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The electronic nose as a warning device of the odour emergence in a compost hall

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Abstract

A self-made electronic nose consisting in a sensor array of six commercial tin oxide gas sensors is used to monitor the odour emission from a compost facility. Supervised data processing tools, such as discriminant analysis, are able to recognize, in real time, the odour of compost with respect to other possible sources in the hall. The paper shows that with unsupervised methods, such as principal component analysis, it is not essential to identify all the possible odour sources during the learning phase. The closeness to the compost group centroid could be used as an indicator of the compost odour level. Alternatively, by a suitable calibration from olfactory measurements, the signals generated by the sensor array can be used to estimate the odour emission rate from the compost hall. Such real time monitoring should allow to assess and to anticipate the annoyance in the surrounding.

Keywords: Electronic nose; Compost odour; Environment; Odour annoyance

1. Introduction

The environmental monitoring is a very promising field of applications for the electronic nose [1]. The objective is to assess the odour annoyance generated by a plant, as an indicator of life quality. This paper discusses the ability of the electronic nose to monitor continuously the emission of the odour generated in a compost hall. The aim is to supply a warning signal to the compost manager when the compost odour is identified and when its level exceeds a given threshold.

The results of the monitoring of the gas emission from a compost pile, using an electronic nose at the outlet of an emission chamber, were already presented [2]. The aim of that specific study was chiefly to provide the manager of the compost facility with a fast method for on-site detection of stress events, like anaerobic conditions in the windrow. The present study concerns the same compost area, but, this time, the electronic nose is placed in the middle of the compost hall and measures the odour in the ambient air. The concerned odour results from the mixing of all the emissions in the compost hall: compost itself, exhaust gas from the machines or neutralising agents. The system must be able to distinguish the compost odour among all those possible sources and to supply a warning signal when it exceeds the annoyance threshold. The monitoring must be carried out at the emission level, but not just above the source. It is more typical of the global odour prevailing in the compost hall and can be used to inform the manager of a possible odour annoyance for the neighbouring.

Some scientific papers concern the monitoring of real-life odours. For instance, Persaud et al. [3] use a hybrid sensor array to continuously monitor the environment of the MIR space station over a 6 months period. The good correlations between the sensor responses and in situ conventional NO_x and CO instruments measurements demonstrates the potential of the device in term of sensor performance and selectivity under real operating conditions. The e-nose is also used to monitor the water quality [4] by analysing the headspace above samples collected in the effluents.

But the monitoring of environmental odours in the field remains challenging. Firstly, the construction of a regression or classification model requires not only the collection of a sufficient amount of observations for the sensor signals but also the determination of the quality of the odour source or an information about the odour level. The sensor signals are generated

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by the electronic nose as an autonomous instrument, but the collection of the additional variables needs the continuous presence of a human operator, during a long period. That is a severe constraint for field measurements, not only during the model construction phase, but still during the further validation and test phases. Secondly, the end user would like to have at his disposal a simple function allowing him to clearly evaluate the membership of a given observation to a given odour group or to assess the annoyance level, in order to quickly make a decision. Different regression techniques can be proposed to achieve that goal [5]. This paper proposes some possible issues to create an "odour annoyance index", if possible, without having to identify all the possible types of odours in the field.

2. Material and methods

The self-made electronic nose consists in a sensor array and a PC board, with a small keyboard and a display. Six commercial metal oxide sensors (Figaro®) are placed in a rectangular 160 cm^3 metallic chamber. The sensors were selected on the basis of some operating criteria among the range of sensors proposed by the Japanese manufacturer Figaro and chiefly among the 12 SnO_2 sensors used in previous studies [6]. Some sensors were eliminated for their too low sensitivity towards compost emissions: relative $\Delta R/R_0$ resistance variations near zero caused the removal of two sensors. Two ones were eliminated because of there too long recovery time, their poor stability or their too large signal to noise ratio and an additional one for its redundancy with TGS842. Finally the selected sensors were those for which the contribution to the discrimination power between compost and background air was the highest. When two sensors were available for the same purpose, one from the "800" series and the other one from the "2000" series, this last one was preferred for its low electrical consumption. The six selected sensors are listed in Table 1.

Though TGS2180's response to compost emission was low, this sensor was kept if a signal for humidity correction was needed.

The chamber temperature is kept at 60 C by a heating resistor and natural cooling, thanks to a suitable control system. Relative humidity of the sensor chamber is also recorded. The ambient air is sucked in though a teflon tubing with a flow rate of 200 ml/min thanks to a small pump controlled by the computer code. Data are recorded in the local memory and downloaded in an external computer to be off-line processed by statistical and mathematical tools (Statistica and Matlab). The features considered for the data processing are the normalized raw sensor electrical resistances, without any reference to a base line (or $R/\sqrt{\sum R_i^2}$, where R and R_i are the raw resistance values) or just the resistances R for the two last figures of the paper.

Table 1
The six selected Figaro sensors and their sensitivity to different vapours

Sensor	Sensitivity to vapours
TGS822	Organic solvents (ethanol, benzene, acetone, . . .)
TGS880	Volatiles vapour from food (alcohols)
TGS842	Natural gas, methane
TGS2610	Propane, butane
TGS2620	Hydrogen, alcohols, organic solvents,
TGS2180	Water

The compost deposit area of Habay, in Belgium, is studied. It is situated under a shelter. It receives two types of material: either crushed municipal waste, containing an organic fraction, or pure organic waste, resulting from a selective sorting. The aeration is achieved by turning the pile about twice a week. The odour emission from the compost varies with time and with the type of handling. Some trucks or machines also emit exhaust gases and an odour neutralising product is sometimes sprayed in the hall.

During the learning phase, two types of approaches were used.

The first one implies prior identification of the four possible ambiences prevailing in the compost hall: odourless air, compost, neutralizing product or exhaust gas from the engines. Measurements by the sensor array are made either by putting the air intake near the emission source, or by sampling in Tedlar bags and subsequent analysis.

For each ambience presentation, all the recorded resistance values, with a sampling rate of 1 record every 3 s, are considered for the model calibration. Hence, this approach favours the learning of the electronic nose with "pure emissions", directly at the source level.

The second approach consists simply in placing the instrument in the middle of the compost hall and to continuously record the sensor signals. The nose of the operator remains close to the air uptake of the instrument and each odour personal feeling as well as all events happening in the compost area are noted, together with the time of their appearance. The resulting file consists in the six sensors resistances facing the type of event for each 3 s observation. It can be used either to validate the model calibrated with pure emissions or to calibrate a new model.

Such monitoring aims at showing the interest of considering as global odour signal the pattern of a sensor array rather than the response of one single sensor. The reason of the rise of the sensor signals may indeed be the compost odour increase, but also the increase of any other gas emission or a sudden change in ambient temperature or humidity. The identification of the cause of the increase of the sensor signal is essential.

Parallel olfactometric measurements are carried out. From time to time, during the electronic nose monitoring, the gaseous emissions of the ambient air is sampled in a 60 l-Tedlar bag placed in a sealed-barrel maintained under negative pressure by a vacuum pump. The bag is directed to the Certech olfactometry laboratory (Seneffe, Belgium) where the odour of the tainted air is evaluated using human panels (standard EN13725). The odour evaluation is made as soon as possible after the sampling.

3. Results

The first approach, considering sequential measurements, may lead to the classification of the observations according to the four identified sources of odour. Such common result is pro-