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How the dynamic plume method can be used tot assess odour impact

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In 2016, the European standard EN 16841 on the determination of odour in ambient air by using field inspection was published. Part 2 of this standard describes two plume profiling methodologies to determine the extent of the odour plume downwind of a source: the dynamic and the static method.

This paper describes the dynamic plume method, showing some practical issues and some possible applications of this methodology that could be of good use for odour managers. Dynamic plume profiling can be used to estimate the total odour emission rate of a source using reverse dispersion modelling, for example in cases where dynamic olfactometry has some shortcomings.

* 1. Introduction

In 2003 the standard on dynamic olfactometry EN 13725 was finally published. This standard introduced some key concepts relevant for that time such as the procedure and statistics relevant for the calibration of a panel with a reference substance. The EN 13725 was taken as a reference and the text was transposed to analogue standards in countries such as Australia, New Zealand, Canada, Chile or Colombia.

However this standard had some limitations that restricted the use of dynamic olfactometry to cases in which the odour concentration was a few tens of times above the odour threshold of the odorants measured. The
EN 13725 also has some drawbacks when large surfaces need to be sampled.

To cover this gap a new European Standard on ambient air was published in 2016, the EN 16841. This European Standard is based on field inspections and it describes two methods for direct assessment of odours in ambient air making direct use of the effect of odorants on the human sense of smell.

The EN 16841 is divided in two parts: the EN 16841 Part 1 that describes a grid method which uses direct assessment of ambient air by panel members to characterize odour exposure in a defined assessment area and the EN 16841 Part 2 that describes a plume method for determining the extent of the downwind odour plume of a source.

This standard is the result of the work on plume measurements made in Belgium and Germany during the nineties (Bilsen et al(a), 2008; Kamp M., 2001). The methodology used to profile plumes in these two countries were, however different. In Germany the plume was traditionally profiled by a so called static method, whilst in Belgium the plume was calculated by using a dynamic method. That is why the new standard EN 16841-2 is also divided in two parts: the dynamic plume method and the static plume method.

The following image shows a schematic overview of the two methods described in EN 16841-2.

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Figure 1: Schematic of the dynamic plume (left) and the static plume (right) measurement according to the EN 16841. (Source, EN 16841).

In the dynamic method the assessors walk (or go by bike) in zigzags through the plume getting either closer or far away from the source whilst in the static method the assessors do several transects across the plume. Both techniques should give similar results, although to date no study has been published comparing the results of both methods. In the static plume measurement the assessors stay in a certain point and do evaluations of the smell every 10 seconds for ten minutes, while in the dynamic method the assessors stay for just a few seconds and then they move to another point.

Ambient odour measurement methods (and thus odour plume profiling) have a known drawback: sensory adaptation to the smell (Dalton et. al, 1996). For example, let’s consider hydrogen sulphide (H2S), a well-known odorant in wastewater. Stuck et. al (2014) showed that the time that an assessor takes to achieve desensitization under a constant flow of H2S in a lab varies between 40 to 70 seconds for H2S concentrations of 1 to 8 ppm, respectively.

Thus there is an important difference between the static and the dynamic plume methodologies for profiling a plume in the time that the assessor stays inside the plume, thereby increasing the risk of desensitization.

Of course, in the field it is somehow difficult to have a constant flow of an odorant unless the plume measurement is performed under steady state meteorological conditions. It is worth noting that calm wind conditions are specifically excluded from EN 16841, however, wind speeds of 2 to 8 m/s and a constant unvarying wind direction, might still cause a small variation of the odorant concentration over time at a point in space which may lead to nasal adaptation.

In a static plume measurement, the assessors must stay for ten minutes (600 seconds) in the field in order to obtain a representative sample, so there is some risk of desensitisation. This adaptation will likely occur more quickly with constant uniform low-varying meteorological conditions, emission rates and stack exit velocities.

The approach of the dynamic plume measurement method is however different. The assessors do not stay in the same position for any length of time and are kept moving constantly changing their position. In addition they stay inside the plume for just a short time after recording a positive odour response and, after that, they move out of the plume. Finally, as a further measure to prevent nose adaptation, the edge of the plume profile is recorded only when the assessor is entering the plume and not whilst exiting it.

The aim of this paper is to show how dynamic plume method described in the EN 16841 part 2 can be very useful for odour managers in cases where dynamic olfactometry analysis is difficult and may not offer representative results.

* 1. Materials and methods
		1. Determination of the plume extent

When applying the dynamic plume method, at least two experienced panel members who are qualified according to EN 13725 independently traverse the plume either on foot or by bike, while conducting observations at frequent intervals.

