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/CET1230026

Experimental Approach for the Validation of Odour Dispersion Modelling

Laura Capelli*[a], Licinia Dentoni[a], Selena Sironi[a], Jean-Michel Guillot[b]

[a]Politecnico di Milano, Department of Chemistry, Materials and Chemical Engineering “Giulio Natta”, Piazza Leonardo da Vinci 32, 20133 Milano, Italy
[b]Ecole des Mines d’Alès, Laboratoire Génie de l’Environment Industriel, 6 Av. de Clavières, F-30319 Ales Cedex, France
laura.capelli@polimi.it

Different approaches can be adopted in order to validate the results of odour dispersion modelling. This paper describes the approach adopted for odour dispersion modelling considering the specific case of a MSW landfill located in Northern Italy. This work represents the first step of a more extended research project between Ecole des Mines d’Alès and Politecnico di Milano, which will study different approaches to evaluate the exposure to odours and odorous compounds.

1 Introduction

The aim of the research project object of the collaboration between Ecole des Mines d’Alès and Politecnico di Milano is the validation of odour dispersion models. Different approaches can be adopted in order to verify the results of dispersion modelling, in terms of odour concentration or of concentration of other compounds. Such methods may include field inspections for the determination of the odour plume extensions and field measurements of specific compounds. Another method for further verification of dispersion modelling outputs may be represented by field monitoring with electronic noses. The first phase of the project, which is described in this paper, involved the identification of a suitable site where to run a study for the verification of the results obtained by odour dispersion modelling. The chosen site is the Regional MSW landfill of Gorla Maggiore, located in Northern Italy. The study included a bibliographical research for the identification of an appropriate way of characterizing landfill emissions, in order to obtain suitable emission data for dispersion modelling. Moreover, an ad hoc field inspection protocol was established. Field inspection will be used as the method for verifying the results of odour dispersion modelling.

2 Model validation at the landfill of Gorla Maggiore

The landfill of Gorla Maggiore is a MSW landfill located in Northern Italy, between two municipalities: Gorla Maggiore (province of Varese) and Mozzate (province of Como). Its geographical coordinates are 493.82 Km E, 5057.07 Km N. The landfill measures about 26 ha (260,000 m^2), which makes it one of the biggest landfills of Northern Italy. At the moment, the landfill receives about 500 t of MSW per day. A map of the landfill is shown in Figure 1.
The choice of this landfill as the site where to run the model validation study was based on the great availability of data regarding the landfill odour impact. This is due to the fact that the landfill is running regular odour monitoring campaigns four times per year (once every 3 months) since 2005. These monitoring campaigns include chemical analyses on sources and immissions, olfactometric analyses

Please cite this article as: Capelli L., Dentoni L., Sironi S. and Guillot J.M., 2012, Experimental approach for the validation of odour dispersion modelling, Chemical Engineering Transactions, 30, 151-156 DOI: 10.3303/CET1230026

on the landfill sources and ambient air monitoring by electronic noses. All these data represent a significant basis of knowledge of the landfill odour emissions and immissions (Capelli et al., 2008) and may be used in order to set up the strategy for the study.
Another important aspect is the great availability of meteorological data relevant to the site, which are necessary for dispersion modelling.
Besides the identification of the site to be studied, the program of the study should include the following steps: i) study of the methods for evaluating the emissions of odours and H_2S from a landfill; ii) source sampling and emission measurement: determination of the concentration of odour and H_2S; iii) immission measurements by field/plume inspection and field measurements of H_2S in ambient air; iV) evaluation of the dispersion of odours and H_2S by dispersion modelling.

3 Odour dispersion modelling

3.1 General principles

The dispersion of emissions is determined by applying an atmospheric dispersion model, which calculates the pollutant concentration in ambient air at the ground level, by processing three kinds of data: emission data, meteorological data and terrain profile.
The model used for the simulation of the emission dispersion is the CALPUFF model (Wang et al., 2006). This model is realized by Earth Tech Inc. for the California Air Resources Board (CARB) and the U.S. Environmental Protection Agency (US EPA).
The model data pre-processing and post-processing are realized by means of a specific software developed at the Department of Chemistry, Materials and Chemical Engineering “Giulio Natta” of the Politecnico di Milano.

