CHEMICAL ENGINEERING TRANSACTIONS, Volume 15, 2008
Edited by Renato Del Rosso

Evaluation of odour emissions from a landfill through dynamic olfactometry, dispersion modelling and electronic noses

Riccardo Snidar[1], Barbara Culòs[1], Alessandro Trovarelli[2], Alfredo Soldati[3], Selena Sironi[4], Laura Capelli[4]*
[1] LOD S.r.l., Via J. Linussio 51, 33100 Udine, Italy
[2] Università degli Studi di Udine, Dipartimento di Scienze e Tecnologie Chimiche, Via Cotonificio, 33100 Udine, Italy
[3] Università degli Studi di Udine, Dipartimento di Energetica e Macchine, Via delle Scienze 208, 33100 Udine, Italy
[4] Politecnico di Milano, Laboratorio Olfattometrico, Dipartimento CMIC "Giulio Natta", Piazza Leonardo da Vinci 32, 20133 Milan, Italy

This paper describes the experimental approach adopted in order to evaluate the odour impact of a landfill in the South of Italy, having a surface of about 26 ha, divided in two parts, dedicated to the disposal of MSW and hazardous waste, respectively.
A complete and in depth study was conducted using three different approaches for odour impact determination: dynamic olfactometry, dispersion modelling and electronic noses. The results of the olfactometric analyses enabled quantify the landfill odour emissions in terms of odour concentration, and their use as input data for the application of a mathematical model for odour dispersion simulation allowed to evaluate the impact of landfill odours on the neighbouring land. Finally, two electronic noses, specifically developed for the continuous monitoring of environmental odours were used in order to instrumentally determine the landfill odour impact on a specific receptor. The very good correspondence of the electronic nose responses with the meteorological data (wind speed and direction) relevant to the monitoring period and with the odour detections reported by the people living at the receptor allowed to confirm the reliability of the obtained results.

1. Introduction

Among existing types of industrial installation that can cause odour nuisance, landfills represent one of the most common sources of odour emissions and complaint. Odours from landfill sites originate principally from the atmospheric release of compounds that are formed during the biological and chemical processes of waste decomposition (El Fadel et al., 1997, p. 1).
This paper describes the experimental approach adopted in order to evaluate the odour impact of a landfill in the South of Italy, having a surface of about 26 ha, divided in two parts, dedicated to the disposal of MSW and hazardous waste, respectively.

A complete and in depth study was conducted using three different approaches for odour impact determination: dynamic olfactometry, dispersion modelling and electronic noses.

The results of the olfactometric analyses enabled to quantify the landfill odour emissions in terms of odour concentration, expressed in European odour units per cubic metre (EN 13725, 2003).

These results were then used as input data for the application of a mathematical model for odour dispersion simulation, which enabled to evaluate the impact of landfill odours on the neighbouring land.

Finally, two electronic noses, specifically developed for the continuous monitoring of environmental odours (Sironi et al., 2007, p. 336) were used in order to instrumentally determine the landfill odour impact on a specific receptor, i.e. a dwelling located at about 1.4 km East from the landfill boundaries. One instrument was installed at the above mentioned receptor, while the second one was positioned at the plant fence line, with the aim of repeatedly analyzing the external ambient air.

2. Materials And Methods

2.1 Olfactometric analyses

Dynamic olfactometry is a sensorial technique, which allows to determine odour concentration, which represents the number of dilutions with neutral air that is needed in order to bring an odorous sample to its odour detection threshold, and it is expressed in (ou_E/m^3). The analyses are carried out using a suitable dilution device, called olfactometer. The samples to be analyzed by dynamic olfactometry were collected the 1st August 2007 on the landfill most representative odour sources, which were considered to be the landfill gas, the fresh waste and the leachate collection tanks.

2.2 Odour dispersion model

The model used for the simulation of the emission dispersion is the CALPUFF model. This model is realized by Earth Tech Inc. for the California Air Resources Board (CARB) and the U.S. Environmental Protection Agency (US EPA).

