CHEMICAL ENGINEERING TRANSACTIONS
VOL. 30, 2012
Guest Editor: Renato Del Rosso

ISBN 978-88-95608-21-1; **ISSN** 1974-9791

A publication of
AIDIC
The Italian Association
of Chemical Engineering
Online at: www.aidic.it/cet

DOI: 10.3303/CET1230034

Odour Impact Assessment by a Multiparametric System (Electronic Noses/CH_4-NMHC Analyser)

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Odour impacts are assessed according to two principal approaches: evaluation and estimation of the pollutant relapse on the territory and monitoring through standard methodologies. In particular, odour monitoring is characterized by a great complexity due principally to the strict association of odour pollution to human perception. The standardized methodology for the determination of odour concentration is represented by an instrumental sensory technique, the dynamic olfactometry, that is affected by some limitations. This methodology provides punctual odour concentration data and it does not allow to perform continuous and field measurements, useful for monitoring the industrial processes causing odour emissions. The need of carrying out a continuous monitoring having been encouraged the use of an odour surrogate monitoring, performed by specific or not specific instruments (chemical analysers or electronic noses). The surrogate measurements employment is based on the fact that the ratio of surrogate concentration to odour units must be relatively constant and known. This paper focuses on the development of a multiparametric system for the evaluation of odour impact caused by an industrial source. The system has been tested during olfactometric monitoring campaigns conducted at the industrial site, coupling the results of electronic noses. The purpose of the research work has been to find an indicator for the odour emissions produced by the examined industrial site, and to correlate it with odour concentrations. This study has allowed to demonstrate the real applicability of not specific instruments to odour continuous monitoring, useful to detect a change of state in operating conditions of industrial processes and control it.

1. Introduction

In the last decade great attention has been paid to the issue of air quality as it directly affects the environmental and human health. Currently, people's awareness of the effects of anthropic activities on the environment rises from the sensorial perception: nowadays olfactory nuisances, coming from various industrial activities, are at the top of the list of air pollution complaints (Yuwono and Lammers, 2004). The odour annoyance evaluation must take into account some complex issues, concerned the strict association of odour pollution to human perception (Freeman, 1991). For this reason, both the monitoring and the evaluation of odour impact relating to the pollutant relapse on the territory cannot be strictly handled by using the conventional approaches employed in the air pollution (Gostelow et al., 2001). In fact, new analytical approaches have been developed for odour monitoring application, such as sensory methods and artificial olfaction systems, in addition to chemical characterization (Stuetz and Frechen, 2001). However, each methodology is not able to provide exhaustive information about a

Please cite this article as: Amodio M., Brattoli M., Dambruoso P., De Gennaro L., De Gennaro G., Demarinis Loiotile A. and Trizio L., 2012, Odour impact assessment by a multiparametric system (electronic noses/ch4-nmhc analyser), Chemical Engineering Transactions, 30, 199-204 DOI: 10.3303/CET1230034

case of olfactory pollution but it is necessary to integrate more methodologies, opportunely selected for the investigated sources. The present paper describes an integrated study conducted in a landfill, considered a source of olfactory annoyance for the residents. The aim of the work has been to consider a multi-parametric system, represented by electronic noses, able to indicate the occurrence of odour events and to correlate them with odour emissions.

2. Materials and methods

2.1 Experimental design

The investigated plant is represented by a landfill for non-hazardous wastes coupled with an uptake biogas plant and energy recovery, located in an industrial area characterized by an intensive anthropic pressure. For better understanding the typical annoyance produced by the landfill odour emissions and for controlling them, it has been necessary to perform a continuous monitoring. The standardized methodology for the determination of odour concentration, the dynamic olfactometry, can provide only punctual data (EN 13725, 2003); for this reason for carrying out a continuous monitoring, in the last years, a great development of specific or not specific instruments having been encouraged (Brattoli et al., 2011). However, their employment is not standardized and therefore their results must be related with the odour concentrations obtained by dynamic olfactometry, in order to be representative of the emissive phenomena.
The experimental design has been planned in order to consider the source properties, the transport meteorological phenomena and the receptors, eventually involved by the industrial activity impact. To this purpose, two commercial electronic noses (PEN3 Airsense Analytics GmbH, Schwerin, Germany) have been installed; one has been placed at the receptor, and the other near the fresh waste disposal area of landfill. The PEN 3 electronic noses are based on ten semiconductor metal oxide sensors, working on temperature range 200 °C -500 °C, properly treated with metal layer (Sn, Pd, Ir or mixtures of these) for being sensible to different classes of volatile compounds. The Table 1 describes the classes of compounds associated to each sensor, as indicated by the instrumental manifacturer:

