



An Alternative Approach of the E-Nose Training Phase in Odour Impact Assessment

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Odour emissions are causing serious nuisance for the population, especially in the surrounding of waste water treatment plants (WWTP) and solid waste treatment plants. Extended exposure to odours generate undesirable reactions ranging from emotional stresses such as unease, discomfort, headaches, or depression to physical symptoms. Odour emission characterization is currently discussed in international literature for opportune implementation. Measurement of emissions can be achieved using different methods (analytical, sensorial and/or senso-instrumental) that have different advantages and problems. Among these techniques, there is a growing interest towards the environmental applications of electronic noses. Electronic nose is the only technique that allows continuous monitoring of odours. However, at present there are several limitations affecting the application of electronic nose in the environmental sector.

The study investigates the electronic nose potentialities in the environmental sector. Scope of this research activity is to investigate an alternative method to build training data set necessary to distinguish different odour sources generated by solid waste treatment facilities through electronic nose application. The proposed methodology is based on the straightforward application of the electronic nose directly in field with the aim to reduce the time to build the complete data set.

Results highlight the great efficiency of the proposed approach to reduce the time to build the complete data set, to maximize the electronic nose capability of operating a qualitative classification of odour sources.

1. Introduction

Offensive odours from WWTP and solid waste treatment facilities are a frequent cause for complaints by the community and may cause environmental nuisance (Stuetz et al., 2001). Odours generate a variety of undesirable reactions in people, from annoyance to documented health effects (Zarra et al., 2009a). In communities exposed to odorous emissions, even though there may be no immediately apparent diseases or infirmities, it is clear that physical, as well as mental, wellness is not promoted (Gostelow, 2001; Zarra et al, 2008; Zarra et al., 2009b; Zarra et al., 2010). Currently, available techniques for odour characterisation and quantification are of three different kinds (Gostelow et al., 2001): analytical, sensorial and sensorial – instrumental that have different advantages and problems. Among the senso-instrumental techniques there is a growing interest towards the environmental applications of electronic noses and many studies have been done. Electronic nose is the only technique that allows continuous monitoring of odours (Persaud and Dodd, 1982). The electronic nose has the best potentialities to answer to the expectations of the various actors of the environmental

environmental sector are associated with the properties of chemical sensors (Barsan et al., 2007), the signal processing performances, and the real operating conditions of the environmental field (Romain et al., 2009). The monitoring of environmental odours in the field remains challenging (Nicolas et al., 2004). The classification of the odours is based on the comparison of the e-nose signals with a database of patterns acquired by the instrument in a previous training phase. The training of the electronic nose is a very important phase (Capelli et al., 2008); this phase is usually made up by different steps summarized below: the identification of the principal odour sources of the plant to be monitored; the collection of representative gas samples in correspondence of these odour sources; the preparation of a set of odorous gas samples to be analyzed by electronic nose; the instrumental analysis of these samples; the data processing, evaluation and selection of the acquired data for the creation of qualitative and/or quantitative model. In order to characterize the odour emissions relevant the plant, gaseous samples are collected in the field at the emission source and analyzed using the electronic nose in laboratory in a controlled indoor environment.

The scope of this study is to investigate an innovative alternative method to build training data set necessary to distinguish different odour sources generated by solid waste treatment facilities through electronic nose application. The proposed methodology is based on the straightforward application of the electronic nose directly in field. The e-nose is constantly moved over the investigated area for recording in real time the data trends to use for developing odour qualitative model with the aim to optimize the classical method in terms of time and costs and to maximize the electronic nose capability.

2. Material and methods

2.1 Odour monitoring

Research study is carried out in a full-scale waste treatment plant located in the rural area of Habay in Wallonia (South of Belgium). The waste treatment plant consists of a municipal solid waste reception unit, an area dedicated to the composting process of windrows of green waste, a landfill area, a garbage acceptance point where customers can get rid of their waste, such as textile, paper and cardboard and plastic bottles. In Figure 1 are showed both the two odour emission sources investigated (P1 – P2); the dotted line represents the defined pattern to move the portable e-nose across the plant.



