CHEMICAL ENGINEERING TRANSACTIONS
VOL. 54, 2016

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

Guest Editors: Selena Sironi, Laura Capelli

ISBN 978-88-95608-45-7; **ISSN** 2283-9216

DOI: 10.3303/CET1654013

Environmental Odour Impact Assessment of Landfill Expansion Scenarios: Case Study of Borgo Montello (Italy)

Vincenzo Naddeo[a], Tiziano Zarra[a], Giuseppina Oliva[a], Agostina Chiavola[b], Alberto Vivarelli[c]

[a]Sanitary Environmental Engineering Division (SEED), Department of Civil Engineering of the University of Salerno, via Giovanni Paolo II,132, 84084, Fisciano (SA), Italy
[b]Sapienza University of Rome, Via Eudossiana 18, 00184, Rome, Italy
[c] Ind.Eco S.r.l., Sda Monfalcone, 23, 04100, Latina, Italy
vnaddeo@unisa.it

One of the most reliable methods for the prediction of odour impact from environmental facilities, strongly influenced by topography and local atmospheric dynamics, involves the use of atmospheric dispersion models.
The present study focuses on the implementation of a dispersion model for the prediction of odour impact from a large and complex landfill system, localized in Borgo Montello (Latina), in the Lazio Region (Central Italy). The Calpuff dispersion model was selected for the simulations of odour impact, since it is well recognized as the preferred model for assessing the long range transport of pollutants. The odour emission rates, which are the inputs to the dispersion model, were defined on the basis of dynamic olfactometric analyses on air samples taken in the landfills areas. Different scenarios were simulated, with the aim of evaluating the odour impact caused by a project of landfill expansion through height raise. The environmental odour impacts were assessed through the evaluation of the area which would be impacted by odour emissions due to the implementation of the expansion project, in comparison to the actual air quality conditions with no further control measures. This one allowed for quantifying the alteration of the environmental quality state as well as designing the systems and interventions to be implemented to reduce the odour in the impacted area of the surroundings.

1. Introduction

The disposal of municipal solid waste (MSW) in landfills implies the release of gases into the atmosphere, which have the potential to cause odour annoyance to the surrounding populations. The annoyance related to odour emission are among the main causes of public complaints (Brancher and de Melo Lisboa, 2014). Consequently, the location of many facilities is strongly influenced by their odour acceptability (Chaignaud et al., 2014). Organic wastes are subjected to aerobic and anaerobic degradation, resulting in an intensive production rate of landfill gases, which consist mainly of methane, carbon dioxide and volatile organic compounds. The negative impacts of these types of facilities on air quality and life conditions of the people living nearby the landfills are well documented (Zarra et al., 2009). The negative health effects may be related to pathophysiological reasons, stress-induced illness, as well as mass psychological hysteria (Schiffman et al., 2000; Shusterman, 2001; Hayes et al., 2014). Thus, there is a need to implement odour impact assessments in order to evaluate the environmental quality in the landfills proximity and eventually to implement control measures. It has become standard practice to use atmospheric dispersion models to predict the occurrence of odour nuisances around intensive odour plants. Atmospheric dispersion modelling, particularly if used in conjunction with knowledge of the site operation conditions, is a suitable tool to deal with issues related to odour complaints from solid wastes facilities, under given meteorological conditions (Chemel et al., 2012). A dispersion model is an effective method to predict odour impacts from existing or proposed plants, to evaluate the most sustainable locating of new facilities, as well as to identify optimal odour control strategies (Hayes et al., 2006). Another method is to use trained “sniffers” to field assess the odour impact of the process unit

Please cite this article as: Naddeo V., Zarra T., Oliva G., Chiavola A., Vivarelli A., 2016, Environmental odour impact assessment of landfill expansion scenarios: case study of borgo montello (italy), Chemical Engineering Transactions, 54, 73-78 DOI: 10.3303/CET1654013

(Naddeo et al., 2012; Zarra et al., 2010). The odour emission rates from investigated sources have to be known for the assessment of odour annoyance by dispersion models (Schauberger et al., 2014). Among the main tools for the characterization of odour, olfactory sensorial methods, which use human noses as detectors, can deal with the complexity of the involved complex odourants (Zhao et al., 2015, Sarkar and Hobbs, 2003). The dynamic olfactometer, a dilution instrument, is widely used for the determination of odour concentration (Zarra et al. 2012).
The paper describes the methodology and results of the implementation of a dispersion model for the prediction of odour impact caused by a landfill expansion scenario. A dispersion modelling approach to determine the odour impact of case study is also discussed. A comparison analysis made it possible to identify suitable solutions for the reduction of odour emissions.