Table 1: Indication of volatile compounds associated to the ten sensors

Identification number of each sensor	Classes of volatile compounds
1	Aromatic
2	Broadrange
3	Aromatic
4	Hydrogen
5	Aromatic - aliphatic
6	Broad methane
7	Sulphur-organic
8	Broad-alchol
9	Sulphur-chlor
10	Methane-aliphatic

The first step of the work have consisted in the characterization of the sources, represented by the different typologies of wastes, put in landfill. According to the Ronchi Decree (1997) and to the successive European legislative decrees, 2000/532/CE and its subsequent amendments, each type of waste have to be associated to a code (CER, waste disposal code). After having examined the types of wastes in input, the most odorous ones have been selected for characterizing the landfill odour emissions. In particular two waste categories have been considered:

- 19.12.12: “other wastes (including mixtures of materials) from mechanical treatment of wastes other that does not contain dangerous substances”
- 19.08.05: “sludges from treatment of urban waste water”

Twenty-one cumulus of wastes, belonging to the two selected categories and coming from different producers, have been sampled using a wind tunnel, a specific device for passive areal sources, and the samples have been collected in Nalophan bags through the use of a depression pump. The samples have been analyzed through dynamic olfactometry and the same bags has been exposed to the electronic nose (PEN3 Airsense Analytics GmbH, Schwerin, Germany), in order to associate the different emissive patterns to the odour concentrations. In addition, the characterization of the landfill odour emissions has been carried out by considering the odour emissions produced by the whole landfill area, suitably divided into twenty five storage cells. In fact, during the landfill filling process, the wastes are not stored as such but they are preliminarily mixed for obtaining the correct density for avoiding structural stability problems and, once stored in a defined cell, they are covered by inert material. So, the cell odour concentrations have been measured by using dynamic olfactometry and the same samples have been analyzed by the electronic nose. Moreover, in order to understand the real extent of the odour annoyance and to compare and integrate the instrumental data, it was considered opportune to involve actively the local population through the administration of questionnaires. A survey form was given to each receptor, who had to take notes about the odour critical episodes, indicating the date, the duration and associating an intensity degree, according to a scale of three categories: perceptible odour/strong odour/very strong odour. This approach had been useful, together with meteorological parameters, for integrating and justifying the instrumental results and for finding the possible correspondence.

2.2 Principal Component Analysis (PCA)

Principal Component Analysis (PCA) has been widely used to characterize emission source categories observed at a receptor site (Amodio et al. 2010; Andriani et al., 2011; Hellebust et al. 2010; Henry et al., 1984). The purpose of PCA is to identify patterns in data and to express the data in such a way as to highlight their similarities and differences. In this way, it is possible to compress the dataset in order to reduce the number of variables which explain their total variance. New orthogonal and uncorrelated variables, called Principal Components (PCs), are created as linear combinations of the original variables; the first PC explains the largest amount of variance of the original data. The first step of the procedure consists in calculating eigenvalues and eigenvectors of the correlation data matrix; the eigenvectors are rotated in order to obtain a clear pattern of loadings, that is, factors that are somehow clearly marked by high loadings for some variables and low loadings for others. In this work, PCA with Varimax rotation was applied to the electronic nose responses to odour samples during the monitoring campaign at landfill. The main purpose of the procedure was to evaluate the effectiveness of principal components (PCs) in capturing the cluster structure of the data and to individuate the signals directly correlated with the odour events in order to obtain proper indicators for the continuous monitoring.

3. Results and discussion

3.1 Landfill odour characterization

The Figures 1 and 2 show the odour concentrations determined for the selected CER wastes and for the landfill cells respectively.

