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DISPERSION MODELING AND FIELD INSPECTIONS APPROACH TO EVALUATE THE ODOR IMPACT OF A COMPOSTING PLANT IN LISBON

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Abstract: Composting Plants are a potential source of offensive odors that can create annoyance within communities. Therefore, odors have been rated as the primary concern of the public relative to implementation of composting facilities. Engineers must be conscious of this fact and be familiar with odor generation and control.
In this study, dispersion modeling and field inspections were used to quantify the potential odor impact, around a particular Composting Plant site in Lisbon, Portugal.
The short-term model ISCST3, developed by the Environmental Protection Agency (US-EPA), was applied to this case study. Field inspections, based on VDI 3940 part II: 2006 were made near the composting Plant.
Given the lack of national legislation or guidelines on this subject, the odor levels evaluation was performed based on German Guideline: Determination and Assessment of Odor in Ambient Air (Guideline on odor in ambient air / GOAA). In these guidelines, odor assessment is based on the concept of the so called odor hour. An hour is called “an odor hour” when, at least 10% of the time within this hour odor is perceived (VDI 3788 part I: 2000). The frequency of occurrence of “odor hours” within a year is then compared to given limit values. These limit values are 10% for residential areas and 15% for industrial areas.
In this work, the odor perception frequency was obtained by converting the odor concentrations, simulated by the dispersion model ISCTST3, to "odor hours", applying a conversion factor.
A period of September 2008 was chosen as baseline data for field inspections, and consequent application of model dispersion. These field inspections revealed an impact on local residents, which exceed the limit value of 10% of odors perception. The dispersion modeling confirmed the obtained values, and demonstrated that the odors frequency perception, from the operation of the Composting Plant, could get to the population at a level higher than the 10% limit, in a region that exceeds 1500 m south to the facility.

Key words: *Odor impact assessment, Dispersion Modeling, Field inspections.*

INTRODUCTION

Exposure to odors that are perceived to be unpleasant can affect well-being at levels of exposure well below those that would lead to physiological or pathological effects, e.g. sleep disorders, headaches, respiratory problems.
A smell that is perceived to be unpleasant in the context of a person’s personal environment is hard to ignore, and easily leads to an overall negative appraisal of that environment itself.
Moreover, prolonged exposure to foul odors can generate undesirable reactions ranging from emotional stresses such as unease, discomfort, headaches, or depression to physical symptoms including sensory irritations, headaches, respiratory problems, nausea, or vomiting. When this occurs, exposure to odors becomes an issue of public health. Odor annoyance occurs when a person exposed to an odor perceives it as unwanted or objectionable (Environment Agency, 2002).
Responses to odors are highly variable and can result in a wide variety of effects. Generally, the impact of an odor results from a combination of interacting factors, collectively known as FIDOL: frequency (F); intensity (I); duration (D); offensiveness (O) and location (L). These factors influence the extent to which odors adversely affect individuals and can be used as a basis for odor investigations and impact assessments (Environment Agency, 2002).

Odor complaints are common in urban communities when residential neighborhoods are located near some activities like agriculture, sewage treatment works, composting plants, resins and chemical manufacturers, refining operations and landfills, among others.

Characteristics of Odor from Composting

The nature of the odor emitted from the composting process will depend on the type of material being processed and the stage within the composting cycle. Due to the necessary reliance on microorganisms to degrade the organic waste, there will always be some odor emitted at each stage of the process. The key to good composting is to manage the process to avoid excessive odor emissions (DEFRA, 2009).

Odor Sources

The primary releases of odors can be greatly reduced by ensuring that the composting process does not become anaerobic. Where significant emissions are released in the initial composting phase, emissions may need to be contained. The potential release points are as follows (DEFRA, 2009):

- Raw material reception, storage and handling;
- Accelerated decomposition of the raw materials often due to storage of wet material prior to delivery to site;
- From the application of leachate onto the feedstock;
- From the storage, handling and transport of the feedstock during the composting operation, particularly during, and after, mechanical turning and mixing operations;
- From the composting process particularly if the material becomes anaerobic;
- From the storage and disposal of any waste materials;
- From the collection, storage and re-use of liquid effluent (leachate);

- From the collection, treatment and discharge of waste and effluent from the odor arrestment plant; and
- From the odor arrestment plant discharge (this may be a stack or vent or may be a biofilter with an area source at ground level).