CALPUFF is a non-stationary puff atmospheric dispersion model. It is suitable for the estimation of emission from single or multiple industrial sources. It allows to calculate dry and wet deposition, building downwash, dispersion from point, area and volume sources, the gradual plume raising in function of the distance from the source, the influence of the soil orography on dispersion, and the dispersion in case of weak or absent wind. The dispersion coefficients are obtained from the turbulence parameters (u_*, w_*, L_{MO}), instead of being calculated from the Pasquill-Gifford-Turner stability classes. This means that the turbulence is described by continuous functions, not by discrete ones. During the periods in which the boundary layer has a convective structure, the concentration distribution inside each puff is gaussian on the horizontal planes, but asymmetric on the vertical planes, i.e. it takes account of the probability distribution function of the vertical speeds. In other words, the model simulates the effects on dispersion due to ascending and descending air movements that are typical of the day hottest hours and due to big scale vortex.

The model needs three different kinds of input data: orographical, meteorological and emission data.

2.3 Senso-instrumental monitoring by electronic nose

The instruments used for this study (EOS^{835} 20 and EOS^{835} 28) have been developed in collaboration with Sacmi s.c.a.r.l. and the Sensor Laboratory of the University of Brescia (Falasconi et al., 2005, p. 73). The system includes a pneumatic assembly for dynamic sampling (pump, electro-valve, and electronic flow meter), a thermally controlled sensor chamber with 35 cm^3 of internal volume and an electronic board for controlling the sensor operational conditions. Both instruments have been equipped with an array of six thin film MOS (Metal Oxide Semiconductor) sensors, which make the system sensitive to a large spectrum of volatile compounds, and a humidity sensor.

In principle, the sensor selectivity and sensitivity can be changed by tuning their operating temperature (Lee et al., 1999, p. 35; Yamazoe et al., 2003, p. 63). However, we observed that, when very complex mixtures are analyzed (gaseous emissions from plants for the treatment of MSW contain hundreds of different compounds), the sensor responses are strongly correlated, and their temperature dependence is not clearly definable.

The instrument remote control and the data acquisition can be performed by an external personal computer through the standard communication port RS232 or a USB port. Two special software have been developed for the electronic nose data processing: the Nose Pattern Editor (NPE), which is used for data preprocessing and for multivariate statistical analysis (e.g. PCA), and the Nose Pattern Classifier for pattern recognition and data classification.

Each electronic nose analysis is composed of a measurement phase and a recovery phase. The air to be analyzed is sucked during the measurement phase; during the recovery phase, reference air is pumped into the sensor chamber in order to desorb the volatile compounds from the sensor active layer and bring their response back to the base line. For the analyses, the carrier flow rate was 150 cm^3/min and the temperature of the sensor chamber was kept constant at 50°C.

The first and most delicate phase of a monitoring with electronic nose is the instrument training. During this phase, it is necessary to create a complete database that the instrument uses as a reference for subsequent pattern recognition. The training consists in the analysis of different gas samples of known olfactory quality at different odour concentration values, in order to teach the instrument to recognize odours from the qualitative and quantitative point of view (Capelli et al., 2008, p. 53). In this case, the training involved the execution of two campaigns for the collection of gas samples and their subsequent analysis by dynamic olfactometry and by electronic nose.

The samples for the electronic nose training must be collected in correspondence of the main odour sources of the plant to be monitored, in order to teach the instrument to recognize those odours that may be detected during the monitoring phase. The odour sources considered for this study were the landfill gas, the leachate collection tanks and the fresh waste. Moreover, some ambient air samples were collected near the landfill plant to be monitored, in particular moments in which odours attributable to the plant were not perceivable, in order to create a reference olfactory class, corresponding to non-odorous, i.e. “neutral” air.