Figure 1: Identification of odour sources of the waste treatment plant investigated and e-nose pattern

The portable e-nose has been constantly moved over the investigated area to record data trends in real time. The monitoring activity started at the odour source, whereas subsequent measurements have been carried out, using the portable e-nose device, at increasing distance from the odour source. The measurements were made on the field after 30 min, needed to achieve a perfect stabilization of sensor signals. At the same time of the e-nose measurements, the dedicated operator kept close to the instrumentation as to write down all his personal feeling in terms of odour as well as every remarkable event happening in the site together with the time of their appearance.

Odour monitoring was carried out during 6 campaign measurements from May to June 2011.

2.2 Electronic nose

The portable electronic nose consists in a battery powered sensor array and a PC board, with a small keyboard and a display. The system is equipped with six metal oxide gas sensors commercially available and differing in selectivity and sensitivity (Figaro®) (TGS822, TGS2620, TGS2180, TGS842, TGS2610, TGS880). They are placed uniformly in an optimized small sensor chamber to allow a fast change of the air volume at the working flow rate (200 mL/min). A temperature sensor and a humidity sensor are also placed inside the sensor chamber. So, the humidity rate and the temperature of the studied atmosphere are recorded during the measurements. To minimize the influence of these two factors on the gas sensor responses, their value are taken into account by the data processing.

A specific software controls the hardware and allows the acquisition of the sensor signals. The raw electrical conductances of the sensors are recorded each 30 s in the local memory. Afterwards, they are downloaded to be off-line processed by statistical and mathematical tools (Statistica® and Matlab®). The features considered for the data processing are the raw sensor electrical conductances (S), normalized by the square root of the sum of all the sensors conductance values squared without any reference to a base line. The TGS2180's sensor is very sensitive to the water vapour and it is considered only for humidity correction and not to develop odour classification model.

2.3 Data analysis

In this study, both supervised (Linear Discriminant Analysis - LDA) and unsupervised (Principal Component Analysis - PCA) processing techniques are used to develop odour qualitative model for the waste treatment plant of Habay-la-Neuve investigated.

Principal component analysis (PCA) is a linear, unsupervised pattern-recognition technique very useful for analyzing, classifying, and reducing the dimensionality of numerical datasets in multivariate problems. PCA is often used for visual inspection of the evolution of observations over short time periods (Bourgeois W. et al., 2003).

Linear Discriminant Analysis (LDA) is one of the mostly used classification procedure which maximizes the variance between categories and minimizes the variance within categories (Lachlan, 1992).

The pre-processing work and data analysis was conducted using ad hoc softwares (Statistica® and Matlab®).

3. Results and discussion

Figure 2 shows the trend of the e-nose sensor signals as directly used in field versus time. The figure also shows the evolution of the response in terms of conductance (S) of the 6 TGS sensors during a measurement (duration time: 3 h). Based on the operator feedback that has been recorded simultaneously with the use of electronic nose, different time intervals have been identified (as determined on the Figure 2), in which the electronic nose has been exposed to different gas mixtures: odourless air - waste - compost.

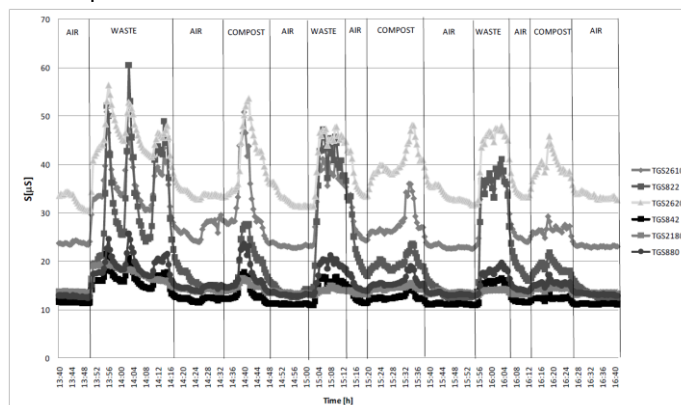


Figure 2: Trend of sensor signals of the e-nose in the field

The most interesting results can be obtained through the correlation of the instrument information along with the observations of the operator nose. Some of these results are summarized as it follows:

- the main peaks of the odour class "waste" have been recorded when the trucks emptied their transported volume into the waste pit;
- the higher peaks of the odour class "compost" have been recorded at the time of the mechanical operations of the green waste windrows turning.