3.2 Orographical data

The dimensions of the spatial grid considered as the simulation domain are 4,000 m x 4,000 m, with a receptor every 100 m (Figure 1). More in detail, the geographical coordinates (UTM) of the four grid summit angles are: i) 490.740 km E, 5,059.254 km N (NW); ii) 496,828 km E, 5,059.245 km N (NE); iii) 490.731 km E, 5,053.161 km N (SW); iv) 496,859 km E, 5,053.163 Km N (SE).
The presence of orographical reliefs, in the studied area, are considered by means of the CALPUFF “Partial plume path adjustment” option. The matrix of the altimetrical quotes of each receptor on the simulation domain was introduced as model input data.

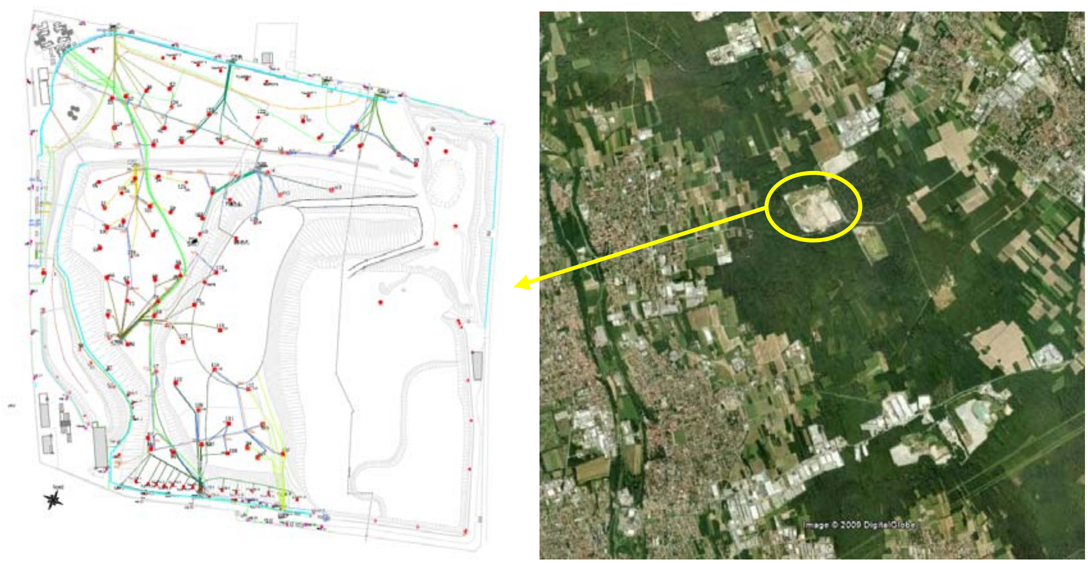

Figure 1: Map of the landfill (left) and of the spatial domain considered for dispersion modelling (right)

3.3 Meteorological data

The meteorological data used for dispersion modelling are registered by three different stations located at the studied landfill, at another landfill at about 400 m East-South-East with respect to the studied landfill, and at a sports field in the municipality of Gorla Minore, at about 2 km South-South-East from the landfill, respectively. Given that the data registered by the three stations turned out to be similar, they were averaged. The meteorological data used for dispersion modelling are reported in Table 1.