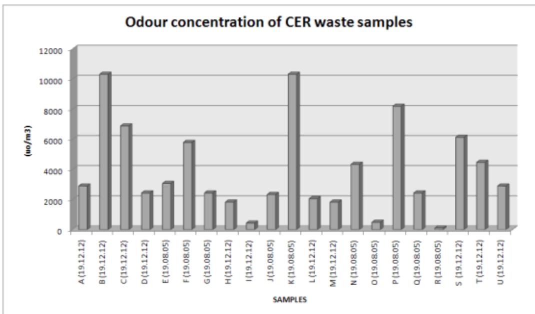


Figure 1: Odour concentration (ou/m^3) of CER waste samples

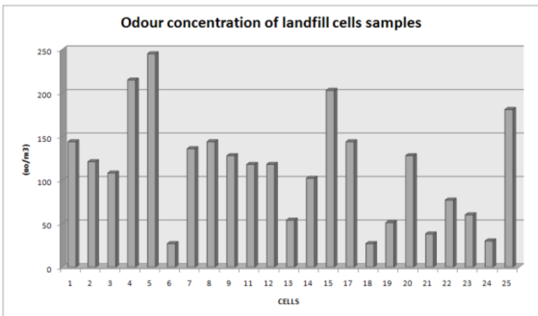
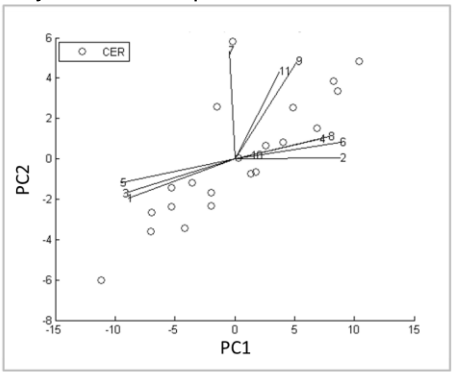


Figure 2: Odour concentration (ou/m^3) of landfill cell samples

It can be observed that the odour concentration of the different cells are considerably lower than the wastes as such, principally due to the covering with inert materials. In order to find a pattern associable to landfill sources, a PCA analysis (explained variance equal to 80%) has been carried out, considering the selected CER wastes and the landfill cells emissions. The PCA analysis has been applied to two datasets containing odour concentrations (ou/m^3) and the electrical responses (the variation of resistance (Ohm)) of the ten sensors exposed to the considered samples. The first one includes the CER waste samples while the second one comprises samples collected by the different landfill cells.
The Figures 3 and 4 show the scoreplots of the PCA analysis, relative to the first two principal components that explain the variance percentage, fixed for the analysis. The ten sensors are indicated with the correspondent number (see Table 1) while the odour concentration is identified with the number 11. In the Figure 3 the sensors n. 2, 4, 6 and 8 present high loading values on the PC1 while 7 and 9 show high loading values on the PC2; the odour concentration displays its contribution both to the PC1 and to the PC2. It can be observed that the scores referring to the less odorous samples have negative values both on PC1 and on PC2. Conversely, the most odorous samples have positive values for both the principal components. Instead, in the Figure 4 the odour concentration is not significantly discriminating among the different cell emissions. It can be highlighted that both cases show that the sensors 1, 3 and 5 are not correlated with the odour concentration, suggesting that they are not influenced by odorous compounds.



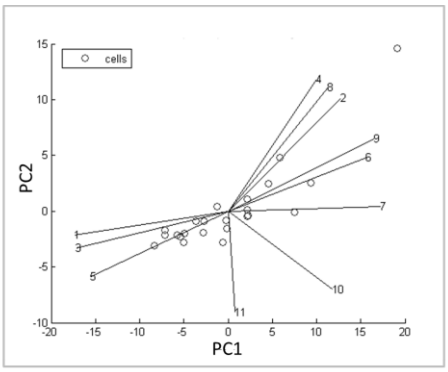
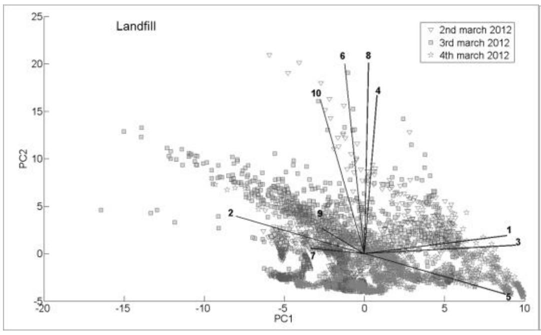


Figure 3: PCA plot for CER wastes. *Figure 4: PCA plot for landfill cells*.