The PCA score plot of 301 observations recorded every 30 s for three continuous hour for the first of May is presented in Figure 3 in the plane of the two first components (explaining 90.88 % of the total variance). First, PCA has been carried out on the whole data set, the score plot allows to highlight the time evolution of the different odour events.

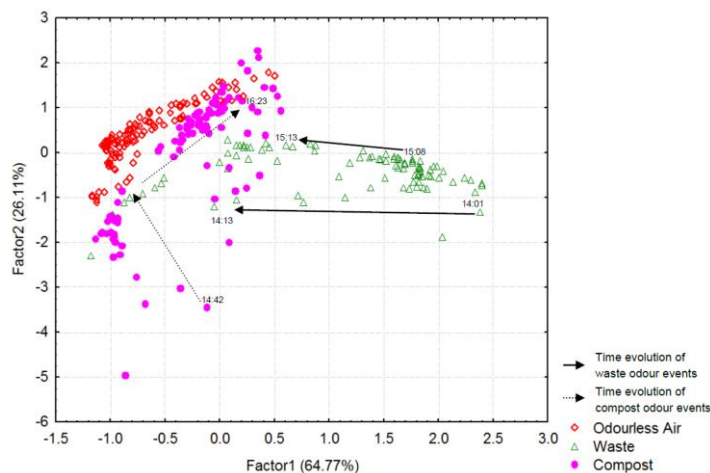


Figure 3: Score plot of a PCA showing the time evolution of different odour events

In Figure 3 it is shown that the e-nose reports variations in terms of odour concentration, as the point at 14:01 was monitored at the time waste trucks were discharging solid waste in the pit; on the opposite, at 14:13 the e-nose operator was moving away from the odour source. Moving from 14:01 to 14:13, Factor 1 value changed.

We can observe some lack of definition between some observations of the odourless air group and the compost ones. Explanation of this phenomenon might be given as it follows: the points identified as "compost" on the upper part of the score plot are those for which the operator noted a "light odour". Similarly, "waste" detections at low concentrations highlight a lack of definition in that the sampling did not occur at the source, but instead at a certain distance from the emission point. This has, in turn, led to a bad correlation of these points with the whole "waste" group, that, on the overall, is well defined on the score plot. As to consider all the previously described elements, four groups have been introduced: the first group "waste" represents all the data where a strong odour has been recorded straight on the odour source; the second group "waste 1", consists in all the points where a similar odour has been monitored, even though its intensity is lower; the third group "compost" represents all the inspected points where the e-nose operator correlates the odour with a compost matrix; the fourth group, "odourless", is made up of all the points over the plant where the operator cannot detect any odour at all. These new rules of classification have been applied on a new data set. Only the data with a perfect identification of the class by the operator and after a separation in "waste" and "waste 1" are considered. So the data are non-contiguous in time: the observations concern several short intervals of time covering 5 odour campaign measurement for a duration time of 2 hour for every analysis. At the end, 366 observations are retained. These observations were recorded each 1 min for the different sources: 154 for the background air, 87 for the group "waste", 46 for the group "waste 1" and 79 for the group "compost".

The PCA score plot of these is presented in Figure 4 in the plane of the two first components (explaining 91.1 % of the total variance).