Table 1: Meteorological data used for dispersion modelling

Meteorological parameter	Type of data	Unit of measurement	Period
Temperature	Hourly average	°C	
Wind speed	Hourly average	m/s	From
Wind direction	Predominant (1h)	Sexagesimal degree	01/01/2010
Global solar radiation	Hourly average	W/m^2	To
Relative humidity	Hourly average	%	31/12/2010
Rainfall	Total (1h)	mm	

The raw data were pre-processed in order to eliminate vacancies (non-registered data or invalid data). Vacancies below 6 h were completed by linear interpolation of the two valid adjacent values. Larger vacancies were completed based on averaged valid data calculated in function of the month and hour.
The output parameters of the pre-processor used for the calculation of the micrometeorological variables, i.e. surface heat flux, friction velocity, Monin-Obukhov length, convective velocity scale (Thomson, 2000) and mixing height (Scire et al., 2000).

3.4 Emission data

3.4.1 Critical aspects

Odour emissions from landfills are mainly due to the emission of landfill gas (LFG) from the landfill body. In general, these emissions are not constant, and they are affected by different factors: the quantity of produced LFG, the quantity of LFG sucked by the landfill gas suction system and the meteorological conditions. Therefore, it is necessary to make a preliminary evaluation of such aspects, in order to make model the emission correctly and give a realistic overview of the pollutant dispersion.

3.4.2 Quantification of emissions

Different approaches may be adopted in order to quantify the LFG emissions from the landfill body.
One possible approach is reported by Sironi et al. (2005), and consists in considering the landfill as a passive emitting surface. For the landfill body, an Odour Emission Factor (OEF) could be defined and this value can be used to calculate the Odour Emission Rate (OER), which depends on the wind speed (OER ~ $v^{0.5}$). This approach does not consider that the landfill body is not a proper passive surface, because of the presence of a LFG flux. Moreover, the OEF is obtained by using a wind tunnel and such a device has not been validated on solid surface, and it’s commonly used to evaluate the OER form passive liquid surfaces.
A second possible approach could be to consider the landfill body as an active surface, with a proper defined flux. In order to evaluate the LFG emission, the methane emission could be considered (LFG is composed of CH4 for the 50 %). In the reported work, methane concentration data from three different detection stations in the landfill area were collected and analyzed. Unfortunately, the detection systems were not placed on the landfill body, where the emission takes place, and the correlation between methane concentration and emissions is difficult to evaluate. For this reason, other data obtained by using a static hood directly on the landfill body were analyzed, in order to estimate the methane flux through the landfill body surface. These data suggest a LFG flux about 140 m^3/h, and this value seems to be underestimated in comparison to the quantity of LFG collected, that is around 2,500 m^3/h.
One third possible approach consists in evaluating the LFG emissions from the landfill as the difference between the quantity of LFG produced and sucked. The data relevant to the sucked LFG are normally available from the design of the suction/burning system. As far as the quantity of produced LFG is concerned, this may be calculated using specific software (e.g., Landgem, by US EPA). This software

combines data regarding the quantity and typology of the yearly conferred waste for the whole operational period and meteorological data for estimating the quantity of produced LFG.

One last approach provides the use of literature data regarding the LFG flow through the landfill surface. For instance, the German guideline VDI 3790 (2000) indicates an indicative LFG flow ranging from 20 to 40 L/h/m^2.

The three approaches will be adopted and compared.

Independently from the approach adopted for estimating emissions from the landfill body, given the huge extension of the landfill at issue (about 200,000 m^2), in order to simulate the dispersion of emissions, it is necessary to divide the landfill surface in smaller areas. In this specific case the landfill body was divided in 11 sub-areas, as shown in Figure 2. For each of the identified sub-areas, surface and equivalent diameter were calculated, as required by the dispersion modeling software.

Figure 2: Division in sub-areas of the landfill surface

3.4.3 Evaluation of the variability of emissions

Based on the technical literature and bibliography about the issue, as well as on the experience of both research groups, LFG emissions are not constant. Emissions are affected by meteorological conditions, especially by atmospheric pressure and stability. Several studies report how LFG emissions tend to decrease while atmospheric pressure increases. Despite of the numerous studies, it is difficult to establish a precise correlation between those two parameters. Interesting studies that were considered for the present work are for instance those published by Czepiel et al. (1996, 2003), Alan (1990) and Chakraborty et al. (2011). The above mentioned studies will be used as a basis for the determination of a relationship between meteorological parameters and emissions from the landfill body, in order to make it possible to model such emissions.