3.2 Continuous monitoring at the landfill and at the receptor

A continuous monitoring by electronic noses have been performed at the receptor (far 600 meters from the landfill) and at the landfill, near the fresh waste disposal area. This instrumental monitoring has been integrated with the results of the questionnaires filled by the local population, in order to find the correspondence between the instrumental results and the occurrence of critical events. So, after having examined the questionnaires' responses, the results of the two electronic noses, referred to a temporal range centered to the hours of the resident complaints, have been elaborated by using PCA analysis (explained variance equal to 80 %). As example, the Figures 5 and 6 display the scoreplots of the PCA analysis implemented to the two datasets, landfill and receptor respectively, during the period 2nd - 4th March 2012. The Figures show the first two principal components because they explain the great percentage of the variance fixed for the analysis. In particular, both cases illustrate that a group of scores cluster and that they belong to the 3rd March measurements, during which critical odour event have occurred.



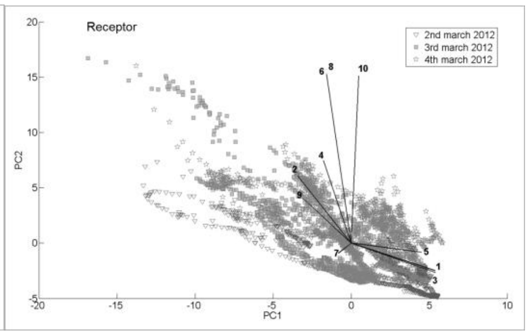


Figure 5: PCA plot of measurement results of the electronic nose placed at landfill (period 2^{nd} - 4^{th} March 2012)

Figure 6: PCA plot of measurement results of the electronic nose placed at receptor (period 2^{nd} - 4^{th} March 2012)

Moreover, both figures show that high loading values have been found for the sensors n. 4, 6, 8 and 10 on the PC2 and for sensors n. 1, 3 and 5 on the PC1. Even in this case, the signals 1, 3 and 5 are anticorrelated with the others. Since the landfill characterization study, discussed in the previous paragraph, has demonstrated that these sensors are not influenced by the odorous compounds, the PC2 has been considered for further examination. In the Figure 7 a comparison between the PC2 of the two elaborations (landfill and receptor) has been plotted. In the same figure only the periods during which the wind blowed towards the receptors from the emission source (range ESE - SSO) have been reported. The comparison shows that, when the PC2 scores in landfill have high values and the wind direction is towards receptor, even the PC2 scores for the receptor exhibits high values. These events are consistent with the indication of annoyance perceived by the receptors, valuated by the questionnaries responses. It can also be observed that high values of PC2 scores for landfill does not correspond to high value for PC2 scores for receptor when it is not downwind relative to the source; moreover, low values for landfill PC2 scores agree with receptor PC2 scores even when the receptor is downwind.