2. Materials and methods

2.1 Landfill description

Research studies were conducted at a non-hazardous waste landfill, located in the municipality of Latina, Lazio Region (Middle Italy). The landfill is approximately located at 11.5 km from the centre of the town (Figure 1). The investigated plant consists of five basins. Four basins are used in the post-management phase and are permanently covered, while one is used in the operating phase. The main activities of the post-management basins consist of: management and control of the drainage system and leachate collection; management and control of the collection system and biogas combustion; management of human and technological resources available at the plant. While, in the active basin, the operating cycle provides the following steps: weighing, inspection and acceptance or refusal of the waste; transport of waste to the landfill under management; waste disposal; transit of vehicles; management and control of the drainage system and leachate collection; management and control of the collection system and combustion of biogas; management of human and technological resources available at the plant.

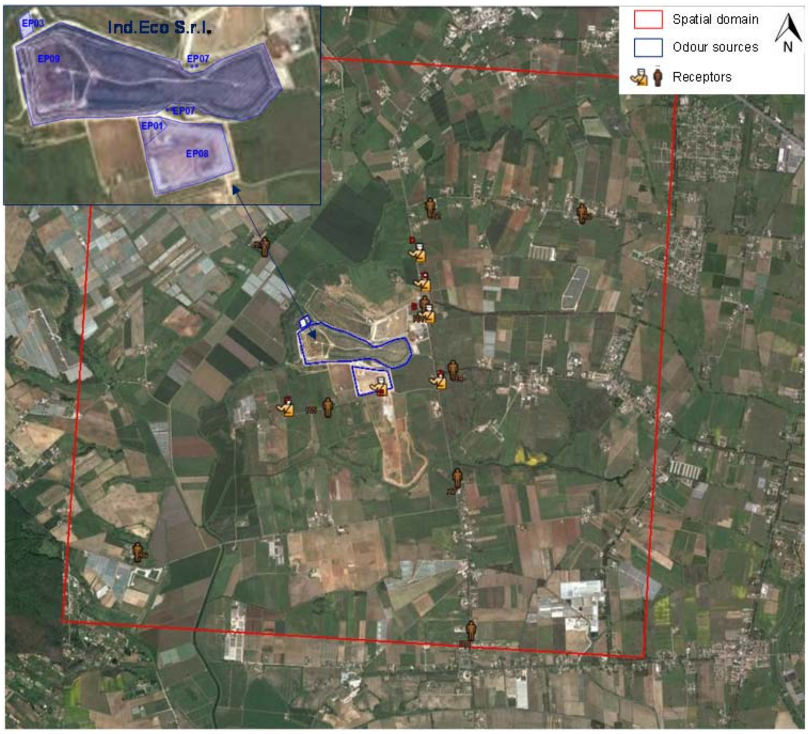

Figure 1 – Spatial domain, odour sources and receptors

2.2 Simulated scenarios

In order to assess the odour impact due to the implementation of an expansion project, two different scenarios were simulated: operating scenario and project scenario.
The odour sources considered for the simulation of the operating scenario are the following (Figure 1): EP01 (active basin, front in cultivation); EP03 (retention basins for leachate storage); EP07/1, EP07/2, EP07/ 3, EP07/4 (torches for biogas combustion); EP08 (active basin, front not in cultivation); EP09 (basins in post-management phase). The project scenario provides an increasing of the landfill capacity corresponding to

25.000 tons, without altering the base area. The height raise of the waste disposal is equal to 5.5 meters, reaching a maximum quota of 39,9 meters above sea level. In the project scenario, in order to reduce the odour emissions, the leachate is directly sent to the storage tanks; in this way, the retention basins for leachate storage do not represent an odour source. Therefore, the identified sources for the project scenario were (Figure 1): EP01 (active basin, front in cultivation); EP07/1, EP07/2, EP07/ 3, EP07/4 (torches for biogas combustion); EP08 (active basin, front not in cultivation); EP09 (basins in post-management phase).

