^{-3}\cdot\text{d}^{-1}$  of C for each period associated with a given volume of stored slurry (table 3).

$\text{NH}_3$  emissions increased rapidly from the beginning of storage and then generally fell until the end of storage, except for the emissions measured with FA which increased for several days at the end of October. This phenomenon coincided with the readjustment of the outlet flow of FA to 15 l/min (identical to FB). Because of a technical problem FA operated with an outlet flow of 3 l/min for the first 39 days of storage.  $\text{N}_2\text{O}$  emissions varied little and were low during the storage period and very low compared with total nitrogen emissions.

For all the gases the hourly emissions were found to be very variable over the course of a day. The within-day variability was found to be greater than the between-day variability.

## DISCUSSION

### Effect of measurement method on gaseous emissions

Comparison of gaseous emissions measured with slurry mass balances shows that, for all the storage modalities, the chambers under-estimate the  $\text{NH}_3$  emissions. The air speed applied to the slurry covered surfaces in C2, FA and FB (0.01 m/s), much lower than the wind speed at the uncovered slurry surface, explains the results as shown by Sommer et al. (1993) and Balsari et al. (2007). This is confirmed by the results from tanks 1 and 2 which indicate significantly different  $\text{NH}_3$  emissions according to the applied wind speed (0.01 or 1 m/s).

The results underline the effect of other factors affecting  $\text{NH}_3$  emissions : the difference in the measured  $\text{NH}_3$  emissions between tanks 1 and 2 (twofold) is not proportional to the difference between the two wind speeds in C1 and C2 (100-fold). Summer temperatures may have greatly stimulated the  $\text{NH}_3$  emissions as suggested by Balsari et al. (2007). Furthermore, the temperature within C2 tended to be higher than the external temperature.

Concerning the carbon emissions, the effect of chambers differed according to the two storage modalities (experimental tanks and pit) : emissions were under- and over-estimated respectively.

For the experimental tanks, higher carbon emissions could occur on the uncovered surface because of a higher wind speed applied on the slurry surface. The wind speed could enhance the part of the carbon emissions (Sebacher et al., 1983) produced at the slurry-air interface by aerobic microbial degradations processes (Moller et al., 2004). However, this is not confirmed by results obtained for tank 1 and 2 because higher  $\text{CH}_4$  emissions were measured with C2 with the lower wind speed (0.01 m/s). The temperature in C2, higher than the external temperature because of the weak ventilation flow, might have stimulated carbon emissions (Husted, 1994) more than the wind speed.

For the pit, the over-estimation of carbon emissions is explained partly by the spatial variability of carbon emissions (Safley and Westerman, 1988). It is confirmed by the significantly different carbon emissions measured with FA and FB. FA was placed nearer from the zone of pit feeding than the majority of FB positions. This zone might have a thicker coat of sludge in bottom of pit and higher carbon emissions. Moreover a thin crust was formed on the slurry surface uncovered during the storage, but not inside FA and FB (due to the lower wind speed). The crust had limited the carbon emissions on the uncovered slurry surface (Husted, 1994).

### Estimation of emissions factors for stored slurries

According to Steed and Hashimoto (1994), the degradation processes of  $\text{CH}_4$  and  $\text{CO}_2$  emissions are assumed to be anaerobic. If processes mainly occur inside slurry, chamber could have an effect on the level of total carbon emissions but not on the proportions of the two gases. Therefore, we used the mean ratio of the concentrations of these two gases ( $\Delta[\text{CH}_4\text{-C}] / \Delta[\text{CO}_2\text{-C}]$ ), calculated over the whole measurement period of gaseous emissions, to evaluate the fraction of the shortfall in the carbon balance associated with  $\text{CH}_4$  and  $\text{CO}_2$  emissions respectively.

The emission factors estimated (Table 4) with C1, C2, FA and FB respectively, were, for CH<sub>4</sub>, 9.4g, 10g, 6.4g and 7g CH<sub>4</sub>-C .m<sup>-3</sup>.d<sup>-1</sup> and for CO<sub>2</sub>, 59.3g, 63.3g, 4.1g and 4.7g CO<sub>2</sub>-C.m<sup>-3</sup>.d<sup>-1</sup>. Those results encourage to think that chambers hadn't affect the proportions of the two gases due to the very similar emissions factors obtained with C1 and C2, and FA and FB respectively. However, those results are debatable because according to Moller et al. (2004), significant part of CO<sub>2</sub> (and not CH<sub>4</sub>) is also produced at the slurry-air interface by aerobic microbial degradation at 15°C. It could be enhanced by wind speed, contrary to CH<sub>4</sub> and CO<sub>2</sub> emissions linked to anaerobic processes.

