Integration of different electronic nose technologies in recognition of odor sources in a solid waste composting plant

P. Giungato[1,*], P. Barbieri[2], F. Lasigna[3],
G. Ventrella[1], S. C. Briguglio[2], A. Demarinis Liotile[1],
E. Tamborra[1], G. de Gennaro[1]

[1] *Chemistry Department, University of Bari "Aldo Moro", Via Orabona, 4 - IT-70125 Bari, Italy; pasquale.giungato@uniba.it; gianluigi.degennaro@uniba.it; annamaria.demarinis@uniba.it; gianrocco_ventrella@yahoo.it; eliana.tamb@live.it*
[2] *Chemical and Pharmaceutical Science Department, University of Trieste, via Giorgeri 1, IT-34127 Trieste, Italy; barbierp@units.it;saracarmela.briguglio@phd.units.it*
[3] *Italcave SpA, via per Statte, 6000 - 74123 Taranto, Italy; tecnici.discarica@italcave.it*
[*] *Corresponding author*

Abstract. *Due to the continuous expansion of urban areas, the problem of emissions in the atmosphere of odors from solid industrial waste composting plants, are often cause of dissatisfaction and complaints by the communities surrounding emission sources.*

Characterization of emission sources by electronic noses is becoming a valuable approach in the management of odor emission, as are required high time resolution instrumental approaches and fast intervention on identified critical wastes, by using abatement systems.

In this paper the authors compare complementary technologies: MOSs and polymer/black carbon (Nano Composite Array – NCA) based sensors electronic noses to monitor odors emitted from an industrial solid waste composting plant, in the aim to implement integrated policies for a better management of composting operations.

10 MOS sensors in the PEN3 (Airsense), operating at high temperature and 32 polymer/black carbon (Nano Composite Array – NCA) based sensors in the Cyranose 320 (Sensigent), operating almost at ambient temperature, were tested on samples collected above three odour sources in the composting plant: biogas, sludge and urban waste.

The integrated dataset obtained from measures were explored by Principal Component Analysis and Discriminant Analysis to identify sensor discrimination capabilities, strengths and weaknesses of the technologies used.

The results obtained highlight the advantages of monitoring the composting process with a multi-tech sensor approach, in order to provide complementary information useful to better discriminate the emissions from a waste composting plant.

Keywords. *Electronic nose, MOS, polymer/black carbon, Nano Composite Array, composting plant.*

---

1 Introduction

Due to the continuous expansion of urban areas, the problem of emissions in the atmosphere of odors from industrial and municipal solid industrial waste composting plants, are often cause of dissatisfaction and complaints by the communities surrounding emission sources. The problem of olfactive nuisance is characterized by considerable complexity as any substances that compose the odorous mixture, produce additive, antagonistic or synergistic effect to olfactory perception [1]. Electronic noses, initially developed as instruments capable to mimic the human olfactory system, are limited by their lack of specificity (as they detect both odorous and odorless volatile compounds), lack of efficiency at remotely located sites, and remain promising instruments to monitor the transient odour level near the source so it could serve as input to mathematical dispersion models that can predict odour concentrations at remote locations together with accurate meteorological data [2,3]. In an industrial waste composting plant, the complexity of the system is enhanced by the lack in the homogeneity of the processed wastes, the numerous variables related to meteorological conditions and the particularity of the emitted odorants. Gaseous emissions in composting facilities are typically constituted by nitrogen- based compounds, sulphur-based compounds and a wide group of volatile organic compounds (VOCs) the latter emitted at the early stages of process i.e. at the tipping floors, at the shredder and during the initial forced aeration composting period [4-7]. Dimethyl sulphide (DMS), dimethyl disulphide (DMDS), limonene and α-pinene were the most significant odorous VOCs at a wastewater sludge composting facility; sulphur compounds were attributed to incomplete or insufficient aeration during composting, the terpenes to wood chips used as bulking agent [8]. Microbial activities during the aerobic decomposition of food wastes can produce peak emissions of sulfur compounds as dimethyl disulfide (DMDS), dimethyl sulfide (DMS), methyl 2-propenyl disulfide, carbonyl sulfide, methyl 1- propenyl sulfide and H_2S [9-10]. Recently new sensing technologies are being developed, as the polymer/black carbon (Nano Composite Array – NCA), to improve selectivity of sensors to specific odorous chemicals. In this case each sensor consists of conductive thin films deposited across electrodes on a ceramic substrate. When the film is exposed to a vapor-phase analyte, the polymer matrix acts like a sponge and absorbs it causing an increase in resistance. There is a lack in the scientific literature about comparative measurements of such emission sources with different sensor technologies. In this paper the authors aims to compare these two complementary technologies as Metal Oxide Semiconductors (MOSs) and polymer/black carbon (Nano Composite Array – NCA) based sensors electronic noses, to monitor odors emitted from an industrial solid waste composting plant, in the aim to recognize the emission sources and implementing integrated policies for a better management of composting operations.

