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# Evaluation of an Odour Emission Factor (OEF) to estimate odour emissions from landfill surfaces

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## HIGHLIGHTS

- Odour emission factors are fundamental tools for air quality management.
- Indirect approaches should preferred for the estimation of Odour Emission Rates.
- The presented refined methodology leads to an OEF of 0.0113 $ou_E/m^2/s$.
- The landfill cover and soil reduce the LFG and odour emissions.
- Some meteorological parameters are correlated to LFG emissions from landfills.

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## ABSTRACT

Emission factors are fundamental tools for air quality management. Odour Emission Factors (OEFs) can be developed in analogy with the emission factors defined for other chemical compounds, which relate the quantity of a pollutant released to the atmosphere to a given associated activity. Landfills typically represent a common source of odour complaint; for this reason, the development of specific OEFs allowing the estimation of odour emissions from this kind of source would be of great interest both for the landfill design and management. This study proposes an up-to-date methodology for the development of an OEF for the estimation of odour emissions from landfills, thereby focusing on the odour emissions related to the emissions of landfill gas (LFG) from the exhausted landfill surface. The proposed approach is an "indirect" approach based on the quantification of the LFG emissions from methane concentration measurements carried out on an Italian landfill. The Odour Emission Rate (OER) is then obtained by multiplying the emitted gas flow rate by the LFG odour concentration. The odour concentration of the LFG emitted through the landfill surface was estimated by means of an *ad hoc* correlation investigated between methane concentration and odour concentration. The OEF for the estimation of odour emissions from landfill surfaces was computed, considering the landfill surface as the activity index, as the product between the mean specific LFG flux emitted through the surface resulting from the experimental campaigns, equal to 0.39 $l/m^2/h$, and its odour concentration, which was estimated to be equal to 105′000 eq. $ou_E/m^3$, thus giving an OEF of 0.011 $ou_E/m^2/s$. This value, which is considerably lower than those published in previous works, should be considered as an improved estimation based on the most recent developments of the research in the field of odour sampling on surface sources.

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## 1. Introduction

Although odorous compounds are not necessarily toxic or hazardous for human health, it is known that the odours resulting directly or indirectly from human activities may cause adverse effects on citizens (Aatamila et al., 2011; Sucker et al., 2009), and are therefore actually considered as atmospheric contaminants. For this reason, odours are nowadays subject to control and regulation in many countries (Nicell, 2009).

Although there are different approaches that can be adopted to regulate odour-related problems, the most recent odour regulations that have been published around the world are based on the application of dispersion modelling (Sironi et al., 2013). One of the main reasons for the spreading of odour impact assessment

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approaches based on odour dispersion modelling is that they allow to overcome the limitation of accounting just for the emission at the source, without considering the consequent citizens' exposure to odours (Capelli et al., 2013a). As a matter of fact, besides source characterization and quantification of the Odour Emission Rate (OER), odour impact assessment should involve the consideration of other factors, such as the orography of the terrain where source and receptors are located, meteorology, land use and density of population (Chemel et al., 2012; Schauberger et al., 2012; Hoff et al., 2006). Odour dispersion modelling allows to account for these factors by simulating how odours disperse into the atmosphere, and therefore to calculate ground odour concentration values in each point of the simulation domain. Odour dispersion models also entail the advantage of being not solely descriptive, but also predictive, meaning that they can be applied for the assessment of the odour impact either of existing or of designed plants.

In the first case, emission data for the model input are generally retrieved experimentally by means of olfactometric campaigns aimed to a detailed quantification of the odour emissions (in terms of $ou_E/s$). In the second case, in order to apply odour dispersion modelling to predict the odour impact of a plant, it is mandatory to be able to predict the entity of the odour emissions required as model inputs.

Based on these considerations, it is clear that emission factors and emission inventories are fundamental tools for air quality management (Capelli et al., 2014a). Emission estimates are important for developing emission control strategies, determining applicability of permitting and control programs, evaluating the feasibility and the effects of appropriate mitigation strategies, and a number of other related applications by different users, including national and local agencies, consultants, and industry.