2.3 Odour sources characterization

Air samples were taken at seven different sampling points, in order to characterize the odour emission at different sources. Point sources were taken, in accordance with EN 13725:2003, using the ‘lung’ technique. Nalophan® sampling bags, with a 7 liter volume, were placed inside a rigid container (length 685 mm, diameter 152 mm) evacuated using a vacuum pump. The areal sources were sampled by Flux Chamber (Scentroid SF450), with the following parameters: diameter 450 mm, with an enclosed surface area of 0.155 m^2, inlet flow of 3.9 lpm. The sampling activities were conducted under ordinary operational and meteorological conditions.

Odour concentrations were determined by olfactometric analyses, conducted at the Laboratory of Environmental Engineering (SEED) of the University of Salerno, according to EN 13725:2003. A TO8 olfactometer (ECOMA, D), based on the ‘‘yes/no’’ method, was used, relying on a panel composed of four trained persons. All the measurements were conducted within 30 h after sampling.

Once the odour concentration value of a collected sample was determined, it was possible to evaluate the odour emission rate (OER) of each investigated source.

The OER for the point sources was calculated as follows,

$$OER = Q \cdot C_{OD}$$

where OER is the odour emission rate, expressed in ou_E/s, Q is the flow rate in Nm^3/s and C_{od} is the odour concentration in ou_E/m^3.

The OER of the passive surface sources was calculated from a SOER (Specific Odour Emission Rate), expressed in odour units emitted per surface unit and time ($ou_E/(m^2s)$).

$$SOER = \frac{Q \cdot C_{OD}}{A_W}$$

where Q is the flow rate of the neutral air stream inlet the chamber, expressed in m^3/s, equal to 3.9 lpm, COD is the odour concentration in ou_E/m^3; A_W is the enclosed surface area of the flux chamber, equal to 0.155 m^2.

The OER for the surface sources, finally, was calculated as follows,

$$OER = SOER \cdot A_E$$

where A_E is the area of surface emission source.

2.4 Odour dispersion model setup

The modelling of odours dispersion was carried out in accordance with international guidelines, using the CALPUFF model. CALPUFF is among the preferred models officially adopted by US EPA for the estimation of air quality and mainly adopted in the scientific practice for odour dispersion modelling. In the model, a spatial domain of 5000 m x 5000 m was considered, with a square grid of receptors every 100 m. The characterization of the “terrain following” was carried out by 7 vertical layers. The coefficients of land use were selected according to the proposed values by Scire et al. (2000) proposition. Hourly average data of the meteorological parameters (Wind Direction, Wind Speed, pressure, temperature, precipitation) were provided by a company of environmental model (MAIND S.r.l.), for a period of 12 months (calendar year - 2014).

Using these values A CALMET model provided the meteorological 3D input data variable in space and time. The combination of the CALMET-CALPUFF models allows for the modelling of phenomena such as the stagnation of pollutants (calm wind), the circulation of the winds, and the temporal and spatial variation of weather conditions. Although the use of punctual meteorological data is foreseen, the full potential of the CALPUFF code is activated if used in conjunction with the three-dimensional meteorological fields generated by CALMET.

CALMET is a diagnostic meteorological model that, starting from the observed data (to the ground and profile) and through geophysical data, produces three-dimensional and two-dimensional wind zones fields of the different meteorological and micrometeorological variables. Although it is possible to use just on-sites meteorological data as CALPUFF input, the full potential of the CALPUFF code is activated if coupled to the three-dimensional meteorological fields generated by CALMET. This combination produces as output, for each hour and each receptor, the hourly average of the odour concentration. In order to obtain the hourly peak concentration, the hourly average is multiplied by the peak-to-mean ratio (P/M). The P/M factor usually adopted for sources with low altitude of the emission point and subject to the wake-effect is between 1.9 and

2.5 (DEC, 2006); for this study, the P/M is assumed equal to 2.3. Fourteen neighbouring odour sensitive receptors were identified, six of which (A, B, C, D, E, F) were suggested by a local control institution (ARPA) (Figure 1). The exposure levels were calculated for each considered receptor throughout the entire period of analysis (one year), at a calculation quota of 2 m.

