CHEMICAL ENGINEERING TRANSACTIONS Volume 23, 2010
Editor Renato Del Rosso
Copyright © 2010, AIDIC Servizi S.r.l., ISBN 978-88-95608-14-3 ISSN 1974-9791
DOI: 10.3303/CET1023050



# Modeling Odour Dispersion from Composting Plants: Comparison with Electronic Nose Measurements

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The dispersion of odour from a composting plant was calculated with the CALPUFF modeling system, where site specific meteorological and geophysical informations were taken into account. The odour emissions, both from forced and free-convection sources, were measured by means of dynamic olfactometry and implemented in the model employing mass-transfer considerations.
The results obtained from the model were compared with measurements from a MOS sensor based Electronic Nose equipped with a preconcentrator (to augment its sensitivity to low concentrations) placed in two locations (at 150 m and 230 m far from the plant in two different directions), for a period of two weeks for each location. Comparisons were made both on a global level (2D maps of percentiles of hourly averages) and on an "instantaneous" point of view (time series correlation); results advocate the need for a truly site-specific meteorology to obtain satisfying predictions, and give some hints for tuning model parameters for odour applications.

## 1. Introduction

The study of the nuisance induced by dispersion of odours in the atmosphere is an issue of growing importance for regulatory purposes. Some models have been developed for the specific scope of determining the dispersion of odours (Schauberger et al., 2000). Among the regulatory models developed for the dispersion of ordinary pollutants, the CALPUFF modeling system (Scire et al., 2000, U.S. EPA, 2005) seems to be a useful tool for many reasons, e.g. non-stationary transport modeling, complex topography and meteorology issues, etc. However, its applicability to odour emissions has to be tested. This study is a comparison between the prediction of the dispersion model as regards nonstationary odour dispersion and field measurements made with an Electronic Nose, in the case of a composting plant.

## 2. Experimental and Methods

The results from the model and field measurements have been processed from a period of observation of nearly a month.

Please cite this article as: Mantovani A., Artoni R., Barausse A., Palmeri L., Pittarello A. and Benzo M., (2010), Modeling odour dispersion from composting plants: comparison with electronic nose measurements, Chemical Engineering Transactions, 23, 297-302
DOI: 10.3303/CET1023050

The studied plant is a typical composting plant, for which the most significant sources were identified as:

- biofilter
- heaps of green material, maturating and ready compost
- opening of doors for introduction of waste and maintenance

In order to implement the dispersion model, meteorological data from the nearest ground meteorological stations (in a 10 km-range from the site of the plant, a distance someway acceptable in the contest of the Po valley) were used together with radiosonde data and geophysical data for terrain elevation and land use. As regards the wind field, on-site measurements were available: in order to understand the importance of site-specific meteorological data, two simulations were carried out considering (1) wind data measured on site (in the following referred as S1) and (2) wind data from the nearest meteorological station (placed 7 km far from the plant, in the following referred as S2). Hourly data suggest to use a time step of an hour for the simulations, eventually re-scaling concentrations to obtain peak values. An analysis domain of 4kmX4km, with a grid of 1600 receptors spaced one from another by 100m, was choosen in order to study the influence of the plant on the surroundings. Two discrete receptors were placed in the position of the E-noses to compare the predictions of the model with the field measurements.

The various types of emission sources, both forced (biofilter) and free convection ones (heaps of material), have been introduced in the model by means of emission estimates derived from dynamic olfactometric measurements (EN 13725). The free convection sources have been sampled using a flux chamber and their emission rate, based on wind strength, represent the result of a power law, obtainable from dimensional analysis.

$$\dot{Q} = \dot{Q}_0 \left( \frac{U}{U_0} \right)^{\alpha} \tag{1}$$

where the reference emission rate and velocity have been determined by means of dynamic olfactometry and the characteristics of the flux chamber used. The power law exponent was taken to be 0.63 according to Jiang and Kaye (1996).

The result available from the model is the concentration on each receptor at each time; these data were treated according to IPPC Guidance H4 (2002), which defines the area affected by nuisance as the area where the $98^{th}$ percentile of hourly means is higher than the threshold value of 1.5 $OUe/m^3$. In order to represent results, data were processed calculating for each receptor the percentile corresponding to the threshold. However, being that the period under study is of a month only, it was preferred to use the $95^{th}$ percentile of hourly means as a reference in order to filter outliers.