The principle of the dynamic plume method is illustrated in Figure 2. Depending on the situation under investigation, the panel members either start smelling close to the source or at a certain distance downwind. The plume is repeatedly crossed at different distances from the source in order to cover the extent of the whole plume. This also includes points downwind where no odour is recognized.

While crossing the plume, each odour ‘presence point or odour absence point is indicated on a topographical map or a portable GPS-system by adding a landmark. In order to prevent adaptation to the odour under investigation, panel members should regularly move in and out the plume, preferably by crossing it in a zigzag way.

A transition point is defined as the location halfway between the last odour absence point and the first odour presence point for the odour under investigation. In order to prevent possible adaptation effects which may cause incorrect observations, a transition point is only determined while entering the plume, and not while exiting.

After having traversed the whole plume, the transition points (if available) are determined for each crossing. The maximum plume reach estimate is determined from observations obtained during two crossings, one of which including at least one odour presence point, and another crossing where only odour absence points were recorded.

Finally the plume extent boundary is determined as a smoothed interpolation polyline drawn on a map using the different transition points, including the transition point at the maximum plume reach estimate.



Figure 2: Schematic of the dynamic plume measurement; in the left drawing the measurement starts downwind of the source; in the right drawing the measurement starts close to the source (EN16841-2)

* + 1. Calculation of the odour emission rate

The result of the dynamic plume measurement is the spatial extent of the odour plume. This result can be used to determine the total odour emission rate using reverse dispersion modelling.

The calculation of the odour emission rate for the dynamic method is included in one of the annexes of the
EN 16841 Part 2 and it is unfortunately only informative The method described in this annex has been used in Belgium for more than 20 years and can easily be applied in other countries. As the Flemish odour policy makes use of these measurements as one of the main techniques to calculate the emission rate and the impact of an odour source (Van Broeck et al, 2001; Dermaux et al., 2012; Van Broeck and Van Elst, 2003), the method is standardized in a Code of Good Practice (Bilsen et al, 2008; Bilsen and De Fré, 2009).

The odour emission rate of the source under study is calculated on the basis of the recorded plume extent, the source characteristics and the local meteorological conditions during the plume measurement.

To underline the differences between the field measurement and the olfactometric measurement, the odour emissions calculated on the basis of the plume measurement are expressed as sniffing units per second (su/s) instead of odour units per second. A fundamental difference with the European odour unit is the fact that sniffing units are determined by recognition of odour whereas European odour units are determined by detection and not necessarily recognition of the odour type. Typically 1 su/m³ corresponds with a concentration of 1 ouE/m³ to 5 ouE/m³.

One sniffing unit per cubic meter can be defined as the odour concentration at the border of the plume. This means that every transition point the odour concentration can be defined as 1 su/m³. It is not possible to quantify higher concentrations (e.g. 5 su/m³) by observation in the field.

The method of reverse modelling is applied as follows: in a first step the plume extent is determined as described above. In a second step a dispersion model is used to calculate the average odour concentrations on ambient air in the surroundings of the odour source under investigation. This is done on the basis of the source characteristics (emission rate, height, temperature, flow…) and the local meteorological data (wind speed, wind direction and stability class) during the measurement. Since the odour emission rate is not known, a fictitious emission rate of for example 5 000 000 ‘model units’ per second is assumed. The calculated odour concentrations on ambient air are expressed in terms of model units per m³.

After calculating the concentrations in ambient air (in model units per m³), the plume extent recorded during the plume measurement is put on the calculated odour distribution grid and the grid points on the edge of the plume are ticked. By definition, the odour concentration at these edge points is equal to 1 sniffing unit per m³ (su/m³). The average of the concentrations on ambient air (in model units per m³) of all edge points is calculated. This average value gives the number of model units corresponding with one sniffing unit. The odour emission rate in sniffing units per m³ is finally calculated by dividing the fictitious emission rate by this average value.

* 1. Results and discussion

The determination of the odour emission rate from a set of sources using plume methodology is relevant when a measurement of this rate using dynamic olfactometry is not possible, and an evaluation of the impact at a receptor is needed.

Unfortunately, the EN 16841 part 2 specifically mentions that the calculation of the emission rate of a source by using reverse dispersion model calculation is out of the scope of the text. Hence the calculation of the odour exposure in ambient air over a long time period is also excluded from the scope of the text.

A few studies have tried to compare the results provided by dynamic olfactometry + dispersion modelling (Capelli, et. al. 2012, Guo et. al. 2006) with those produced using field inspection, but there are still a few challenging questions, such as the type of dispersion model used for validation (Gaussian or Lagrangian) or the comparison of the results as one method is based on the detection threshold (European odour unit) and the other one is based on the recognition threshold (sniffing unit).

