

## Sensorial analysis of pig barns odour emissions

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As consequence of the actual awareness of pollution effects on life quality, people disposition to accept what in the past was identified as the “*unavoidable price of the progress*” is getting lower and lower so that it often happens that the supposed annoyance caused by odor emissions can raise such an opposition from residents that it is more and more difficult to locate or expand livestock farms. Chemical methodologies (e.g. Gas Chromatography and/or Mass Spectrometry), despite being extremely useful for air quality analysis, on the other hand give results not completely fulfilling the need of information caused by human perception of odours, in particular when these are generated by organic matter degradation processes (waste water plants, waste disposals, livestock farms, etc.). In this communication we present the results of one comparison of pig farm odour emissions: odour concentration was determined by dynamic olfactometry according to EN13725:2003 provision while odour characterization was executed with one sensor array. As far as odour concentration is concerned, the farrowing barn recorded the highest odour emission rate (78 OU/s/animal) followed by finishing (59 and 50 OU/s/animal), weaning (from 6 to 9 OU/s/animal) and fattening (4 OU/s/animal). With reference to slurry storages, odour emissions from the undigested one ranged from 74 to 77 OU/s/m<sup>2</sup> while odour emissions from the anaerobically digested one ranged between 0.09 and 2.76 OU/s/m<sup>2</sup>. Principal component analysis carried out on sensor array output was able to discriminate among all the considered sources and the source classification carried out on sensors’ output by Linear Discriminant Analysis (LDA) exhibit 95.9 % correct assignation and 95.6% correct prediction. These results on one hand confirm the importance of anaerobic digestion for odour emission abatement and, on the other, show the usefulness of e-nose approach with reference to agriculture odour emission monitoring.

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### 1. Introduction

Odours are composed by several different compounds but despite this, because of the “loss of identity” of individual odorants in mixtures, they are usually perceived by

humans as if they were composed by one compound only (Laing et al., 1994). Nowadays, the increasing awareness of pollution effects on life quality is lowering people's disposition to accept what in the past was borne as the "*unavoidable price of progress*", so that the interest in evaluating the odour impact of various industrial and agricultural enterprises is increasing. The odorous component of atmospheric emissions is not, in most cases, a threat to public health since it is due to substances whose concentration level is far below the threshold limit value (TLV) fixed by health authorities (American Conference of Governmental Industrial Hygienists, 1991). Nevertheless, it often happens that the annoyance caused by such emissions is able to raise such an opposition from the residents that it is more and more difficult to locate or expand livestock farms.

Chemical methodologies (e.g. Gas Chromatography and/or Mass Spectrometry), despite being very useful for air quality analysis, on the other hand give results which do not completely fulfil the need of information about human perception of odours in particular when they are generated by organic matter degradation processes (waste water plants, waste disposals, livestock farms, etc.).

At the moment the most appropriate odour measuring technique is dynamic olfactometry, which is based on direct measurement of odour intensity by means of one panel of qualified assessors (CEN, 2003), which has the advantages of being standardized and giving the right human response: according to Walker (2001) people are surprisingly stable over time in terms of odour potency in response to precisely controlled chemical concentrations and the method has been proven of being adequately reliable in case of multiple similar odour sources, in particular if coupled with odour dispersion modelling (Sironi et al., 2010). On the other hand, this methodology has the disadvantage of being quite complex, time consuming, labour intensive and expensive (Stuetz et al., 2001).

Therefore, the development of rapid and low cost methods for qualitative and quantitative determination of air polluting compounds is today of great interest for environmental protection agencies and laboratories.