The study involved the use of an E-Nose with 10 MOS sensors, equipped with a preconcentrator to augment its sensitivity to low concentrations. It was choosen to place the E-Nose in two positions (150 m and 230 m far from the plant, the former upwind and the latter downwind with respect to the prevailing wind direction), and imposed measurement cycles of 12 minutes. Both the points reside in the potential area affected

by nuisance, as estimated by previous interviews. In order to compare E-nose measurements with results from the model, data were averaged on hourly basis.
For the training of the E-nose, olfactomectric analyses are carried out in order to construct a calibration curve relating sensor measurements to olfactometric values (gradient, panel sensorial response) expressed in OUe. The more the samples passed to the nose in the training phase, the best will be the calibration relating the two measurements. In this case, due to technical problems, it was not possible to perform a satisfying training of the E-nose, therefore it was not possible to transform measurements in olfactometric units. However, it was possible to evaluate correlations between the response of the nose and model predictions.
The correlation between the concentrations measured in the two positions of the electronic nose (hourly-averaged), and those predicted by the Calpuff model forced with S1 or with S2 meteorology, were evaluated both with Spearman R statistic and with Gamma G statistic (preferable when data display several tied observations, as in the case of zero concentrations here) calculated using Statistica Statsoft software.

## 3. Results and discussion

E-nose measurements, processed with the help of principal component analysis (PCA), can return information about intensity and nature of odours but obviously only on the measurement point, while the model can give information on a wide grid of receptors.
In absence of the training, it was not possible to perform a principal component analysis on the data in order to quantify source contributions. However, a previous campaign (with a succesful training) was used for this scope, suggesting that heaps of green and maturating compost act as the principal source of nuisance episodes in comparison with the biofilter, an issue which was predicted also by the model. An example of PCA is reported in Figure 1.

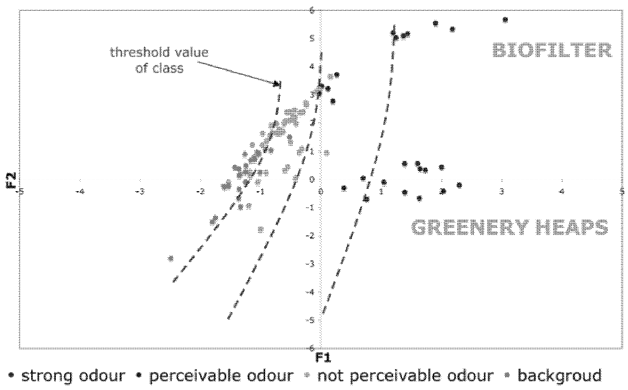


*Figure 1. Example of Principal Component Analysis*

The concentration measured by the E-nose in the first position (150m far from the plant) correlated well with both S1-forced Calpuff outputs ($R = 0.21$, $p < 0.0001$, $G = 0.19$, $p < 0.0001$ ) and S2-forced ouputs ($R = 0.25$ , $p < 0.00001$, $G = 0.19$, $p < 0.00001$ ). For the second observation point, the E-nose concentrations showed a significantly different trend from the Calpuff outputs , both S1-forced (R = -0.06, p = 0.29, G = -0.05, p = 0.28) and S2-forced (R = -0.08, p = 0.19, G = -0.05, p = 0.21) ones.

For the first, nearest position of the E-nose, there is a good correlation between model predictions and nose measurements. No great difference was observed in the correlation when passing from local wind measurement (S1) to less site specific ones (S2). This means that trends are similar, not implying anything about odour intensity. In fact, predicted odour intensity is very different at the receptors when passing from S1 to S2 meteorology. As an example, the 95$^{th}$ percentile of hourly means at the first receptor is 6.9 OUe/m$^3$ when using on site meteorology and 3.45 OUe/m$^3$ when using not on site data. These results can be understood by looking at wind rose plots (Figure 2): the fact that trends are similar is probably due to the fact that the main components of the wind are the same (though being S2 more scattered), while the difference in odour intensity is clearly related to the generally higher values of wind intensity.

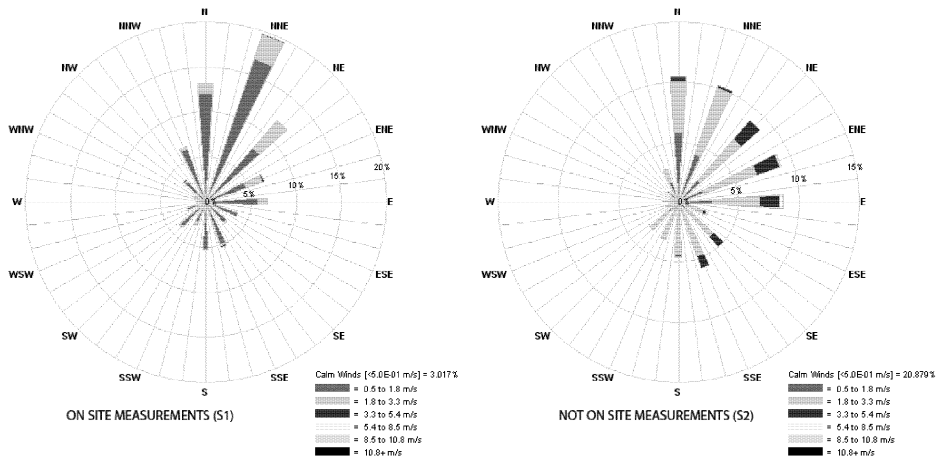


*Figure 2. Wind rose for stations S1 (left) and S2 (right).*

Regarding the second position of the E-nose, a different result was found, with very scarce correlation. Trying to understand this result, it was later recognized that this was due to abrupt changes in the emission properties, which were no more constant along time as the procedure described in section 2 requires. The scarce correlation therefore evidenced the existence of an anomalous behavior of the sources.

