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The European Standard prEN 16841-2 (Determination of Odour in Ambient Air by Using Field Inspection: Plume Method): a Review of 20 Years Experience With the Method in Belgium

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In 2006 the WG27 of CEN TC264 started with the normalisation of the different methods for determination of odour in ambient air. Existing VDI standards for the grid method and the stationary plume method were used as a starting point in this standardization committee.
In Belgium however, there is since the early nineties a lot of experience with a slightly different method. This method, called the dynamic plume method, is since then widely used for determination of odour downwind of a source. The method itself is very easy to execute, doesn't require special instruments and gives a very comprehensible output. The results of these observations are used in modelling exercises to determine the emission strength of a source and hence the odour impact on the surroundings. Emission is expressed as a number of sniffing units per second (su/s). The Flemish odour legislation is based on this methodology.
This paper gives an overview of the advantages and drawbacks of this method and indicates why this complementary method is a very valuable alternative for existing methods for the determination of odour. Attention is also given to uncertainty of this kind of measurements.

1. Introduction

Odours can be quantified at emission level with dynamic olfactometry, by measuring the odour concentration at the source according to the European Standard EN 13725 (2003). However, this method is not applicable for low odour concentrations, as observed downwind the source. Typically, olfactometric values are never given for levels lower than 10 ou_E/m^3 and generally these lower values only start in a range of 30 to 60 ou_E/m^3 (Guillot et al, 2011).
When these low values are to be measured, other methods are used (field olfactometers, sniffing team measurements, observations with grid method, …). However, standardization for the use of these methods was still missing. Therefore, in 2006 Working Group 27 (WG27) of CEN Technical Committee 264 (TC264) started with the normalisation of some methods for determination of odour in ambient air. The objective of these methods is to determine the presence or absence (YES/NO) of recognizable odours in and around the plume originating from a specific odour emission source, for a specific emission situation and under specific meteorological conditions (specific wind direction, wind speed and boundary layer turbulence). The unit of measurement is the presence or absence of recognizable odours at a particular downwind location of a source. Existing VDI standards for the grid method and the (stationary) plume method were used as a starting point in this standardization committee (VDI, 2006a; VDI, 2006b). In case of plume method, the extent of the plume is assessed as the transition of absence to presence of recognizable odour. In this observation, no link is made with the potential annoyance due to the presence of odours.
In Belgium however, there is since the early nineties a lot of experience with a slightly different plume determination method (Van Langenhove & Van Broeck, 2001; Van Broeck et al., 2001). This method, called the dynamic plume method, is since then widely used for determination of odour downwind of a source. The method aims to determine the extent of detectable and recognizable odours from a specific source using

direct observation in the field by human panel members under specific meteorological conditions. The method was developed separately in the northern Dutch-speaking part (Flanders) as in the southern French-speaking part (Wallonia), but showed a lot of similarities. In the CEN commission, this method was drafted to the so-called dynamic plume method, now described in the European pre-standard prEN16841-2.

In practice, the results of these observations are used in modelling exercises to determine the emission strength of a source and hence calculate the odour impact on the surroundings. This calculation however is not treated in the European Standard, since most countries have their own dispersion model with its particularities. Moreover, the limit or guide values used in European countries are differing a lot too, making this a difficult item to standardize.

2. Principles of the dynamic plume method

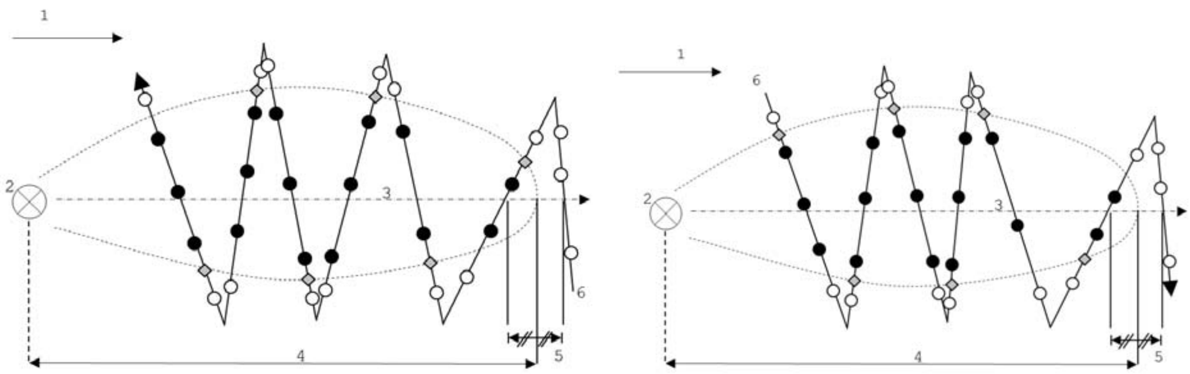
2.1 Determination of the odour plume extent