2.5 Evaluation of odour impacts

Evaluation of the odour impacts was conducted according the 98th percentile method proposed by the Lombardia Region guidelines (Sironi and Capelli, 2010). The D.G.R. Lombardia n. IX/3018 indicates two reference values of odour concentration, 1 ou_E/m^3 and 5 ou_E/m^3, which were adopted for numerical simulation results comparison. The odour impact is defined as negligible if the concentrations are less than 1 ou_E/m^3, unacceptable if the concentrations are greater than 5 ou_E/m^3. The odour exposure levels between 1 and 5 ou_E/m^3 have to be evaluated case by case, in relation to the presence and importance of the exposed sensitive elements. According to the IPPC-H4 English guideline, that introduces the concept of "Annoyance Potential", the odour concentration of 3 ou_E/m^3 was taken as reference for "moderately offensive odours".

3. Results and discussion

In the current scenario, in order to implement the dispersion model, the EP01, EP03, EP08 and EP09 sources were modelled as passive surface sources, with natural wind ventilation. EP07/1, EP07/2, EP07/3, EP07/4 were patterned as point sources, with forced ventilation. In Table 1, the odour emission rates (OER) of all the monitored sources are summarized.

Table 1: Odour emission rates – Current scenario

Odour source			OER [ou_E/s]
ID		Type of source	
EP01	EP01/1*	passive areal source	684
	EP01/2*		76
EP03		passive areal source	3605
EP07**	EP07/1	point source	337
	EP07/2	point source	400
	EP07/3	point source	171
	EP07/4	point source	220
EP08		passive areal source	2644
EP09		passive areal source	2588

* EP01/1 active in the cultivation, from 8 a.m. to 1 p.m.; EP01/2 = partial daily cover, from 1 p.m. to 8 a.m.
** Alternately active for 15 days / torch, 24 hours per day, for a total amount of 8760 hours per year.

Figure 2 presents the daily distribution of the hourly peak odour concentrations in the current scenario. The highest odour concentrations were detected in the night time-band; the waste movement activities at the active basin are carried in the daytime time-band. Hence, the odour emissions were related mainly to the leachate storage since the retain basins occupy a significant area. For this reason, strategies to reduce the odour emissions due to the leachate management were adopted in the project scenario.

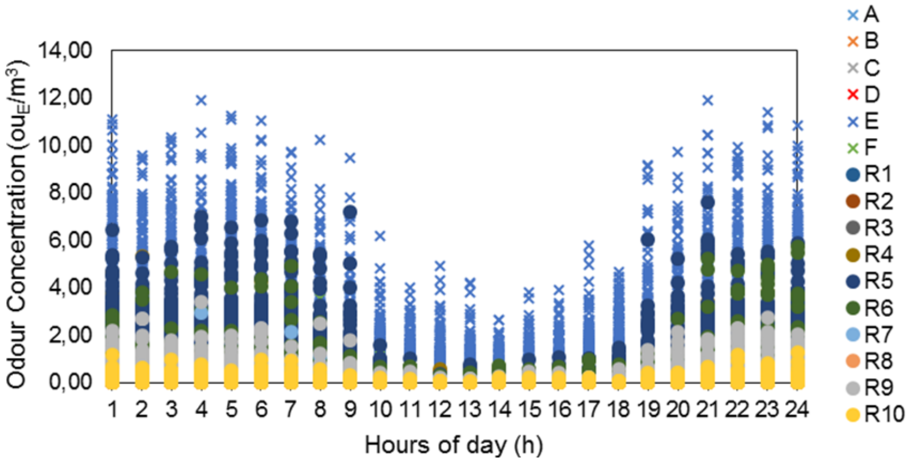

Figure 2: Daily distribution of the hourly peak odour concentrations for each receptor in the current scenario

The Table 2 reports the OER calculated for the project scenario.

