Odour management in landfill during the intermediate covering works: mitigation technologies and impacts assessment

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Abstract

Odours are among the main causes of complaints in regards to environmental issues for a variety of plants, including landfills. The emissions from landfills can lead the quality of life and negatively influence the area nearby. To protect people living surrounding from excessive odour exposures, different environmental protection practices may be implemented. In order to optimize technical and economic aspects, various configurations should be taken into account. In this view, the odour dispersion modelling represents a suitable tool to simulate different scenarios. In the present study, the odour impact from a big landfill located in Borgo Montello (Lazio Region, Italy) has been assessed by dispersion model. Different operating conditions were simulated, with a view at minimizing the odour annoyance also during the intermediate covering works. The Calpuff model was selected as it is well recognized among the preferred models for assessing the long range transport of pollutants. The Odour Emission Rates, input of this kind of models, were calculated based on the results of dynamic olfactometry. The results from the dispersion model were investigated to define the best measures for the control of the odour emissions during the most impactful operations.

Keywords: dispersion model, odour annoyance, environmental protection practices, control

1. Introduction

The waste disposal in landfills entails the release of gases into the atmosphere, which constitute a source of unpleasant odours and, thus, annoyance among the resident population (Brancher and de Melo Lisboa, 2014; Chaignaud *et al*., 2014). The odour emissions, indeed, are among the main causes of complaints and denunciation towards a variety of intensive plants, in particular environmental protection facilities. These remonstrations represent an impediment to the management of existing plants as well as hinder the placement of new ones (Zarra *et al*., 2009). The solid waste in particular are subject to the aerobic and anaerobic degradation of organic matter, which result in an intensive production of gases, including methane, carbon dioxide and volatile organic compounds. A variety of volatile organic and inorganic compounds, although characterized by low odour detection thresholds, are typically the main responsible of nuisance to the near-living population (Lucernoni *et al*., 2016, 2017; Prata *et al*., 2016). The negative impacts on the air quality in the areas nearby the landfills are well known. Despite the fact that nowadays it is still not demonstrated the correlation between odour emissions exposure and the occurrence of clinical diseases, symptoms as headache, nausea, stress are, instead, reported in several studies (Zarra *et al*., 2008). It is not well defined the correlation between the odour exposure and odour annoyance due to the presence of individual and subjective factors, which imply different responses among receptors exposed to comparable odour exposure levels (Boers *et al*., 2016). The odour emissions from landfills are strictly dependent from the release of volatile compounds through percolate and biogas and, thus, to the technologies implemented for their management. With a view at optimizing suitable strategies to control odour exposure, specific methods for odour emissions measurement and odour impact assessment are needed (Lucernoni *et al*., 2016). The odour impact assessment represent an effective tool with regard to the acceptability of odour emitting activities among the population living surrounding. The results of the implementation of dispersion models allow the comparison between different scenarios (Schauberger *et al*., 2014). The overlap of the odour exposure levels resulted from different sources could be taken into account using dispersion model, retrieving information on location, source characteristics and meteorological conditions (Boers *et al*., 2016; Naddeo *et al*., 2016). Dispersion models allow the calculation of ambient concentrations; these values, with regards to odours, have to be modified to take into account the physiology of the human breathe. For this reason, the obtained concentrations are amplified by the peak-to-mean ratio (Piringer *et al*., 2015). The main data input of dispersion models are the Odour Emission Rates (OERs), expressed as odour unit per second (Schauberger *et al*., 2014). With regards to area sources, it is evaluated the Specific Odour Emission Rate (SOER), expressed as the odour units emitted from the source per surface and time unit, referring to the flow rate used for the sampling (Capelli *et al*., 2013). The definitions of the OERs and SOERs consists of 3 main phases: odour samplings, olfactometric analysis and data elaboration (Capelli *et al*., 2008; Sironi *et al*., 2010). Among the main techniques for the characterization of odour emissions, the sensorial methods, which use the human nose as sensor, allow the comprehension of the complexity of the odour mixture to analyze (Zhao *et al*., 2015, Sarkar and Hobbs, 2003). In particular, the dynamic olfactometry represents a widespread solution for the definition of odour concentrations, standardized by UNI EN 13725:2004 (Zarra *et al*., 2012). This technique relies on a panel of trained persons in order to reduce the subjectivity of the measurements (Capelli *et al*., 2008). In the present manuscript are shown the main results with regard to a case study concerning the implementation of a dispersion model to assess the odour impact from a big landfill in the Central Italy. The CALPUFF atmospheric dispersion model was implemented in order to compare different scenarios, to which were related different odour sources configurations and OERs. The investigated conditions were evaluated in terms of impacted area resulting on the territory surrounding the landfill. Different scenarios were simulated, with a view at addressing the optimization of the measures for the control of odour impact. The implementations of different environmental protection practices were analyzed in the operating conditions and also during a temporary phase which included the impactful operations of waste movement.