The monitoring period started during the afternoon of Monday, 26th November 2007, and ended Thursday, 6th December 2007. During this period the electronic nose EOS 28 was installed at the offices located at the landfill entrance, near to the north-western boundary of the plant. The second instrument, EOS 20, was installed at a receptor, in order to detect the presence of odours from the monitored landfill. The considered receptor was represented by a dwelling located at about 1.4 km East from the landfill at issue. In both cases, the Teflon™ inlet tube for the gas suction was let outside the instrument installation room, in order to analyze the external ambient air. The tube for the reference air feed was internal to the electronic nose installation room. The measurement phase duration was set equal to 3 min, with a recovery time of 12 min, which was experimentally found to be a sufficient time in order to let the sensor response return to the base line value. One important problem connected to the use of the electronic nose in the field is the base line instability, due to the variability of the atmospheric conditions in the external ambience. This problem has been partially solved by introducing active carbon and silica gel filters for the deodorization and dehumidification of the reference air.

3. Results And Discussion

3.1 Odour concentration determination by dynamic olfactometry

Table 1 reports the results of the olfactometric analyses.

3.2 Odour impact evaluation by dispersion modelling

Figure 1 illustrates the results of the application of the odour dispersion model for the evaluation of the landfill odour impact on the neighbouring land.

3.3 Odour impact determination by electronic nose

The monitoring results are represented by large tables that report the olfactory class and the odour concentration value attributed to the analyzed air for each measurement carried out during the monitoring period. These results can be synthesized in graphs in which the abscissa reports data and hour of the measurement, while the ordinate reports the olfactory class or the odour concentration attributed by the electronic nose to the analyzed air.

Table 1. Results of the olfactometric analyses

Sample no.	Description	Odour conc. (ou_E/m^3)
1	Hazardous waste heaps	1350
2	Non-covered hazardous waste (15d)	170
3	Covered hazardous waste - post-operation	320
4	Tank for collection of leachate from haz. waste	110000
5	Tank for collection of leachate from MSW	4800
6	MSW heaps	1360
7	Covered MSW (1d)	200
8	LFG well on MSW landfill	27000
9	LFG pretreatment	3400
10	Covered MSW (2d)	200
11	Covered MSW (10d)	230
12	Covered MSW - post-operation	160