Lisbon Composting Plant

This study was applied to a Composting Plant site in Lisbon, which is surrounded by a small population. The emissions data of odor emission concentration of the biofilter and the volume flow rates were provided by the Composting Plant. The odor emissions mass flow for the composting hall were determined on the basis of process data (flow rate, size of the hall, operating hours, etc.). Table 1 summarizes the odor emission concentration used in this study.

Table 1. Odor emission concentrations for the composting plant.

	Odor concentration ($OU.m^{-3}$)
Open biofilter	1740
	3200
	1329
Closed biofilter 1	913
Closed biofilter 2	757
Closed biofilter 3	530
Closed biofilter 4	557
Gas tank	1750
Hydrolyze tank	430
Composting Hall	604

METHODS

Methods for assessing the impacts of odors on communities can be classified according to two distinct approaches that can be used individually or in combination: namely, source characterization and subsequent prediction of impacts in surrounding areas, or direct measurements of impacts in the field.

The most common approach to odor impact assessment is to use mathematical models to predict the downwind odor concentrations on the basis of odor emission rates, topography and meteorological data. Through use of the dilution-to-threshold approach, odor concentrations at the source (in OU or $OU.m^{-3}$) can be quantified using standardized sampling and analysis techniques and instruments (e.g. European Method EN 13725:2003) (CEN, 2003). Subsequently, an odor emission rate from a source may be determined by multiplying the source odor concentration by the volumetric gas emission rate. The total odor emission rate from a facility is the sum of the individual emission rates from each source. Odor concentrations at receptors throughout an impacted region may then be estimated using appropriate dispersion models. Such models are commonly used to determine whether the emissions from a specific or proposed source are or will likely be in compliance with ambient air quality criteria. These models are used to predict the downwind concentration under any weather conditions from different types of sources, and across different terrain conditions (Nicell, 2009).

In this work, field inspections and dispersion modeling were used to quantify the odor impact of Lisbon Composting Plant. Field inspections were based on VDI 3940 Part II: 2006, and the odor levels evaluation was performed based on German Guideline: Determination and Assessment of Odor in Ambient Air (Guideline on odor in ambient air / GOAA) (GOAA, 1999). In Germany, odor assessment is based on the concept of the so-called odor hour. An hour is marked as odor hour if there is a clear odor perception in at least 10% of the time (VDI 3788 Part I, 2000). Limit values exists for the frequency of odor hours, i.e. the fraction of odor hours in a year.
The exposure criteria are differentiated for areas with different land use: < 10% ‘odor hours’ in residential areas; < 15% ‘odor hours’ in industrial areas.

The short-term model ISCST3, developed by the Environmental Protection Agency (US-EPA), was applied to this case study, were the odor perception frequency was obtained by converting the odor concentrations, to "odor hours", applying an adequate conversion factor.

Field inspections

Field panel measurements provide an estimate of total emissions from a source, including all diffuse sources. Field panels consist of 4-6 trained, qualified panel members selected using the same criteria as used for the odor laboratory, according to EN13725. The field panel makes observations on locations in the field, usually to determine the maximum distance of detectability of the odor from a particular source. This result, combined with the meteorological conditions during the field observations, is used for ‘reverse dispersion modeling’, which gives an estimated source emission rate as a result. Field panels can also be used to provide information on odor intensity and/or hedonic tone in field conditions.

The panel can not only be used for evaluating detectability of the source as a whole but it can also be used as a more ‘analytical’ instrument by teaching the panel to identify specific smells on-site and using this perceptive expertise to identify individual sources downwind. Using this technique the following information is recorded: type of smell, intensity and relative annoyance potential to the overall off site smell. This provides useful qualitative data, although they cannot lead to decisive conclusions as they reflect an assessment by a limited sample of the population, only briefly exposed to these odors. The field panel work requires certain weather conditions and requires characterization of meteorological conditions during measurements (wind speed, wind direction and stability class) **(**CH2M BECA LTD, 2000).The inherent uncertainty of the method of measurement is mainly determined by the inaccuracies involved in characterizing the turbulence in the mixing layer of the atmosphere, and the relatively poor capabilities of models to accurately predict short-term downwind concentrations. Generally speaking, the results of modeling impact on the basis of source emission data will give a more reliable result. Field panel data can, however, be invaluable in providing a field check based on actual conditions, especially where sources are complex and include diffuse sources (i.e. natural ventilation, large area sources etc).