Although there are some uncertainties associated with this technique, plume profiling is generally very useful for many situations. The former German standard VDI 3880 recommended to make reverse calculation from plume inspections for complex sources like refineries, but this technique has a greater value in determining the odour emission impact of large surface area sources.

It is well known that the use of wind tunnels or flux chambers results in large differences in the estimation of the odour emission rate. A typical example where these equipment would be used is on open composting facilities or lagoons. Guillot et al. (2012) showed differences of up to 45.000 times in the calculation of the odour emission rate depending on the device used for sampling. For large surfaces, taking a few olfactometry samples using a wind tunnel/flux chamber might not be representative of the whole area. In other cases, the shape, or roughness of the surface (i.e. the front area of a landfill) might make sampling with these devices challenging.

Experience in Flanders shows that the dynamic plume measurement is a simple and effective method to determine the plume extent and to calculate the odour emission, although some practical issues should be taken into account when performing the measurements.

As the meteorological conditions have an important influence on the calculated odour emission, the measurements can only be performed within specific meteorological conditions, such as is slightly stable, neutral or slightly unstable atmospheric conditions and moderate wind speeds (2-8 m/s). Since these conditions are a common occurrence in central European countries such as Belgium, Germany and the Netherlands the method can be easily used here. However, due to the high frequency of calms typical of Southern Europe it is more difficult to meet the required meteorological criteria in these countries. However, this does not mean that the method cannot be used here; it is only harder to plan the measurements at the right meteorological conditions.

In practice, measurements are scheduled for a short time in advance. Planning is done on the basis of prognostic models or weather forecasts. In some studies a meteorological station is put in the field for a period of some months so local meteorological measurements can be taken into account when planning the measurements. Another aspect that should be taken into account when planning the measurements is terrain accessibility. Measurements can only be performed when the terrain downwind of the odour source is accessible by foot.

As the field measurement is performed by two panel members and requires no lab infrastructure, it is less expensive than an olfactometry measurement. However as a field survey consists of at least 10 measurements (in order to take into account possible variations e.g. source emission strength and meteorological conditions), costs may also rise. Where the standard advice is to conduct the 10 measurements over at least 5 different days, in Flanders it is common practice to perform the measurements on 10 different days, except in some exceptional cases (e.g. batch processes that seldom occur). This number of measurement days will also be written in the updated Flemish Code of Good Practice that is drawn this year.

Despite the method being simple and easy to use, it also has some limitations. As mentioned above, the meteorological conditions and the terrain accessibility must always be taken into account when planning the measurements. If the meteorological conditions change during the measurement, the sampling might have to be repeated at another time. Furthermore, the relative contribution of different sources within the same plant cannot be determined by using field inspections. This must be done by olfactometry measurements and individual dispersion modelling. The method can also not be applied to determine the plume extent of a source when the odour plume overlaps with the odour plume of an adjacent (and similar) source.

The following table shows some strengths and weaknesses of the dynamic plume method vs traditional dynamic olfactometry.

Table 1: Strengths and weaknesses of the dynamic plume method vs traditional dynamic olfactometry

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|  | Olfactometry  | Plume method |  |
| Calculation of emission rate from stacks | Suitable | For various stacks, it is not possible to calculate the individual emission rate. |  |
| Calculation of emission rate from unreachable stacks | Not suitable | Suitable |  |
| Calculation of emission rate from small area sources | Suitable | Suitable |  |
| Calculation of emission rate from large area sources | Not suitable | Suitable |  |
| Calculation of emission rate from fugitive emissions | Difficult | Suitable |  |
| Calculation of the relative contribution of different sources with similar odour caracter in the same plant | Suitable | Not suitable |  |
| Calculation of emission rate | Suitable | Suitable |  |
| Terrain not accesible | Suitable | Not suitable |  |
| Meteorological sampling conditions | No influence | Not possible during calm winds |  |
| Laboratory | needed | Needed only for screening assessors. |  |

* 1. Conclusions

The plume profiling methodology defined in the EN 16841, and especially the dynamic method specified in
part 2 is particularly useful in many cases where dynamic olfactometry measurements has shortcomings. This method is of great use when it is necessary to evaluate the odour impact of large area sources, such as landfills. This method is also useful when there are complex sources, when the fugitive emissions are prevalent in the overall odour impact and when there are volumetric odour sources.

The dynamic plume profiling is also suitable in those places where a proper olfactometric lab is not available or in situations where there are technical difficulties for sampling.

Odour managers can use the dynamic plume profiling according to EN 16841 anywhere in the world, even if there are prevalent calm conditions over the year in the area to be assessed.

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