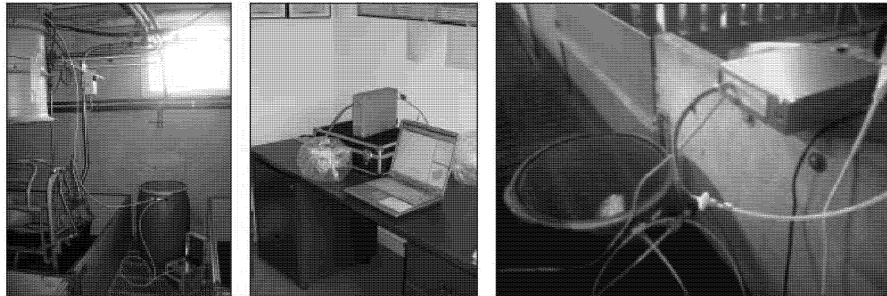
One of the most promising directions for the development of innovative analytical method is the use of electrochemical methods whose speed and on line capabilities, according to Di Francesco et al. (2001), can meet the trends of automation and continuous processing required by modern agriculture. Such methods imply the use of devices consisting of chemical sensor arrays coupled with an appropriate pattern recognition system capable of extracting information from complex signals: the so called "electronic noses" whose importance in headspace analysis of liquid or solid samples (mainly food samples) is nowadays proven (Riva and Mannino, 2004; Labreche et al., 2005; Patrick et al., 2003; Trihaas et al., 2005; Cosio et al., 2006; Falchero et al., 2009) while, in case of environmental monitoring, their application may have some limits in case of similar odours coming from different places or taken in different time periods (Nimmermark, 2001).

In this paper, the performances of the sensor arrays were compared and elaborated together with the results of dynamic olfactometry. The information obtained was treated by pattern recognition techniques such as principal component analysis (PCA) and linear discriminant analysis (LDA). In particular, the study focused the monitoring of

the odour emitted by one farrowing barn by means of both the e-nose and dynamic olfactometry.

## 2. Material and Methods

Odour samples were taken in accordance with to the “lung principle technique” (figure 1, on the left), afterwards odour concentration of the samples was determined by dynamic olfactometry within 24 hours of the sampling using an olfactometer “Olfaktomat n6” (P.R.A. Odournet B. V. - Amsterdam, NL) and according to the EN 13725 protocol (CEN, 2003).



*Figure 1: particular of the air sampling carried out in the farrowing barn (on the left), of the subsequent analysis (in the centre) and of the continuous monitoring (on the right) by means of the e-nose.*

All the monitored pens were provided with mechanical ventilation by means of extraction chimneys which were used as sampling points.

After olfactometry, carried out according to the forced choice method, odour characterization analyses were performed with one portable electronic nose (PEN 2): the system was from Airsense Analytics Inc. (Germany). PEN 2 consists of one sampling apparatus, one detector unit containing the array of sensors and one pattern recognition software (Win Muster v.3.0) for data recording.

The sensor array is composed of 10 metal oxide semiconductor (MOS) sensors which translate changes in the concentration of gaseous chemical species into electrical signals (Yuwono et al., 2004) : MOS 1 (aromatic), MOS 2 (broadrange), MOS 3 (aromatic), MOS 4 (hydrogen), MOS 5 (arom-aliph), MOS 6 (broadmethane), MOS 7 (sulphur-organic), MOS 8 (broad-alcohol), MOS 9 (sulph-chlor), MOS 10 (methane-aliph). The software records the variations occurring in the ratio ( $G/G_0$ ) between the conductance of each sensor,  $G$  ( $\Omega^{-1}$ ), at each second of measurement and the reference,  $G_0$  ( $\Omega^{-1}$ ), which is the conductance that the sensor shows when clean charcoal-filtered air flows the measurement chamber. Odour samples were taken from the different wards, all equipped with forced ventilation in extraction.

- **Farrowing:** the pen was equipped with fully-slatted floor whose slats were made of plastic coated metal. The slurry is stored under the slatted floor in a pit 75 cm deep and it is removed at the end of each lactating period.

- Weaning: the pen was equipped with fully-slatted floor whose slats were made of plastic coated metal. Boxes were equipped with automated feed distribution system giving animals dry feed.
- Fattening: the pen was equipped with fully slatted floor with concrete slats. One automated feed distribution system giving animals liquid feed.
- Finishing: one pen (“A”) is fully slatted and has no physical separation of the lying, eating and dunging areas. Windows allow daylight in and electrical light is used. In this pen, vacuum system for manure removal was applied and the pit is emptied at the end of each cycle. In the same farm, another pen (“B”) with fully slatted floor and mechanical ventilation system was sampled, but in this case manure is trodden through and urine runs off through urine/liquid overflowing pit (deep pit).
- Clean Air: one sample of “clean country air” was taken windward from the farm and far both from any possible livestock odour source (e.g. manure spread).