For this case study, a 5 members panel made observations every 10 seconds, for duration up to ten minutes, at three cross section of wind direction. By traversing the ‘plume’ at intersections at varying distances, the results are gathered in the course of a number of hours. The technique was applied for a short period in September 11th and 12th, 2008, surrounding the composting plant. This work followed Germany’s guideline VDI 3940 Part 2, (2006).

Meteorological measurements, for temperature, humidity and wind speed and direction, were carried out during the field odor inspections. Figure 1 illustrates the wind rose for this period, were a typical NW wind conditions can be seen.

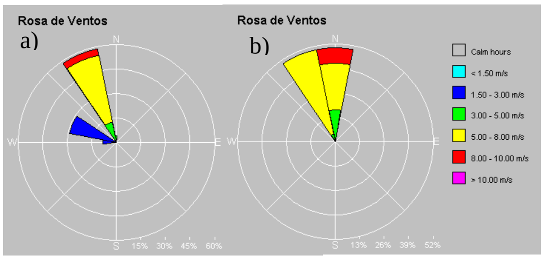

Figure 1. Meteorological wind rose for (a) September 11th 2008. (b) September 12th, 2008.

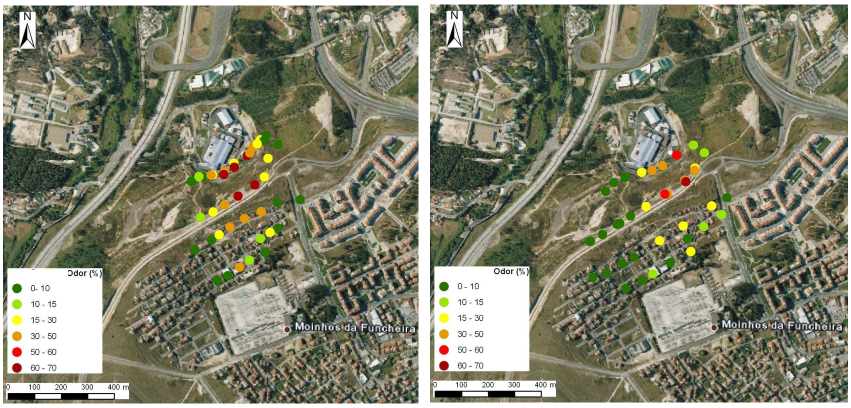

Figure 2. Odors perception frequency on September 11th, 2008 (left) and September 12th, 2008 (right).

Field inspections revealed an impact on local residents, which exceed the limit value of 10% of odors perception. Figure 2 shows that the odors frequency perception, from the operation of the Composting Plant, could get higher than 50%, south to the facility.

Dispersion modeling

Once the odor emission rate from the source is known, the impact in the vicinity can be estimated. The impact of an emission is very strongly determined by the way in which the odor is diluted in the atmosphere, while being carried towards the receptor by the wind.

The dilution can vary considerably, depending on the meteorological conditions: wind speed and turbulence of the atmosphere, also called atmospheric stability. The meteorology of a site will be a major factor determining the impact of a certain release of odors.

Dispersion models are used for predicting odor exposure with a view to assess expected annoyance. The relationship between odor exposure and annoyance has been established in a number of epidemiological studies, where a particular modeling approach was used. Ideally, when using dispersion models for odor annoyance prediction, the objective must be to apply the models that were used to establish dose-effect relationships in the underlying epidemiological case studies. This implies that, although better atmospheric dispersion models may become available, these can only be applied to odor problems after their results have been validated in dose effect studies, or by using base data from previous dose effect studies to establish the relationship between the model output and the annoyance criterion (Nicell, 2009). Such effects are available in newer generation models such as the widely used USEPA Industrial Source Complex Short Term (ISCST3). ISCST3 is a Gaussian dispersion model, which uses input data such as wind speed, wind direction, atmospheric stability and height of the mixing layer to determine ground level concentrations at defined receptor points (EPA, 1995).