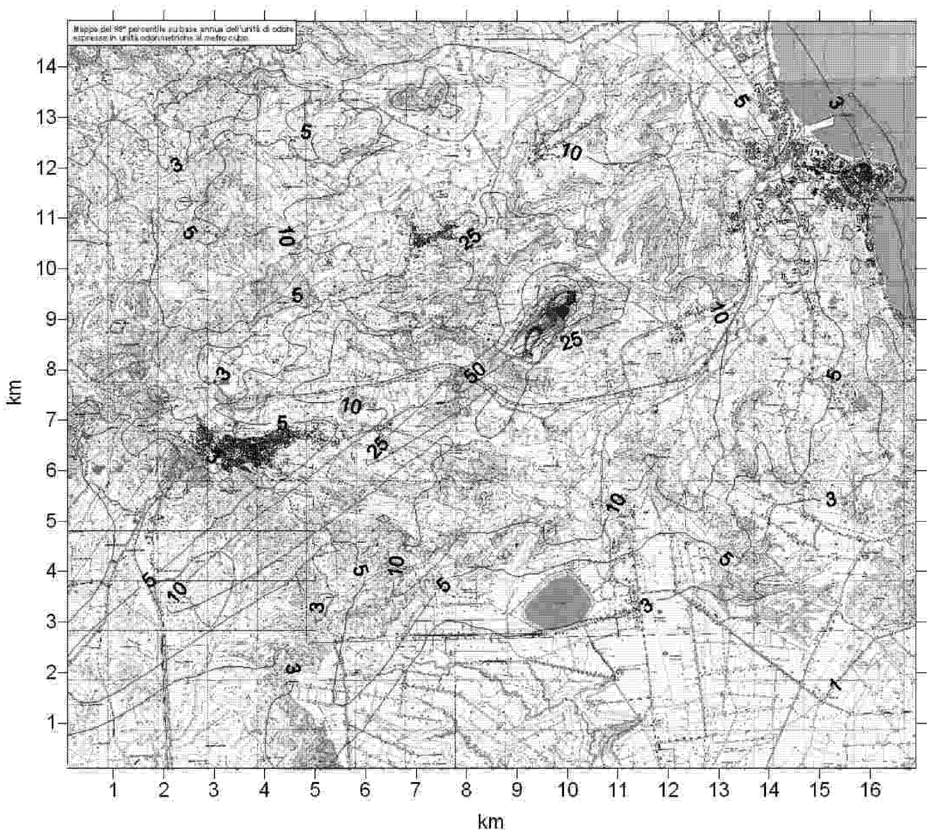

Figure 1. Odour impact evaluation by dispersion modelling

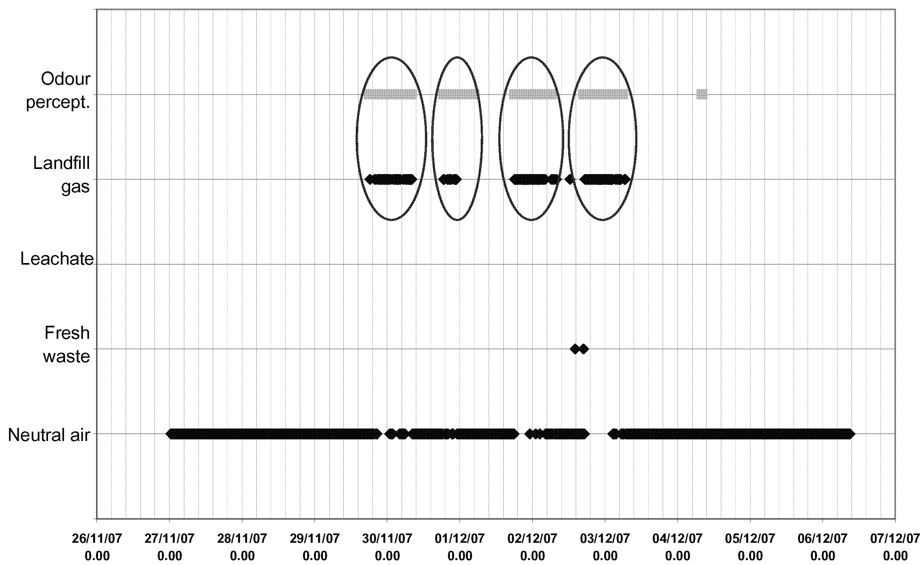

Figure 2. Results of the qualitative classification by EOS 20 at the receptor

Table 2. Odour impact at the landfill boundary

Olfactory class	No. of measurements	Detection frequency
Neutral air	619	73.2%
Landfill gas	136	16.1%
Fresh waste	91	10.8%
Leachate	0	0.0%

Table 3. Odour impact at the receptor

Olfactory class	No. of measurements	Detection frequency
Neutral air	757	84.3%
Landfill gas	139	15.5%
Fresh waste	2	0.2%
Leachate	0	0.0%

Table 4. Comparison between odour perceptions, olfactory classes recognized by the electronic noses and meteorological data

Odour perception	Date	Hour	Intensity	Olfactory class recognized by EOS 20 at the receptor	Olfactory class recognized by EOS 28 at the plant	Wind provenance direction	Wind speed
1	29/11 - 30/11	18.00 - all night	4	Landfill gas	Landfill gas/Fresh waste	N - E	0 - 0.1
2	30/11 - 01/12	all night	5	Landfill gas	Landfill gas/Fresh waste	N	0 - 0.1
3	01/12 - 02/12	18.00 - all night	4	Landfill gas	Fresh waste/Landfill gas	N	0 - 0.1
4	02/12 - 03/12	17.00 - 5.30	4	Landfill gas	Landfill gas/Fresh waste	O - N	0 - 0.5
5	04/12/2008	8.00	3	Neutral air	Neutral air	O - SO	0.5 - 1.2

Figure 2 illustrates the results of the qualitative classification performed by the electronic nose installed at the receptor, together with the odour perceptions by the people living at the considered receptors, who were asked to fill a specific form in order to indicate every odour event perceived during the monitoring period.