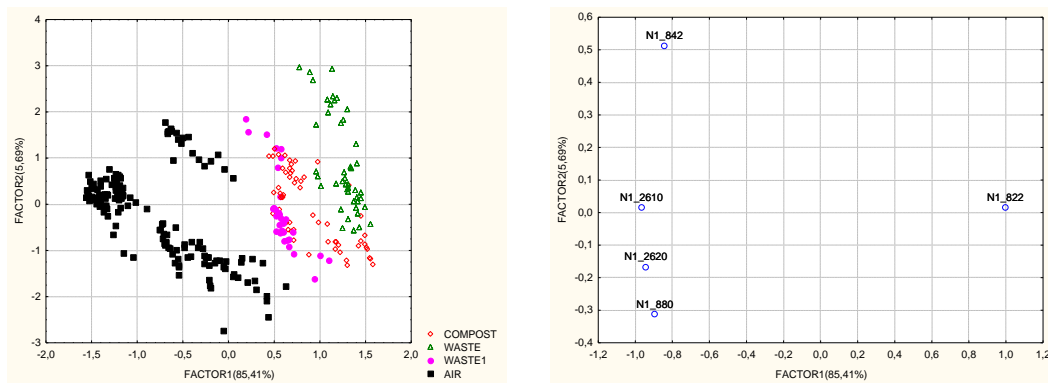


Figure 4: Score plot (left) and loading plot (right) in the plane of the two first components of a PCA

The PCA score plot highlights that there is a good separation between the group “odour” (compost, waste and waste1) and the odourless air. The separation between the three odours is however not always obvious. The PCA loading plot is presented in Figure 4. According to the factor1 trend, the sensor TGS822 is rather correlated with the observations of group “odour”, while TGS 842, 880, 2610, 2620 are better associated with group “odourless”. However, to ensure a good separation among the 4 investigated groups, it is necessary to consider all the sensors as each of them plays a significant role during the operation of separation of all the different groups. However, these preliminary results encourage to develop a classification model with this innovative alternative method.

So, in a second step, LDA is performed on the same observations. Figure 5 shows the results of a discriminant function analysis (LDA). The figure shows the score plot in the plane of the two first roots of the corresponding canonical analysis. To validate the classification performance of the model, it was calibrated with only 70 % of the observations (chosen at random) and the remaining 30 % were set aside for validation purpose. The a priori classification probabilities are set proportional to the size of the four different groups. Table 1 shows the percentage of correct classification for each odour class.

Table 1: Classification result for the 4 odour classes investigated.

Odour class	% correct classification
Waste	98
Waste 1	95
Compost	96
Odourless	100

The classification of each observation is carried out on the basis of the Mahalanobis distance between the observation and the centroid of each group.

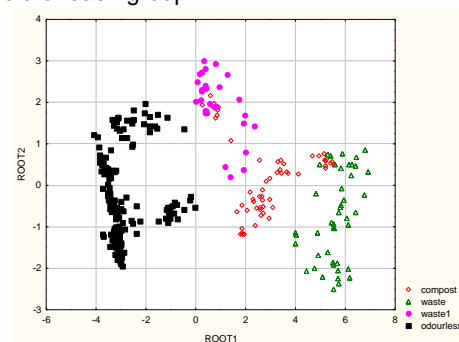


Figure 5: Score plot in the plane of the two first roots of LDA

This plot shows a good clustering of the observations among the sources and confirms the good classification results. It indicates that the sensors array is able to separate the 4 classes of observations and can be used for the odour monitoring of the odours of the investigated waste treatment site. In this study, the drift was checked and compensated with measurements of a standard gas. However, the study was conducted during only one month and therefore, considering this short period, the drift was not significant and there is no related influence over the results of the model. These rather good results are obtained after a simple and fast calibration method directly on the field and not after sampling and measurement in a laboratory.

4. Conclusion

The presented results constitute an important step towards reliable classification for odour continuous measurement in the environmental sector. The results show the great efficiency of the proposed approach of field investigation to reduce the time needed to build the complete data set and to maximize the electronic nose capability of operating a qualitative classification of odour sources. Further enhancements of the e-nose development consist in its application in areas where people complain about odour annoyance. This will lead to a better comprehension of its potentiality in terms of reliability and accuracy.

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