2. Materials and methods

2.1. Site description

The studies were carried with regard to a landfill plant located in Borgo Montello, Lazio Region (Central Italy). The site is 11.5 km far from the city center, in a rural area. The plant is composed of five basins, four of which result in the post-management phase with permanent cover. The main activities carried out at the active basins are: weighing, inspection and acceptance or refusal of waste; transport of waste; waste disposal; transit of vehicles. The activities carried out both at the active and post-operating basins, instead, are: management and control of the drainage and leachate collection systems; management and control of the collection and combustion systems of biogas; management of human and technological resources available at the plant.

2.2. Odour sources characterization

The simulated scenarios, which have been elaborated by the implementation of the dispersion model, allowed the comparison between different environmental protection measures, in the current conditions, in the working phase scenario and in the final closure prospect. In the current scenario, the active basin has an intermediate cover. The simulated project scenario provided for a temporary phase in which a layer of soil was disposed on the top of the active basin, in order to accelerate the solid waste compaction. The foreseen settlement resulted to be between 2.5 to 4 meters. Before the disposal of the load on the basin, a previous leveling of the surface was considered; in order to carry out the leveling, an intensive movement of solid waste resulted necessary. The designed manufacturing activities involved the movement of 13,750 m^3 of solid waste. These working activities were simulated for 8 hours per day, five days per week, in the worst-case scenario, for a period of two months. In the working phase scenario, the active basin was simulated considering three different conditions: covered waste, excavation of waste, handled waste. For this reason, at this source, the odour samplings were carried out at different levels depth: -0.5 m, - 1m, - 4.5 m. A variety of control measures were foreseen in this phase: they consisted of a nebulizers net and a high nebulizer of mask agent, an anti-dust barrier and a vacuum cleaner, all arranged along the main wind direction. In the final closure scenario, a long-term cover was designed. The odour sources considered for all the simulated scenarios were (Table 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). For each investigated source, different air samples were taken. The sampling of point sources was carried out, according to EN 13725:2003, using the ‘lung’ technique. Nalophan® sampling bags, with a 10 liter volume, were placed inside a rigid container (length 685 mm, diameter 152 mm). The sampling of area sources was carried out using a 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 definition of odour concentrations was realized by Dynamic Olfactometry (DO). The analyses were conducted within 30 h after sampling at Laboratory of Environmental Engineering (SEED) of the University of Salerno, according to EN 13725:2003. The olfactometric analyses were carried out using a TO8 olfactometer (ECOMA, D), based on the ‘‘yes/no’’ method, relying on a panel composed of four trained persons. The EP01, EP03, EP08 and EP09 sources were patterned as passive area sources, with natural wind ventilation. EP07/1, EP07/2, EP07/3, EP07/4 were patterned as channeled point sources, with forced ventilation.The odour concentrations of each investigated source were used for the calculation of the OERs. The OERs for the point sources were calculated according to the equation (1).

$$OER = Q \cdot C_{OD} \quad (1)$$

In the equation (1), OER is the odour emission rate, expressed in ouE/s, Q is the flow rate in Nm^3/s and C_{OD} is the odour concentration in ou_E/m^3. The OERs of the passive area sources were calculated multiplying the SOERs (Specific Odour Emission Rate), expressed in odorimetric units emitted per surface unit and time ($ou_E/(m^2s)$) and calculated according to the equation (2), for the emission source surface.

$$SOER = \frac{Q \cdot C_{OD}}{A_W} \quad (2)$$

In the equation (2) Q is the flow rate of the neutral air stream inlet the chamber, expressed in m^3/s, equal to 3.9 lpm, C_{OD} 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.

2.3. Experimental set-up

The odour dispersion was determined according to the guidelines suggested by US EPA, using the preferred model CALPUFF.

Table 1: Odour sources

Odour source		
ID		**Type of source**
EP01	EP01/1*	passive area source
	EP01/2*	
EP03		passive area source
EP07**	EP07/1	point source
	EP07/2	point source
	EP07/3	point source
	EP07/4	point source
EP08		passive area source
EP09		passive area source

* 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.