2 Material and methods

The industrial waste composting plant is located in the city of Taranto, Apulia, in the south-eastern part of Italy and is operated by Italcave SpA. The electronic noses used were the PEN3 (Airsense), operating at high temperature with an array of 10 MOS sensors and the Cyranose 320 (Sensigent), operating at 42°C, with an array of 32 polymer/black carbon (Nano Composite Array – NCA) based sensors. Three sources were individuated: biogas emitted from wells disconnected to the captation network (referred as *biogas*), a waste having CER 19.12.12 (by-products of mechanical treatment of urban wastes, with no organic fraction, referred as *solid)* and the CER 19.08.05 sludge pressed and dehydrated from treatment of urban wastewater, referred as *sludge*. Samples were placed in a Nalophan 8L bag, with the lung technique, and sniffed by the two electronic noses in a randomized way. The signal of the sensors was the integral of the electrical signal (PEN3) and the relative variation of resistance DR/R_0 (Cyranose 320) during the acquisition time. Five samples of each source were collected and the integrated datasets obtained were explored by Principal Component Analysis and Discriminant Analysis, using R software package (version 3.1.2 - 2014; The R

Foundation for Statistical Computing©) together with devtools, ggbiplot and MASS libraries, in order to identify strengths and weaknesses of the sensor technology [11].

3 Results and discussion

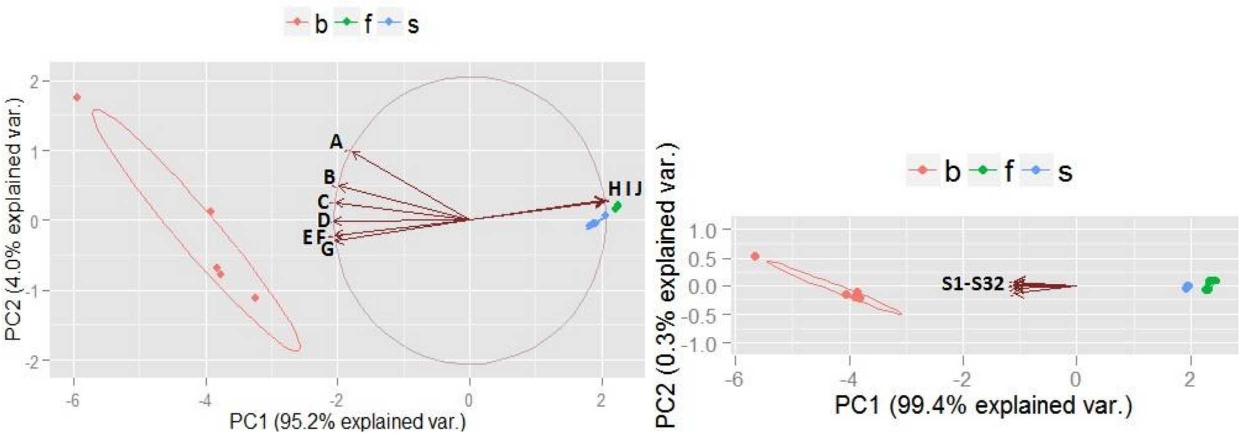

Figure 1. First two principal components of the three sources sensor array signals, using PEN3 Airsense (left) and Cyranose 320 Sensigent (right). Legend: b= *biogas*; s=*solid*; f= *sludge*; A=Broadrange, B=Sulph-chlor, C=Sulphur-organic, D=Broad-methane, E=Methan-aliphatic, F=Broad-methane, G=Hydrogen, H= Aromatic 1, I= Aromatic 3, J= Arom-aliph.

As reported in figure 1 most of the sensors of the PEN3, especially those reported by the producer as sensible to "hydrogen", "methane" and sulphur-containing gases ("sulph-chlor" and "sulphur-organic") points towards biogas scores, whereas "Aromatic 1", "Aromatic 3" and "Arom-aliph" sensors points towards sludge and solid wastes scores, demonstrating higher heterogeneity in response of this MOSs sensor technology. Cyranose 320 sensors (from "S1" to "S32") are collinear and point towards biogas scores, demonstrating higher sensor selectivity response towards these emissions. In table 1 are reported results of Linear Discriminant Analysis and cross validation for the two e-nose sensor arrays, for the combination matrix that can be obtained by integrating 10+32 sensors of both e-noses and processing it as a unique array. To improve array selectivity in this specific application, instead of using too a large array of sensors, in practical terms, a selection of only 6 sensors chosen following the selectivity with the chemicals of the emitting source and its contribution to the principal component (Aromatic, Hydrogen, Broad-methane, Sulphur-organic, belonging to PEN3, S1, S2, belonging to the Cyranose 320) of both e-noses have been tested.