**Table 4 : Gaseous emissions factors estimated from the tanks and the pit**

	Gas	Total emissions estimated from chambers(kg)	Quantity / t slurry stored (kg/t)	initial % / C or N	Emission
Tanks	NH <sub>3</sub> -N	4.3 - 5.2	0.40 - 0.47	7.8 - 9.3	12.1 - 14.6 g.m <sup>-3</sup> .d <sup>-1</sup>
54 days of storage (C1-C2)	CH <sub>4</sub> -C	5.4 - 5.1	0.49 - 0.47	1.9 - 1.8	9.4 - 9.1 g.m <sup>-3</sup> .d <sup>-1</sup>
	CO <sub>2</sub> -C	32.0 - 34.2	2.95 - 3.09	10.6 - 12.0	57.0 - 59.7 g.m <sup>-3</sup> .d <sup>-1</sup>
Pit	NH <sub>3</sub> -N	82	0.32	8.9	4.1 - 5.5 g.m <sup>-3</sup> .d <sup>-1</sup>
193 days of storage (FA-FB)	CH <sub>4</sub> -C	211 - 230	0.83 - 0.90	5.8 - 6.3	7.3 - 9.5 g.m <sup>-3</sup> .d <sup>-1</sup>
	CO <sub>2</sub> -C	139 - 120	0.55 - 0.47	3.8 - 3.3	6.3 - 6.8 g.m <sup>-3</sup> .d <sup>-1</sup>

The carbon emissions of the pit were below those obtained by other authors in husbandry conditions (between 49.8 and 66.6 g C.m<sup>-3</sup>.d<sup>-1</sup> for CH<sub>4</sub> and between 34.6 and 41.9 g C.m<sup>-3</sup>.d<sup>-1</sup> for CO<sub>2</sub> ; Loyon et al. (2004 and 2007). This can be partly explained by the fact that the pit used had been cleaned out. The lack of initial thick permanent layer of sediment at his bottom, heavily loaded with carbon and harbouring a methane-producing flora, could have retarded the emissions (Sommer et al., 2007). Moreover since emissions have often been measured with floating chambers, one has to wonder about the effects of these chambers on the data obtained.

The mean NH<sub>3</sub> emissions obtained for tanks 1 and 2 and for the pit with FA and FB respectively were 12.1g, 14.6g, 4.1g and 5.5g of NH<sub>3</sub>-N .m<sup>-3</sup>.d<sup>-1</sup>. They are higher than most of the ones in the literature for floating chambers, e.g. between 0.5 and 3.5 g N .m<sup>-2</sup>.d<sup>-1</sup> (Balsari et al., 2007 ; Loyon et al., 2007). But they are close to the results obtained with measurement apparatus with a higher air speed; 8.63 gN.m<sup>-2</sup>.d<sup>-1</sup> in summer with a speed of 0.5 m/s (Balsari et al., 2007) and between 3.9g and 4.6g N .m<sup>-2</sup>.d<sup>-1</sup> in autumn/winter with a speed of about 4m/s (Sommer et al., 1993).

#### Effect of storage conditions on gaseous emissions

The results show variations in mean emissions between periods defined by the volume stored. Until November, the increase in the stored volume (increasing depth of the slurry) may have favoured anaerobic conditions; bacteria degraded the fresh slurry, thus increasing the carbon emissions (Loyon et al., 2004). From November, the outside temperature is usually below 10°C. Yet emissions of CH<sub>4</sub> and CO<sub>2</sub> from a slurry pit are clearly influenced by the temperature of the slurry (Husted, 1994). This rather low outside temperature may therefore have inhibited the decomposition of the carbon in the fresh slurry by methanogenic bacteria.

In field conditions, the intervention of numerous indissociable factors which act differently from one another according to the season, and of the storage duration, make the interpretation of emissions difficult. However to obtain the time-course of emissions in field conditions for pits regularly filled over several months is indispensable in order to be in a position to reconstruct the emission factors from periodic measurements.