Using the dynamic method, at least two experienced panel members, who fulfil the criteria of being a EN13725 panel member, traverse independently the plume, while conducting single measurements (observations during one inhalation) at frequent intervals.

The plume direction is traversed at different distances from the source; the crossings can be started far away from the source and heading to it, or vice versa (see Figure 1). These crossings include traverses at distances where no recognizable odour is detected. A transition point is defined as the point halfway between an adjacent odour absence point and odour presence point for the odour type under study. In order to prevent possible adaptation effects causing incorrect observations, the transition points in the dynamic plume method are only determined while entering the plume, and not while exiting.

The maximum plume reach estimate is determined as the distance along the plume direction between the source and the point halfway from the furthest crossing where odour presence points were recorded and the first crossing where only odour absence points were recorded.

Figure 1 shows schematically the two possible routes to determine the odour plume extent. This extent is defined as the smoothed interpolation polyline through the transition points, the source location and the location determined by the maximum plume reach estimate.



- ● single measurement: odour presence point
- ○ single measurement: odour absence point
- ◆ transition point
- crossings
- plume extent

1 wind direction
2 source
3 plume direction
4 maximum odour plume reach estimate
5 equal distance
6 start of the measurement

Figure 1. Schematic drawing of the execution of the dynamic plume method (prEN16841-2)

2.2 Reverse modelling of the source strength

The primary application of the plume measurement is to estimate the total odour emission rate using reverse dispersion modelling. This is not part of the scope of the European Standard, but has been used a lot in Belgium the last decades.

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 (ou_E /s). A very important difference between su and ou_E is the fact that the odour observation during field panel measurements concerns the identification of a recognizable

odour, while in the olfactometric laboratory measurements detectable odours are observed. Typically 1 su/m³ corresponds with a concentration between 1 ou_E /m³ and 5 ou_E /m³.
One sniffing unit per cubic meter can be defined as the odour concentration at the border of the plume. This means that in 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 with this standardized method. Field olfactometers however claim to be able to measure higher concentrations in the field. The use of these instruments however is not yet standardized until now.
The method of reverse modelling is applied as follows. As a first step, the plume extent is determined as explained above. As a second step a dispersion model is used to calculate the average odour immission concentrations in the surroundings of the odour source under investigation. This is based on the source characteristics (emission rate, height, temperature, flow etc) 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 immission concentrations are expressed in terms of model units per m³.
After calculating the immission concentrations (in model units per m³), the plume extent recorded during the plume measurement is pasted on the calculated odour immission 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 immission concentrations (in model units per m³) of all edge points is calculated. This average value gives the number of model units corresponding to 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.

2.3 Determination of the average odour emission strength of a source

In practice, more than one measurement cycle (i.e. the determination of one plume extent) has to be executed in order to average the emission strength and minimize the variability. One of the advantages of relying on more measurement cycles is also the consideration of the possible impact of variations due to production process, seasonal impact, etc.
Experience in Flanders with tracer gas experiments (Bilsen et al., 2008) showed the influence of doing more measurement cycles on the accuracy of the result (the calculated average odour emission strength). Using 5 measurement cycles, the 95% confidence interval was about double the standard deviation; with 17 measurement cycles it was about the same size of the standard deviation, and in order to get the size of half the standard deviation, 60 measurements were needed. It could be concluded that the benefit was lowering exponentially with the number of measurement cycles and became marginal above 15 cycles (< 1% per extra cycle). Ten cycles could be considered as a minimum to obtain a respectable estimation of the average and have an acceptable confidence interval.
Also CEN WG27 advises strongly to conduct ten measurement cycles over at least five different days, in order to take possible variations (e.g. source emission strength, meteorological conditions) into account (CEN, 2015).