Table 2: Odour emission rates – Project scenario

Odour source			OER [ou_E/s]
ID		Type of source	
EP01	EP01/1*	passive areal source	4000
	EP01/2*		800
EP07**	EP07/1	point source	400
	EP07/2	point source	171
	EP07/3	point source	220
	EP07/4	point source	220
EP08		passive areal source	3966
EP09		passive areal source	2588

* EP01/1 active in the cultivation, from 8 a.m. to 2 p.m. from Monday to Friday; EP01/2 = partial daily cover, from 2 p.m. to 8 a.m., from Monday to Friday; 24 hours per day on Saturday and Sunday.
** Alternately active for 15 days / torch, 24 hours per day, for a total amount of 8760 hours per year.

Figure 3a) shows the results of the numerical simulation of odour dispersion in the current scenario, represented as the map of the 98th percentile of the hourly peak odour concentration. The analysis of the results has shown how the pattern scenario was not related to significant olfactory exposure levels. For the modelling of the operating scenario, on the side of safety, the mitigation measures were not taken into account. From the analysis of the exposure map, it can be observed how the trend of the concentration isopleths was mainly influenced by the weather conditions, while the orographic conditions had a negligible influence on account of the flat terrains in the surrounding area. Figure 3b) reports the map of the 98th percentile of the hourly peak odour concentration, output from the numerical simulation of odour dispersion in the project scenario. The project scenario has revealed negligible levels of odour exposure, complying with UK-EA guidelines, at the main receptors. Individual isolated receptors and a group of scattered houses resulted potentially affected by the levels of exposure within the “evaluation range”. The emission point rise has determined a wider impacted area than the current scenario; however, the exposure levels at the receptors nearest to the landfill were found to be lower. The ‘worst’ olfactory exposure levels were recorded in “downwind” conditions of the odour emission sources.

a) b)

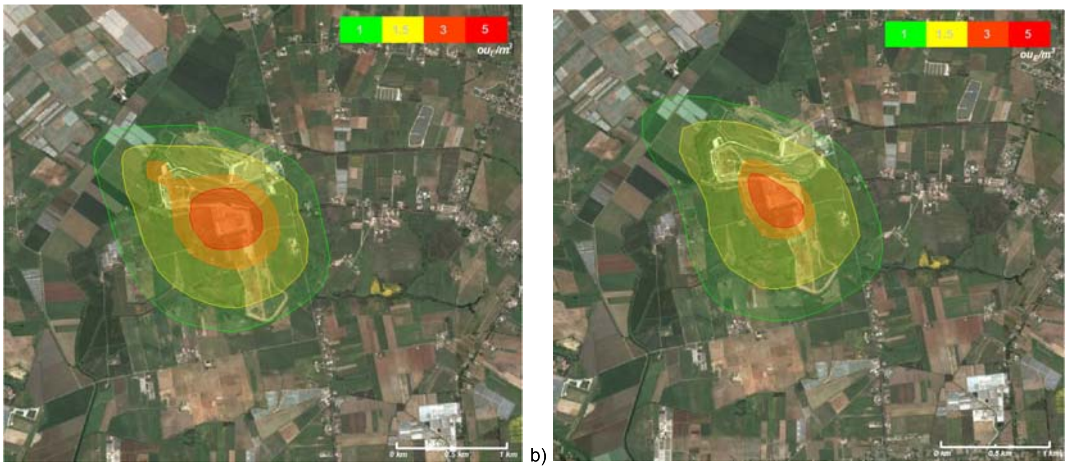

Figure 3: Maps of the 98th percentile of the hourly peak odour concentration – a) Current scenario; b) Project scenario

4. Conclusions

The study provides useful tools to implement dispersion models for the simulation of odour impact from intensive plants, such as the large investigated MSW landfill. The odour emission rates are the main inputs for the calculation of exposure levels by dispersion models. The olfactory exposure levels of both simulated scenarios resulted negligible at the main receptors. The results of the simulated scenarios were used for the recognition of the best odour control strategies. The pattern expansion scenario, which basically consists of raising heights of the odour point sourcespatterne, entailed the increasing of the impacted area and the reduction of the odour exposure levels at the main receptors. The isopleths of the odour concentration were mainly influenced by the weather conditions, since the morphology of the territory is flat. The highest odour exposure levels were recorded under "downwind" emission sources conditions and in the night time-slot. Therefore, since the waste movement in the active area of the active basin is implemented during the daytime hours, these activities do not significantly influence the odour impacts.