Modeled contaminant concentrations using dispersion models are normally based on long averaging time periods, whereas odors can generate community complaints from a series of short detectable exposures (Mussio *et al.*, 2001). This model is typically used to predict ambient contaminant concentrations averaged over a 1-h time period or longer. That is, the concentration values predicted by these models represent the concentration of a contaminant that would be present in a mixed sample of ambient air that had been sampled over a 1-h period. For the case of a continuous plume, the duration of the time-averaged period or sampling time determines the effective size of the plume. Averaging over a specified period will smooth out some of the variations in the air contaminants concentrations and, therefore, averaging conceals peaks that may result from short-term variations in emission rates and meteorological conditions.

Since meteorological conditions are highly variable over very short periods of time, the use of a 1-h average fails to show the short-term peak odor concentrations that are likely to occur and be experienced during that period. The ambient odor concentrations underwent fluctuations that ranged from imperceptible levels to higher levels (Venkatram, A., 2002). The effect of time averaging is to significantly mask the peaks in odor concentration that are actually experienced by the population. Notably, odor may actually be experienced over much shorter intervals than 1 hour. Therefore, after predicting odor concentrations using the dispersion model ISCST3, it was necessary to convert the concentrations to a suitable averaging time to have a more realistic prediction of the conditions under which odors will be experienced. The most widely-adopted approach to estimating concentrations at shorter intervals from values predicted using dispersion models at longer averaging periods (e.g., 1-h) involves the following equation:

$$C_1 = C_0 \left(\frac{t_0}{t_1} \right)^n \qquad (1)$$

Where C_o and C_1 are the contaminant concentrations for the longer and shorter averaging times, respectively (e.g., in OU); and t_o and t_1 are the longer and shorter averaging times, respectively (e.g., in minutes); and n is an empirical exponent (dimensionless) that is dependent on the degree of atmospheric turbulence (i.e., stability) and typically ranges from 0.17 to 0.68 (Cha, Li and Brown, 1992). A value of n of 0.65 has been used for converting concentrations between averaging times.

ISCST3 was applied for the simulation of the dispersion of odor emissions from the composting plant. The model was applied for the same period of the field inspections, and to the entire year 2008, with a 5x5 km domain and 250 m grid spacing.

The results of dispersion calculation, for September 11th and 12th confirmed the obtained values, from field inspections and demonstrated that the odors frequency perception exceeded the 10% limit. Figure 3 shows frequency of odor- hours for 2008. The analysis of the distribution pattern shows the occurrence of an area with an odor frequency above the limit value of 10% (residential areas) to the south of the Composting Plant.

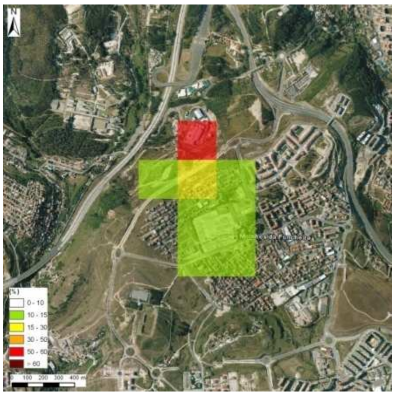

Figure 3. Frequency of odor-hours, in 2008 (space resolution 250x250 m).

CONCLUSIONS

This work demonstrates that field measurements and dispersion modeling provide a suitable method of determining the odor load on site. Field measurements allow to measure present odor load expressed as an odor frequency in relation to space and dispersion modeling provides a long term estimation of the odors concentrations.

The short-term model ISCST3, was applied to this case study, for estimating odors concentrations. Odor perception frequency was obtained by converting the odor concentrations, to "odor hours", applying an adequate conversion factor. The obtained values of occurrence of “odor hours” within the year 2008 were compared to German limit values.

Field inspections revealed an impact on local residents, which exceeds the limit value of 10% of odors perception and the dispersion modeling confirmed these values, and demonstrated the extent of this problem. Odors frequency perception, from the operation of the Composting Plant, could get to a region that exceeds 1500 m south to the facility.

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