The spatial domain implemented was 5,000 m x 5,000 m, with a square grid of receptors of 100 meter per side. The characterization of the terrain following was carried out taking into account seven vertical layers. The coefficients of the land use were selected according to Scirè *et al.* (2000). The full potential of CALPUFF model was possible to obtain in combination to the 3D meteorological and micro meteorological data generated by CALMET. The hourly meteorological data (wind speed and direction, pressure, temperature and rainfall), needed as input to CALMET, were acquired from MAIND, for a period of one year.

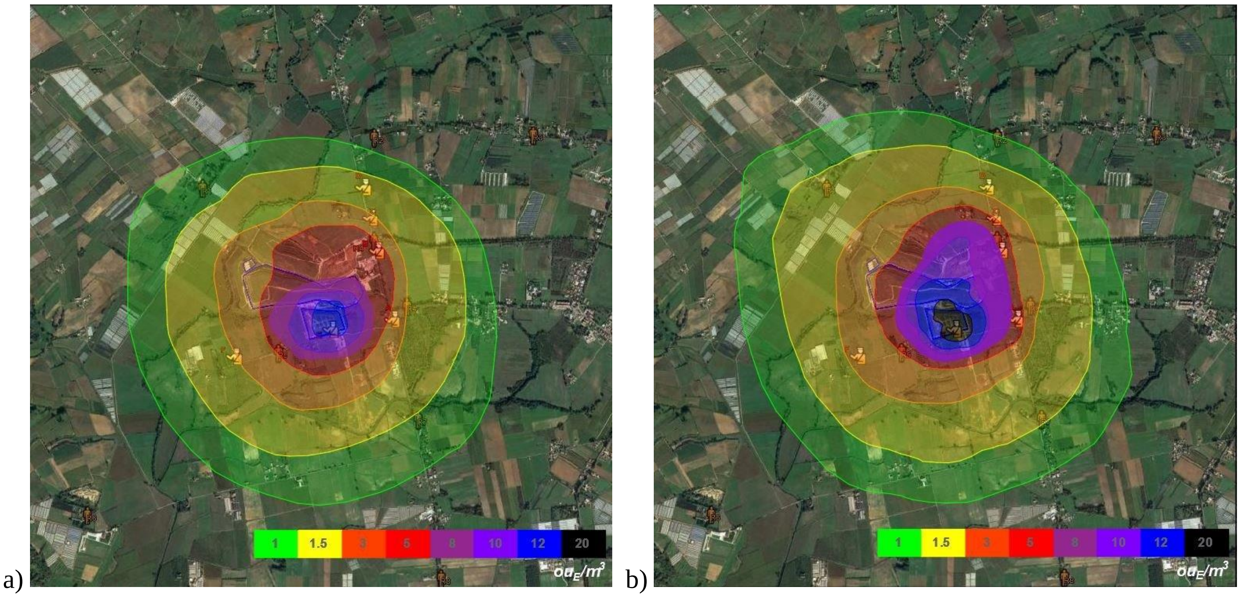

Figure 1. Comparison of the working activities scenarios with (a) and without (b) mitigation measures