Acknowledgement

The data provided by Ind.Eco S.r.l. have been essential in order to conduct this study.

References

Brancher, M., & Lisboa, H. D. M. (2014). Odour Impact Assessment by Community Survey. Chemical Engineering Transactions, 40(I), 139–144. http://doi.org/10.3303/CET1440024

Chaignaud, M., Cariou, S., Poette, J., Fages, M., Despres, F., & Fanlo, J. (2014). A New method to Evaluate Odour Annoyance Potential. Chemical Engineering Transactions, 40, 13–18.

Chemel, C., Riesenmey, C., Batton-hubert, M., & Vaillant, H., 2012. Odour-impact assessment around a land fill site from weather-type classification , complaint inventory and numerical simulation. Journal of Environmental Management, 93(1), 85–94.

Department of Environment and Conservation (DEC), 2006. Technical notes - Assessment and management of odour from stationary sources in NSW

Environment Agency, 2002. Integrated Pollution Prevention and Control (IPPC) - Odour - H4 Part 1

Hayes, J. E., Stevenson, R. J., & Stuetz, R. M., 2014. The impact of malodour on communities: A review of assessment techniques. Science of the Total Environment, 500-501, 395–407. http://doi.org/10.1016/j.scitotenv.2014.09.003

Hayes E.T., Curran T.P., Dodd V.A., 2006. A dispersion modelling approach to determine the odour impact of intensive poultry production units in Ireland, Bioresource Technology, 97 (15) pp. 1773-1779.

Naddeo, V., Zarra, T., Giuliani, S., & Belgiorno, V. (2012). Odour Impact Assessment in Industrial Areas. Chemical Engineering Transactions, 30(i), 85–90.

Sarkar, U., & Hobbs, S. E., 2003. Landfill odour : assessment of emissions by the flux footprint method, 18, 155–163. http://doi.org/10.1016/S1364-8152(02)00071-3

Schauberger, G., Piringer, M., & Heber, A. J., 2014. Odour emission scenarios for fattening pigs as input for dispersion models: A step from an annual mean value to time series. Agriculture, Ecosystems and Environment, 193, 108–116. http://doi.org/10.1016/j.agee.2014.04.030

Schiffman, S. S., Walker, J. M., Dalton, P., Lorig, S., Raymer, J. H., Shusterman, D., Dalton, P., 2008. Potential Health Effects of Odor from Animal Operations , Wastewater Treatment , and Recycling of Byproducts Potential Health Effects of Odor from Animal Operations , Wastewater Treatment , and Recycling of Byproducts, 0813(March 2016). http://doi.org/10.1300/J096v07n01

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, MA.

Shusterman, D., 2001. Odor-associated Health Complaints : Competing Explanatory Models, 339–343.

Sironi S., Capelli L., Céntola P., Del Rosso R., Pierucci S., 2010. Odour impact assessment by means of dynamic olfactometry, dispersion modelling and social participation. Atmospheric Environment, 44 (3), pp. 354-360.

Zarra T., Naddeo V., Belgiorno V., 2009a. A novel tool for estimating the odour emissions of composting plants in air pollution management. Global NEST Journal, Vol 11, No 4, pp 477-48.

Zarra T., Naddeo V., Giuliani S., Belgiorno V., 2010. Optimization of field inspection method for odour impact assessment. Chemical Engineering Transactions, 23, 93-98.

Zarra, T., Reiser, M., Naddeo, V., & Belgiorno, V. (2012). A comparative and Critical Evaluation of Different Sampling Materials in the Measurement of Odour Concentration by Dynamic Olfactometry. Chemical Engineering Transactions, 30, 307–312.

Zhao, Y., Lu, W., & Wang, H., 2015. Volatile trace compounds released from municipal solid waste at the transfer stage : Evaluation of environmental impacts and odour pollution. Journal of Hazardous Materials, 300, 695–701.