The Calpuff modeling system is able to simulate the trends of concentration measured near the first position of the E-nose reasonably well, in spite of a relatively rough hourly time-step. Indeed, not all the measured peaks are reproduced (Figure 3) and an even more faithful reproduction of them could possibly be achieved with a finer (sub-hourly) modeling resolution; however, discrepancies between measurements and simulations could also indicate the presence of incomplete or imprecise model inputs. For example another emitting source not in the model could be linked to the non-simulated peaks or, alternatvely, the cause could be a poor characterization of the emitting source, as we think it has happened with the second.

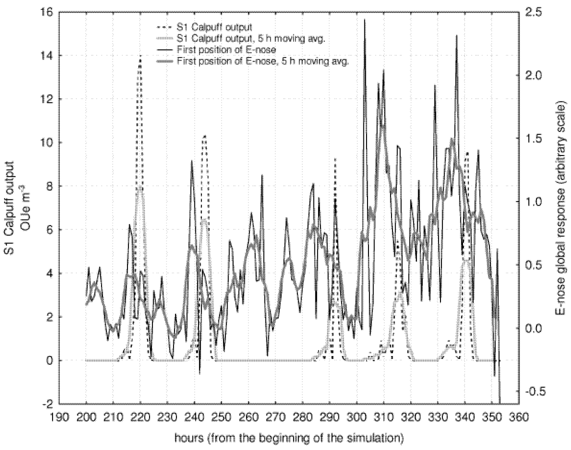


*Figure 3. Example of odour episodes predicted by the model and measured by the E-nose (a 5 hours moving averaged is also superimposed to better highlight correlation).*

The importance of the choice of meteorological data can be stressed also by comparison of 2D maps of ground odour concentrations, when a grid of receptors is considered. In Figure 4 a comparison of model predictions for different meteorological data is given taking as a reference the curve where the 95$^{th}$ percentile takes the threshold value of 1.5 Oue/m$^3$. Indeed, in this case the model predicts that using on site wind data allows for a different, larger nuisance affected area than using data from station S2; as it was already discussed, this is probably related to the existence of stronger winds in S2, which act augmenting puff transport and dispersion.

These results suggest that, particularly when considering ground level emissions, meteorology must be carefully accounted for, and it would be obviously preferable to have at least on-site wind measurements.

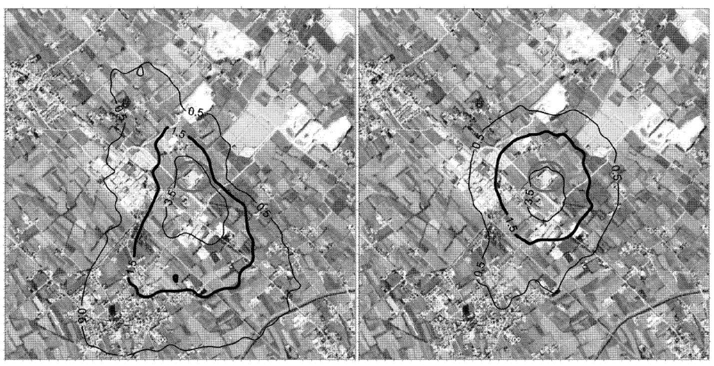

*Figure 4. Maps of the 95th percentile of ground odour concentration, for S1 meteorology (left) and S2 meteorology (right)*

## 4. Conclusions

This work yields positive ideas on the harmonization of monitoring techniques for odour dispersion problems. Model predictions for the dispersion of odour from a composting plant were compared to continuous E-nose measurements taken at two different locations; both forced and free convection sources were considered using appropriate scalings for the flowrate and dynamic olfactometric measurements.
Results suggest that the model is able to simulate the trends of concentration measured near the first position of the E-nose reasonably well, while for the second position of the E-nose differences between data and model results allowed to recognize an anomalous emission pattern. A comparison was also made between Calpuff simulations using on-site wind measurements and measurements from a station 7 km far from the plant, which stressed the importance of having on site data, having verified the strong sensitivity of the model to meteorology.
Next studies will hopefully take into account a full comparison between measurements and predictions, with the first transformed into odour units. In addition, future refinements will deal with treatment of sub-hourly emission and meteorological data.

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