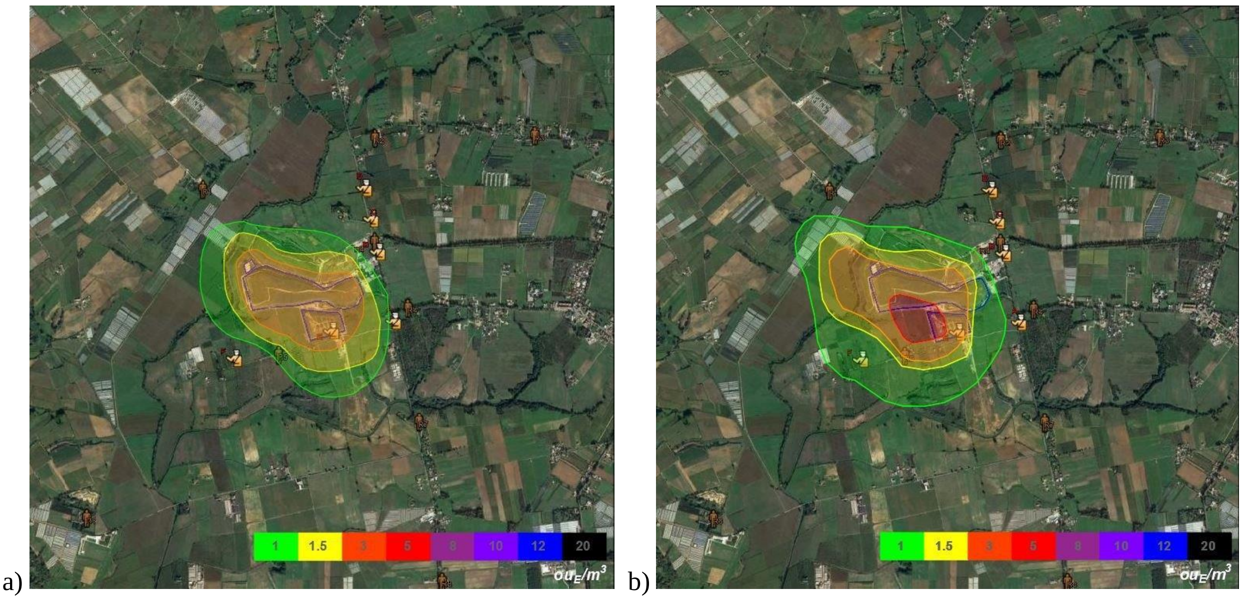

Figure 2. Comparison of the project scenario (a) and current scenario (b)

The outputs of dispersion model were, for each hour and each receptor, the hourly average of the odour concentrations. These values were multiplied for the peak-to-mean (P/M) ratio, in order to obtain the peak odour concentrations. For sources at low latitude of the emission point and affected by trailing effect the P/M was assumed equal to 2.3, as suggested by the Department of Environment and Conservation (DEC, 2006). Fourteen sensitive receptors were identified. The odour exposure levels were calculated at an elevation of 2 m.

3. Results and discussion

In Figure 1 are reported the results of the numerical simulation of odour dispersion in the working phase scenario, in the presence and without mitigation measures, represented as the map of the 98th percentile of the hourly peak odour concentration. This phase has resulted as a highly odour impacting phase, due to the fact that it was foreseen waste handling at different depths. Without the implementation of the protection practises (Figure 1b), the isopleth corresponding to an odour concentration of 1 ou_E/m^3, the perception threshold, covered an area of more than 9 km^2. The area in which the odour impact resulted "unacceptable", according to the definitions of the Regional Decree of Lombardia Region n. IX/3018, presented odour concentrations greater than 5 ou_E/m^3 and resulted of about 1.5 km^2. By the implementation of the described mitigation measures (Figure 1a), the isopleths corresponding to the 98th percentile of the hourly peak odour concentration, covered a smaller area. The impacted area, contained within the isopleth corresponding to 1 ou_E/m^3, resulted equal to 8 km^2 and the maximum value of hourly peak odour concentration resulted lower than 20 ou_E/m^3. The impacted area with a level of exposure defined as "unacceptable" resulted of about 1 km^2, and the sensitive receptors exposed to a corresponding odour concentrations greater than 5 ou_E/m^3 decreased from five to two. The simulations of the working phase scenarios, both with and without the control measures, were carried out taking as reference time only two months, instead of one year. In Figure 2 are reported the results of the operating scenario, implemented both in the current conditions and in the project scenario of final closure. In the project scenario, the hourly peak odour concentrations resulted lower than 5 ou_E/m^3 over the entire investigated area. 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". In the project scenario, only one sensitive receptor resulted exposed to moderately offensive odour levels and the corrisponding impacted area decreased from 2.2 km^2 (current scenario) to 1.7 km^2 (project scenario).

4. Conclusions

The implementation of dispersion models resulted a useful tool for the optimization of mitigation strategies with the aim at evaluating odour impact surrounding a big landfill. The numerical simulations allowed to compare different operating conditions along with a variety of operative solutions, in order to minimize the odour exposure levels. The exposure levels resulted significant during the working phase; however, this phase has an expected duration of two months and the designed measures allowed a considerable decreasing of the levels of exposure at the receptors closer to the investigated landfill. In addition, should be noted that the modelling of this phase was carried out referring to its real expected duration, without spreading the considerable odour emissions over one year, the reference time considered for the other simulated scenarios. In the project scenario, the hourly peak odour concentrations resulted lower than 5 ou_E/m^3 and, therefore, below the threshold considered "unacceptable" according to the above-mentioned Regional Decree. Since the morphology of the territory resulted flat, the isopleths of the odour concentrations were mainly influenced by the weather conditions.

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