As far as odour emissions are concerned, Odour Emission Factors (OEFs) can be developed in analogy with the emission factors defined by the United States Environmental Protection Agency (1995) for other pollutants/chemical compounds, which relate the quantity of a pollutant released to the atmosphere to a given associated activity. In the estimation of OEFs for industrial plants, these values can be calculated as the emitted odour emission rate (in $ou_E/s$), divided by a specific activity index, which may be for example the gross weight production, the site surface or a time unit. Based on such considerations, OEFs would represent a simple and effective mean to predict the odour emissions from a given plant typology, using one (or more) parameter (activity index) related to the odour emission itself. Of course, OEF, despite their simplicity, allow a rather "rough" estimation of odour emission rates, but knowing the order of magnitude of the odour impact expected is in most cases sufficient in order to evaluate the appropriateness of the location of a new plant or the design of possible odour control systems. Nonetheless, OEFs may be further "refined" by evaluating their dependence from more parameters than just one activity index, such as atmospheric conditions or seasonality (Schauberger et al., 2013).

In the scientific literature it is possible to find some specific studies, giving indications about odour emission factors for some plant typologies, such as for instance composting plants (Sironi et al., 2006), wastewater treatment plants (Capelli et al., 2009a,b), rendering plants (Sironi et al., 2007), and livestock operations (Nicholas et al., 2002; Schauberger et al., 2014).

A first study on OEFs was published in 2005 (Sironi et al., 2005) regarding the estimation of OEFs for the assessment and prediction of landfill odour emissions, which represent one of the most common sources of odour-related complaint. For this reason, the development of specific OEFs allowing the estimation of odour emissions from this kind of source would be of great interest both for the landfill design and management. Unfortunately, the data presented in the paper of Sironi et al. (2005) should be considered obsolete, mainly due to the use of a sampling technique that was later proven to significantly overestimate emissions (Capelli et al., 2015).

The present study proposes an up-to-date methodology for the development of an OEF for the estimation of odour emissions from landfills, thereby focusing on the odour emissions related to the emissions of landfill gas (LFG) from the landfill surface. As a matter of fact, due to its large extension compared to the other sections of the plant (e.g., fresh waste tipping, torches), as well as to the offensive odour character of LFG (Dincer et al., 2006), this is recognized to be the main source of malodours from landfills (Saral et al., 2009; Sarkar and Hobbs, 2003).

## 2. Materials and methods

### 2.1. The sampling hood

Starting December 2014, the research group of the Olfactometric Laboratory of the Politecnico di Milano (LabOlf) uses a specific sampling device for investigations in the field (Capelli et al., 2014b). The hood is based on a design inspired by the models proposed in literature, namely the UK EA design (UK EA, 2010) and a variant proposed by a German research group (Rachor et al., 2013). More in detail, the German design is an evolution of the UK EA proposal and is a cylindrical chamber with a base area of 0.12 $m^2$ and a height of 50 cm, giving an internal volume of 60 l. The novel aspect of this hood is that it is equipped with a 3 m long tube with a 4 mm inner diameter that assures no overpressures are generated inside the hood during operation due to LFG emission from the surface, while the inner volume is isolated from the outside environment thanks to the long diffusion path imposed, i.e. long tube. The LabOlf research group adopted the idea proposed by Rachor et al. in order to realize the hood that is used for sampling on landfill surface, but the design was further modified as shown in Fig. 1. The hood has a squared base, 50 cm $\times$ 50 cm and height 10 cm, giving an internal volume of 25 l. The main difference with respect to the design proposed by Rachor et al. is the much lower height of the chamber (10 cm vs. 50 cm). This choice is based on the nature of the methane ($CH_4$) concentration increase inside the hood, which is expected to be mainly diffusive, thus very slow, and higher heights would cause the concentration profile inside the chamber to be very inhomogeneous along the hood height. On the other hand, it is However, unfeasible to use sampling hoods with too small heights due to the non-homogeneity of the landfill surface soil. The hood is made of steel, to be partially inserted in the soil in order to minimize LFG

**Fig. 1.** The LabOlf sampling device used for $CH_4$ and odour concentration measurements.

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