Besides emissions from livestock structures we also sampled emissions from manure and digestate storages to collect data about emissions from this kind of structures. Sampling from these sources was carried out by means of one dynamic chamber (APAT, 2005). After olfactometry (which was carried out within 24 hours from the sampling) the same replicates were analysed with the e-nose (measurement time of 300 s flushing time of 180 s). The pattern recognition techniques used in this work were Principal component analysis (PCA) and Linear Discriminant Analysis (LDA) provided with the SPSS 13.0 for Windows® statistical package.

### 3. Results

Results of odour emission monitoring are subsequently displayed in table 1. It can be noticed that there is high variability within odour concentrations and the related odour emission factors. These were completely expected as they largely depend on many factors. The wards which recorded the highest emission factors are “Delivery” and “Fattening”: probably the reason of this can be ascribed to the particular substance use in the former ward to disinfect the indoor environment after sows transfer while, in the latter, it is probably due both to slurry management and to animal size (they were about to reach the end of the production cycle). With reference storages the table clearly shows what high odour abatement can be reached by installing anaerobic digestion units. These results confirm those obtained by Immovilli et al. (2009) who reached found average pig slurry odour abatements of about 64% and with the suggestions given by Pabon Pereira (2009) at the end of his research.

Results of PCA are summarized in figure 3 representing the “score plot” where all the considered odour sources are well discriminated. As a matter of fact, on the first PC we can notice that clean air, taken as control, is displayed clearly far from the other sources. Along the 2<sup>nd</sup> PC it’s interesting noticing that odour from weaning and fattening (deep pit) wards are significantly different from all the other sources.

Table 1: odour concentration of the collected samples together with emission factors

Odour source	Slurry Management	Ventilation	OU/s/animal Min – max	OU/s/animal average
Farrowing	Vacuum System	Mechanical	68 – 117	78
Fattening	Vacuum system	Mechanical	3 – 7	5
Weaning	Vacuum System	Mechanical	2.8 – 12.8	6
	Deep pit	Mechanical	5.0 – 27.3	9
Finishing	Deep pit	Mechanical	38 – 65	50
	Vacuum System	Mechanical	49.7 – 71	59
Storages			OU/s/m <sup>2</sup> Min - Max	OU/s/m <sup>2</sup>
Slurry			74 – 77	76
Digestate			0.09 – 2.76	1.23

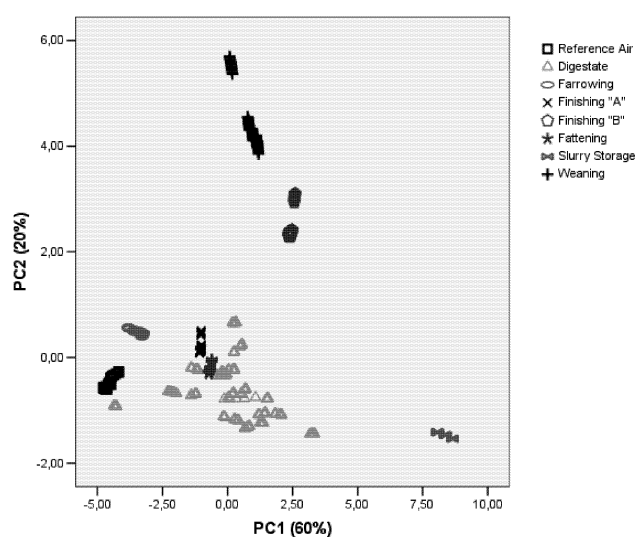


Figure 2: “score plot” obtained by PCA of e-nose sensor’s signals

The source classification carried out on sensors’ output by Linear Discriminant Analysis (LDA) exhibit 95.9 % correct assignation and 95.6% correct prediction after leave-one-out cross validation with LDF1 and LDF2 accounting respectively for 74.2% and 17.5% of explained variance. These results on one hand confirm the importance of anaerobic digestion for odour emission abatement and, on the other, show the usefulness of e-nose approach with reference to agriculture odour emission monitoring

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