4 Field inspection

Field inspections may be run following different approaches. One future European Norm will summarize the possible approaches for evaluating environmental odour exposure (Guillot et al., 2011).

One of the methods consists in making one-year observations in order to represent every possible meteorological condition and thereby having a statistical approach. This method is very expensive and doesn't comply with the aims of the study, as for correlating dispersion model and environmental

measurements, just one or two meteorological conditions favourable to odour dispersion should be considered, whereby odours from the monitored source are perceivable in the surroundings.
For this reason, another approach of the future Norm consists in highlighting the exposed zone by determining an odour plume (plume measurement). This method consists in using a panel of examiners for determining the absence or presence of odour downwind relative to the source, in order to determine the plume extent. The panel may zigzag and traverse the plume (dynamic approach) or be located in specific points on perpendicular axes (static approach), as shown in Figure 3. In some cases, the terrain complexity makes it difficult to strictly follow the one or the other measurement method.

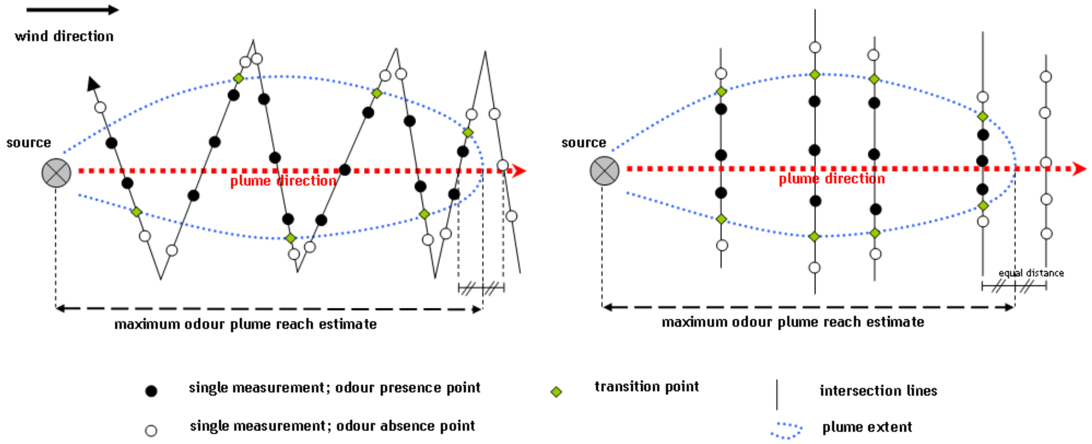

Figure 3: Dynamic (left) and static (right) plume measurement

In this specific case, in order to set up a plume measurement approach, the paths located around the landfill to be studied, in the direction of the most frequently blowing winds, have been mapped. This allows the location of the points to be used for the static approach in the area most difficult to be accessed. Figure 4 shows the map (1800 m x 1200 m) of the paths identified in the southern area relative to the landfill at issue.