3. Advantages and drawbacks

The use of this method over more than 20 years revealed a lot of advantages:

- simplicity and comprehensibility of the method: the method is easy to explain and to execute; any motivated and normal odour-sensitive person can do the observations and doesn't need high-technological laboratory equipment. By experience it was found that even one single observer is sufficient since the difference in observed maximum perception distance for different observers is only 10–15% (Moortgat et al., 1992). This is less than the standard deviation on a series of ten measurement cycles (i.e. one normal odour survey study). However, to have mutual control on the correct execution and in order to minimize the risk of being less sensitive to a certain odour type, CEN WG27 requires the use of two panel members.
- Even with the presence of two panel members, the method is less expensive compared to other methods where a panel of six persons is required.
- The global impact of a source is evaluated, since diffuse, surface and other less clear sources are also considered. The method also automatically takes cumulation of and interaction between different subsources into account: during the dynamic plume measurement, panel members smell downwind the real mixture of the different emission points from the source (and possibly other (background) sources in the surroundings), exactly in the same way as the potentially annoyed neighbours do.
- The method reflects the actual perceptibility of an odour in the environment (it includes potential deposition, adsorption and absorption effects), whereas with the olfactometric method the odour is perceived in artificial (laboratory) circumstances. The time lapse between sampling and analysis with

olfactometry can cause degradation effects in the sampling bag (e.g. when ozone is present in the bag), diffusion through the bags and/or sorption or chemical reaction between components, making the analyzed odour different from what neighbours of the source are exposed to.
- The execution of a measurement cycle itself can have a non-negligible social function. It can generate interaction and construct a link between (unsatisfied) neighbours, the odour-emitting company and even the local administration. Certainly when a dynamic plume measurement is executed together, a much better understanding can grow about the problem and the difficulties to control the emissions.
- One measurement cycle leads to an immediate result, expressed by the maximum odour threshold estimate and the observed odour type(s). This information can be a direct feedback to the emitting source, leading to immediate changes in the production process or ventilation parameters.

However, there are also some drawbacks of the method that have to be taken into account:
- terrain accessibility: before starting a measurement cycle, the wind direction and the accessibility of the downwind terrain has to be checked. Presence of large inaccessible areas (lakes, railway switchyards, motorways, private industrial grounds, …) should be avoided.
- Unless a clear distinction can be made in odour type, this method is not able to assign emission strengths to different subsources.
- the dependence of certain meteorological conditions to perform a correct measurement: only with neutral to stable turbulence situations, the plume can be easily delineated. This makes the method in practice less usable in eg the Mediterranean area. Together with the requirement of having at least 10 measurement cycles to perform a complete survey, the minimal duration of a typical study takes 6 weeks to 3 months.
- The uncertainty factor of modelling. The use of a model to back-calculate the emission strength of the source, gives rise to additional uncertainty. This item will be discussed in more detail below.

For every single case, a good evaluation has to be made which odour measurement tool is best used, depending on the situation, the complexity of the source and the questions to be answered. Dynamic plume measurement is a very good and complementary method that should be considered when solving odour problems. Yet chemical and olfactometric analyses can provide useful additional information. Olfactometry is especially useful for the estimation of the relative contribution of each emission point. For determining odour emission factors one also has to rely on olfactometry. Chemical measurements are especially valuable to assess the homogeneity of an industrial sector (and determine standard abatement tools in this way). It is used very frequently for choosing or improving odour abatement installations.

4. Possible use of the results

As mentioned before, the dynamic plume method is mainly used in situations where the impact of the emission of a (complex) source on the surroundings has to be determined. The method is especially interesting in situations where:
- diffuse sources contribute to the total odour. Our experience is that whenever there is an odour generating activity (mixing, preparation of materials, heating, …) inside a building, wind effects can create an important diffuse emission, even when the building is sealed and extracted.
- more than one emitting source is present and hence the total odour impact has to be determined, with possible interaction between the different odour types. As an alternative, the different odour fluxes can be measured with dynamic olfactometry, but the simple summation of odours doesn’t always give the right results (1 + 1 is not always 2).
- surface sources or outdoor sources cannot be measured with olfactometry. A typical example are outdoor composting plants where breaking of material or turning of the composting heaps can generate high temporarily odour flows. The alternative can exist in trying to measure the emission with flux chambers or Lindvall hoods, but a comparative study (Nicolas et al, 2013) pointed out that huge variations could be observed between the emission rates deduced from dynamic flux chambers and wind tunnels. Factors 100 to 1000 are not exceptional between the two techniques for the same emission source and the same sampling period. In that case, dynamic plume measurement is a very interesting alternative. Moreover, the importance of the incorporation of these kind of sources in the odour survey can be demonstrated with results from a study, where emission values were below 100,000 su/s with no specific activity in the installation and up to 800,000 su/s when material was grinded or turned.
- a social interaction between neighbours, industry and government can help in resolving the problem. It is often seen that a better understanding of as well the complaints and the activities of the industry, can resolve the problem already partially. Doing a dynamic plume measurement together and meanwhile discussing the problems and the interpretation of the odour stimulates this.