The evaluation of the relative detection frequency of each considered olfactory class in the two monitoring positions enabled to determine the landfill odour impact and to identify the most problematic odour source among the ones being considered, which turned out to be the landfill gas (Table 2 and Table 3).

In order to evaluate the odour impact of the monitored landfill it is important to compare different data. For this purpose, Table 4 reports, in correspondence of each odour episode indicated by the people living at the receptor, the olfactory classes recognized by both electronic noses, and the meteorological data (i.e. wind speed and direction) registered by a meteorological station installed inside the landfill during the monitoring period.

4. Conclusions

Based on the discussed results, it is possible to draw some important conclusions about the olfactory impact of the monitored landfill on the neighbouring land.

- The time percentage during which the electronic nose EOS 20, installed at the receptor, detected the presence of odours from the landfill, is equal to 15.7%.

This percentage is slightly higher than the limit of 15% fixed by the german guideline “GIRL Geruchsimmisions-Richtlinie” (LAI, 1998) on odour immissions for agricultural or industrial zones.

- The time percentage during which the electronic nose EOS 28, installed at the landfill entrance, detected the presence of odours from the landfill, is equal to 26.8%. In this case it is not possible to compare these results with limit values, as there are no regulations fixing limits in terms of detection frequency at plant fence lines. Nonetheless, it is possible to highlight that, because of dilution effects, the detection frequency and the odour concentration values outside the landfill should be lower than the values registered at the plant fence line.
- In both monitoring positions, the high percentage of measures attributed to the olfactory class “landfill gas”, allow to affirm that the landfill gas emitted through the landfill surface or through the not perfectly airtight extraction wells represents the most important odour source of the landfill at issue.
- The very good correspondence of the electronic nose responses with the meteorological data (wind speed and direction) relevant to the monitoring period, with the odour detections reported by the people living at the receptor, where the second electronic nose was installed, and with the result of the odour dispersion modelling allowed to confirm the reliability of the obtained results.

5. References

Capelli, L., S. Sironi, P. Céntola, R. Del Rosso and M. Il Grande, 2008, Electronic noses for the continuous monitoring of odours from a wastewater treatment plant at specific receptors: focus on training methods, Sens. Actuators B Chem. 131, 53.

El Fadel, M., A.N. Findikakis and J.O. Leckie, 1997, Environmental Impacts of Solid Waste Landfilling, J. Env. Manage. 50, 1.

EN 13725, 2003, Air quality - Determination of odour concentration by dynamic olfactometry, Comité Européen de Normalisation, Brussels, Belgium.

Falasconi, M., M. Pardo, G. Sberveglieri, I. Riccò and A. Bresciani, 2005, The novel EOS^{835} electronic nose and data analysis for evaluating coffee ripening, Sens. Actuators B Chem. 110, 73.

LAI (Länderausschuss für Immissionsschutz), 1998, Geruchsimmissions - Richtlinie (GIRL - Odour Emissions Guidelines), Ministry of Environment, Environmental Planning, and Agriculture of the State Nordrhein-Westfalen, Germany.

Lee, A.P. and B.J. Reedy, 1999, Temperature modulation in semiconductor gas sensing, Sens. Actuators B Chem. 60, 35.

Sironi, S., L. Capelli, P. Céntola and R. Del Rosso, 2007, Development of a system for the continuous monitoring of odours from a composting plant: Focus on training, data processing and results validation methods, Sens. Actuators B Chem. 124, 336.

Yamazoe, N., G. Sakai and K. Shimanoe, 2003, Oxide semiconductor gas sensors, Catalysis Surveys from Asia 7, 63.