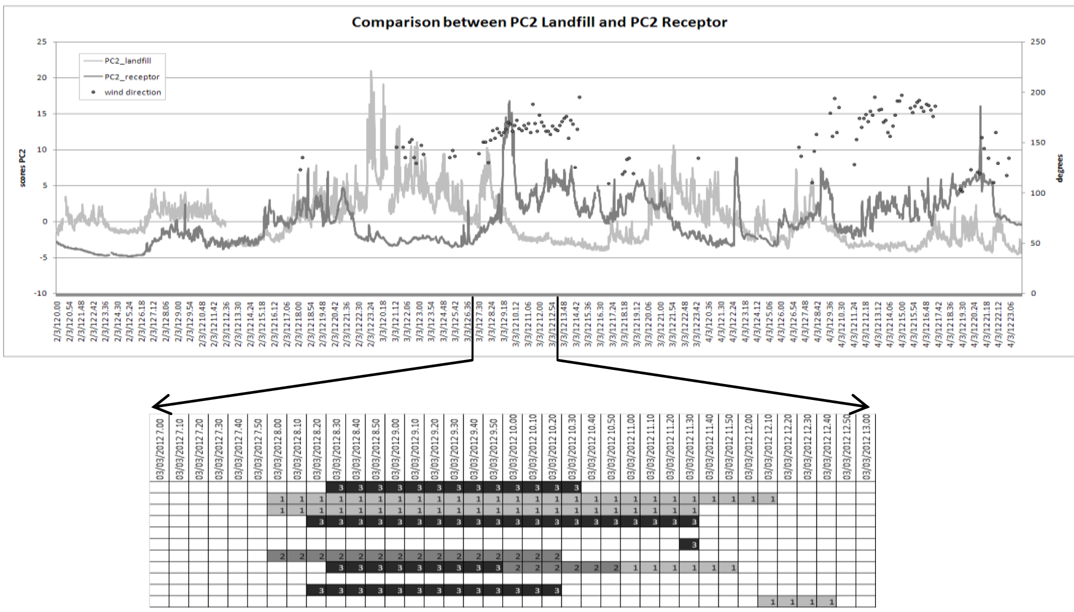


Figure 7: Comparison between PC2 valuated for landfill and PC2 for receptor for the period 2^{nd} – 4^{th} March 2012. The black circles indicate when the wind is directed to the receptor from the source. In the

under part of the figure, a detail of the questionnaires responses for the odour event recorded in 3^{rd} March 2012 is reported.

4. Conclusions

The experimental design applied to this work has permitted to demonstrate the real applicability of not specific instruments for the continuous monitoring of odour sources. An integrated approach, using the standardized methodology and a multiparametric system, have been performed and it has been validated by the administration questionnaires for the evaluation of the olfactory annoyance and by the meteorological data. After having characterized the odour emission of the specific source, it has been possible to individuate the parameters taken into account for the typical emissions produced by landfill. The comparison between these parameters, verified at the landfill and at the receptor, has permitted to describe exhaustively the odour phenomena and to individuate an indicator directly connected with the annoyance perceived. So, the employment of a multiparametric approach can represent a valid alternative to the standardized method and provide a great advantage in order to evaluate in continuous the odour emissions of a specific industrial activity and to control its productive process.

Acknowledgments

The authors acknowledge the support of Italcave SpA for funding the study under the research contract “CONTROLODOR” and for having permitted to use the data of monitoring campaigns.

References

Amodio M., Andriani E., Angiuli L., Assennato G., de Gennaro G., Di Gilio A., Giua R., Intini M., Menegotto M., Nocioni A., Palmisani J., Perrone M.R., Placentino C.M., Tutino M., 2011, Chemical characterization of PM in Apulia Region: local and long-range transport contributions to Particulate Matter. Boreal Environment Research, 16, 251-261.

Andriani E., Caselli M., de Gennaro G., Giove A., Tortorella C., 2011, Synergistic use of several receptor models (CMB, APCS and PMF) to interpret air quality data. Environmetrics, 22, 789-797.

Brattoli M., de Gennaro G., de Pinto V., Demarinis Loiotile A., Lovascio S., Penza M., 2011, Odour Detection Methods: Olfactometry and Chemical Sensors. Sensors, 11, 5290-5322.

EN 13725: Air Quality—Determination of Odour Concentration by Dynamic Olfactometry; Committee for European Normalization (CEN), Brussels, Belgium, 2003.

Freeman J.W., 1991,The physiology of perception. Sci. Am. 264, 78-85.

Gostelow P., Parson S.A., Stuetz R.M., 2001, Odour measurements for sewage treatment works. Water Res., 35, 579-597.

Hellebust S., Allanic A., O'Connor I.P., Wenger J.C., Sodeau J.R., 2010, The use of real-time monitoring data to evaluate major sources of airborne particulate matter. Atmospheric Environment, 44, 1116-1125.

Henry R.C., Lewis C.W., Hopke P.K., Williamson H.J.,1984, Review of receptor model fundaments. Atmospheric Environment, 18, 1507-1515.

Ronchi Decree, 1997. Italian Legislative Decree n. 22, from 5 February 1997.

Stuetz R., Frechen F.B. Eds. 2001. Odours in Wastewater Treatment: Measurement, Modelling and Control; IWA Publishing: London, UK,.

Yuwono A.S., Lammers P.S. Odor pollution in the environment and the detection instrumentation. Int. Agr. Eng. J. 2004, VI, 1-33.