E-nose	Recognition	CV% (k=1)
PEN3	100	86.7
Cyranose 320	100	53.3
PEN3+ Cyranose 320	100	60.0
Selected sensors	100	93.3

Table 1: LDA recognition by modeling set and Cross Validation prediction (k=1) of the two e-noses sensor arrays (PEN3, Cyranose 320), that of the integration (PEN3+ Cyranose 320) and that of the selected six sensors of both e-noses.

4 Conclusions

Two selected commercial gas sensor arrays, with different technologies, MOSs and polymer/black carbon (Nano Composite Array – NCA) have been tested for real-time and on-site detection of malodours in a waste composting plant. Field tests of the two gas sensor arrays have been performed to explore the possibilities of source discrimination. A comparison of the two gas sensing technologies in the electronic noses has been carried out showing the potentialities of the portable gas sensor-system Cyranose 320 in detecting odor nuisance and the discrimination capacity in recognize the origin of the odor of the PEN3 (Airsense). Both the technological approaches were suitable for waste composting plant odor measurements in order to assess the origin of odor nuisance in critical sites. The results demonstrate that arrays of selected low-cost gas sensors may be very useful for air-pollutants monitoring and odor control applications, provided the number of sensor is reduced and the correlation between them is as short as possible: for this reason a combination of both selected MOSs and polymer/black carbon sensors should be preferable, with a selection of most sensible sensor tailored for the specific application. This work represent the first attempt to discriminate such type of sources difficult to sample and consequently with few objects per groups with commercially available e-noses, but further efforts should be done in optimizing source recognition and to select the ri ght array of sensor with tailored technology suitable to the case study.

Acknowledgments. The authors would like to thank Apulia Regions and EU for the financial support to the research activities given by the "Bando Aiuti a Sostegno dei Partenariati Regionali per l'Innovazione Investiamo nel vostro futuro", FESR P.O. 2007-2013 and the Italcave SpA for the in-field support and hosting.

References

[1] Brattoli M., Cisternino E., Dambruoso P. R., de Gennaro G., Giungato P., Mazzone A., Palmisani J., Tutino M. (2013) Gas Chromatography Analysis with Olfactometric Detection (GC-O) as a Useful Methodology for Chemical Characterization of Odorous Compounds, *Sensors* **13**, 16759-16800.

[2] Romain A-C., Delva J., Nicolas J. (2008) Complementary approaches to measure environmental odours emitted by landfill areas, *Sensors and Actuators B* **131**, 18–23.

[3] Nagle H.T., Gutierrez-Osuna R., Kermani B.G., Schiffman S.S., (2003) Environmental monitoring. *Handbook of Machine Olfaction—Electronic Nose Technology*, Wiley–VCH, Weinheim.

[4] Eitzer, B.D. (1995) Emissions of volatile organic chemicals from municipal solid waste composting facilities. *Environmental Science and Technology* **29**, 896– 902.

[5] Clemens J., Cuhls C. (2003). Greenhouse gas emissions from mechanical and biological waste treatment of municipal waste. *Environmental Technology* **24**, 745–754.

[6] Haug, R.T. (1993). *The Practical Handbook of Compost Engineering*. Lewis Publishers, Boca Raton, Florida, USA.

[7] Cadena E., Colón J., Sánchez A., Font X., Artola A. (2009). A methodology to determine gaseous emissions in a composting plant, *Waste Management* **29**, 2799-2807.

[8] Van Durme, G.P., McNamara, B.F., McGinley, C.M. (1992). Bench-scale removal of odor and volatile organic compounds at a composting facility. *Water Environment and Research* **64**, 19–27.

[9] Wu T., Wang X., Li D., Yi Z. (2010). Emission of volatile organic sulfur compounds (VOSCs) during aerobic decomposition of food wastes, *Atmospheric Environment* **44**, 5065-5071.

[10] Kim K.H., Pal R., Ahn J.W., Kim Y.H. (2009). Food decay and offensive odorants: a comparative analysis among three types of food. *Waste Management* **29**, 1265-1273.

[11] Penza, M., Suriano D., Cassano G., Pfister V., Amodio M., Trizio L., Brattoli M., De Gennaro G. (2014). A case-study of microsensors for landfill air-pollution monitoring applications. *Urban Climate*, in press.