## CONCLUSION

This experiment show the importance of the measurement method used to estimate gaseous emissions from stored pig slurry. By comparing the gaseous emissions measured from the total losses estimated from the slurry mass balances, the 46L dynamic floating chambers with an air speed of 0.01 m/s does not seem to be appropriate. Their air speed, which is below the wind speed applicable to the surface of uncovered slurry, partly explains the results obtained for NH<sub>3</sub> and especially CH<sub>4</sub>. Another error is due to the fact that chambers only cover a small part of the stored slurry surface. Used in a fixed position, it cannot take account of possible spatial variability in



gaseous emissions. Finally, the surface of slurry covered by chamber may develop differently from that of an uncovered one, depending on whether or not a crust forms, and thus modify the emissions under the dynamic chamber. It is therefore necessary to consider new measurement systems which are still simple to apply on livestock farms and which make it possible to measure gaseous emissions representative of those which occur over the entire slurry surface.

During the 5 months of storage in the pit, the variability of the gaseous emissions appear to be dependent on the stored volume, which is indissociable from the storage duration and the temperature variations. It seems necessary to ascertain the dynamics of emissions for different storage configurations and different storage periods (seasonal effect) to be able to identify the best period or periods for periodic measurements intended to measure emissions factors.

## REFERENCES

1. Balsari, P., G. Airoidi, E. Dinuccio and F. Gioelli. 2007. Ammonia emissions from farmyard manure heaps and slurry stores : effect of environmental conditions and measuring methods. *Biosystems Engineering* 97 : 456-463.
2. Gac, A., F. Béline, T. Bioteau and K. Maguet. 2007. A French inventory of gaseous emissions (CH<sub>4</sub>, N<sub>2</sub>O, NH<sub>3</sub>) from livestock manure management using a mass-flow approach. *Livestock Science* 112 : 252-260.
3. Husted, S. 1994. Seasonal-variation in methane emission from stored slurry and solid manures. *Journal of environmental quality* 23(3) : 585-592.
4. Levasseur, P. 2005. Composition des effluents porcins et de leur co-produits de traitement : quantités produites. ITP.
5. Loyon, L., F. Guiziou, S. Picard and P. Saint-Cast. 2007. Réduction des émissions d'ammoniac au cours du stockage du lisier porcin : évaluation grandeur réelle d'une couverture de balles en polystyrène. *Journées Recherche Porcine* 39 : 49-54.
6. Loyon, L., F. Guiziou and F. Béline. 2004. Evaluation des émissions gazeuse (NH<sub>3</sub>, N<sub>2</sub>O, CH<sub>4</sub> et N<sub>2</sub>O) d'une filière de traitement biologique aérobie de lisier de porc : résultats préliminaires. *Journées Recherche Porcine* 36 : 71-76.
7. Moller, H.B., S.G. Sommer and B.K. Ahring. 2004. Biological degradation and greenhouse gas emissions during pre-storage of liquid animal manure. *J. Environ. Qual.* 33 : 27-36.
8. Peu, P., F. Béline and J. Martinez. 1999. A Floating chamber for estimating nitrous oxide emissions from farm scale treatment units for livestock wastes. *J. Agric. Engng Res.* 73 : 101-104.
9. Safley L.M. and P.W. Westerman. 1988. Biogas production from anaerobic lagoons. *Biological Wastes.* 23 : 181-193.
10. Sebatcher, D.I., R.C. Harriss and K.B. Bartlett. 1983. Methane flux across the air-water interface : air velocity effects. *Tellus. Ser. B.* 35 : 103-109.
11. Sommer, S.G., B.T. Christensen, N.E. Nielsen and J.K. Schjorring. 1993. Ammonia volatilization during storage of cattle and pig slurry : effect of surface cover. *Journal of agricultural Science* 121 : 63-71.
12. Sommer, S.G., S.O. Pertersen, P. Sorensen, H.D. Poulsen and H.B. Moller. 2007. Methane and carbon dioxide emissions and nitrogen turnover during liquid manure storage. *Nutr. Cycl. Agroecosyst.* 78 : 27-36.
13. Steed J. and A.G. Hashimoto. 1994. Methane emissions from typical manure management systems. *Bioresour Technol.* 50 : 123-130.