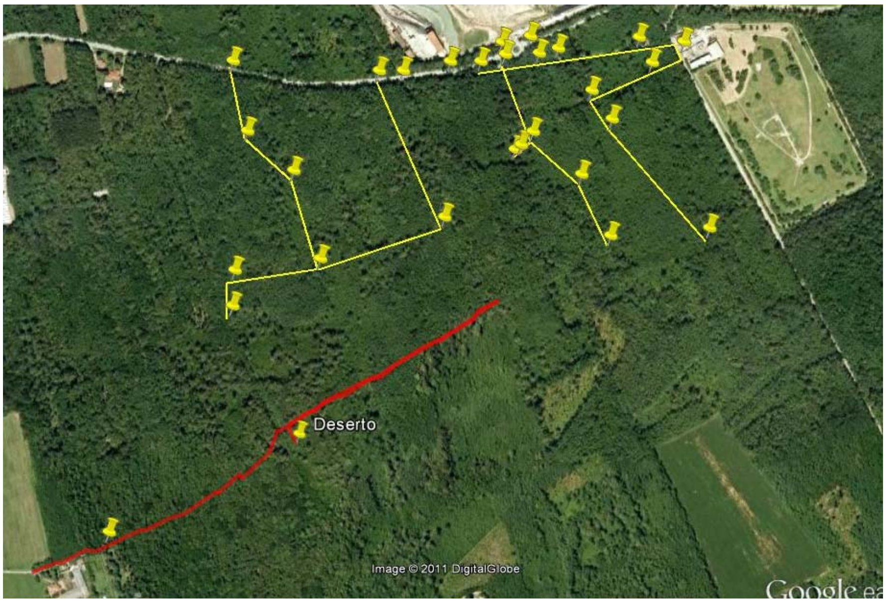

Figure 4: Paths identified in the southern surrounding of the landfill

5 Conclusions

This paper describes the first part of the research project between Ecole des Mines d'Alès and Politecnico di Milano aiming to the validation of odour dispersion models. This first part of the research included the identification of a site where to run the study, which was chosen to be the Regional MSW landfill of Gorla Maggiore, in Northern Italy, as well as a bibliographical research for the identification of an appropriate way of characterizing landfill emissions, in order to obtain suitable emission data for dispersion modelling. Moreover, a specific protocol for a field inspection aiming to the verification of the results of odour dispersion modelling was established.

References

Alan Y., 1990. Volumetric changes in landfill gas flux in response to variations in atmospheric pressure, Waste Manage Res, 8, 379-385.

Capelli L., Sironi S., Del Rosso R., Céntola P., Il Grande M., 2008, A comparative and critical evaluation of odour assessment methods on a landfill site, Atmos Environ, 42, 7050-7058.

Chakraborty M., Sharma C., Pandey J., Singh N., Gupta P.K., 2011, Methane emission estimation from landfills in Delhi: A comparative assessment of different methodologies, Atmos Environ, 45, 7135-7142.

Czepiel P.M., Shorter J.H., Mosher B., Allwine E., McManus J.B., Harriss R.C., Kolb E., Lamb B.K., 2003, The influence of atmospheric pressure on landfill methane emissions, Waste Manage, 23, 593-598.

Czepiel P.M., Mosher B., Harriss R.C., Shorter J.H., McManus J.B., 1996, Landfill methane emissions measured by enclosure and atmospheric tracer methods, J Geophys Res, 101, 16711-16719.

Guillot J.M., Bilsen I., Both R., Hangartner M., Kost W.J., Kunz W., Nicolas J., Oxbol A., Secanella J., Van Belois H., Van Elst T., Van Harreveld T., 2011, The future European standard to determine odour in ambient air by using field inspection, Proceedings of the 4th IWA Conference on odours and VOCs, Vitoria, Brazil.

Scire J.S., Robe F.R., Fernau M.E., Yamartino R.J., 2000, A User's Guide for the CALMET Meteorological Model, Version 5, Earth Tech Inc., Concord, Massachsets, USA, <unix.src.com/calpuff/download/CALMET_UsersGuide.pdf>, Accessed 30/08/2012.

Sironi S., Capelli L., Centola P., Del Rosso R., Il Grande M., 2005, Odour emission factors for assessment and prediction of Italian MSW landfills odour impact, Atmos Environ, 39, 5387-5394.

Thomson D.J., 2000, The Met input module ADMS 3 Documentation paper number P/05/01/00, The Met Office, Exeter, Devon, UK.

VDI, 2000, VDI 3790 – Part 2 Environmental meteorology Emissions of gases, odors and dusts from diffuse sources: Landfills, Verein Deutscher Ingenieure, Berlin, Germany.