- extremely strong odour sources: in this case, dynamic olfactometry and dispersion modelling are not useful for determining the odour impact of a source. The example can be given of a paper mill in the south of Belgium, where during abnormal circumstances a maximum odour threshold estimate of 49 km was measured (with 8 observers located on the terrain). The comparable emission measured with olfactometry gave a value of 900 x 106 ou_E /s.

In Flanders, the results obtained with the dynamic plume method are intensively used to compare the calculated impact with odour limit values. These limit values were derived for a number of specific homogeneous industrial sectors. On the one hand, a number of odour surveys were done around some sources using the dynamic plume method. This results in a calculated odour concentration with a certain frequency for every neighbour. On the other hand, telephonic enquiries revealed the degree of nuisance around the source. In this way, a direct correlation could be made of the odour observed by the people living in the neighbourhood and the psychological interpretation of it (degree of nuisance). This correlation leads to an underpinned odour policy, where the resulting odour limit values can easily be controlled using the dynamic plume method. These controls can be done by accredited consultants but also by environmental inspection services of the government.

5. Uncertainty caused by modelling

Most countries or regions use their own dispersion model, often imposed in national legislation. Typical dispersion models used to back-calculate the emission strength are of the (advanced) Gaussian type, often using stability classes instead of discrete turbulence parameters as the Monin-Obukhov length. Most of these models are no typical odour models and since no peak-to-mean factor is used, those models cannot deal with real momentary odour concentrations. There is an important insecurity originating from the translation of momentary odour perceptions of the dynamic plume measurements to averaged emission values calculated by the dispersion models. We repeat that overall odorous emission can be calculated, using short-term atmospheric dispersion models (reverse modelling). In a second step, long-term dispersion models are used to calculate isopercentile contour plots. According to our experience the short-term atmospheric model is a source of “noise” in the method since the standard deviations on calculated emissions are larger than standard deviations on the observed maximum distance for odour perception (Van Langenhove & Van Broeck, 2001).

Tuymans (1999) investigated the main parameters causing this uncertainty. 566 dynamic plume measurement cycles, executed from 1990 until 1999 around industrial and agricultural odour sources were collected in a database for statistical analysis. Short-term dispersion modelling was executed using four different models, two of them based on the Flemish Bultynck–Malet dispersion parameters, and two based on Pasquill dispersion parameters. Results from this analysis demonstrate some causes of variance in calculated emissions and show the fitness of each model (Van Langenhove & Van Broeck, 2001). A general trend can be observed that there is a systematic overestimation of the calculated values when using higher wind speeds and more unstable parameters. Lower wind speeds and high stability classes on the other hand generally resulted in underestimated values. As a consequence, a clear delineation was made of the meteorological circumstances to be used when doing a dynamic plume measurement (CEN, 2015). Nevertheless, variability caused by model calculations cannot be excluded completely.

A typical example of variability caused by models can be shown with the results of a study around a composting plant in Table 1. It can be seen that the standard deviation of the measured distance is lower than the one of the calculated emission. The differences between minimal and maximal values are quite high, but this is because measurements were done during different activities on site.

Table 1. Results of a complete odour survey around a composting plant in Belgium (Odometric, 2015)

	Calculated odour emission (su/s)	Maximum odour plume reach estimate (m)
Average value (n=10)	474,789	1361
Standard deviation on average	269,987	487
% standard deviation	57	36
Minimal value	63,459	380
Maximal value	836,505	2050

In Flanders, this insecurity however is implicitly built into the applicable odour standard (Van Broeck et al, 2001). To assess the impact of an odour source on the neighbours, a short telephonic enquiry is used. This method has a short execution time, and gives a relatively short response and simple interpretably results.

Since the same model is used in calculating the odour impact, the link between odour concentration and nuisance uses the same insecurity.
To limit the variance in calculated impact a far-reaching standardization of the chain “dynamic plume measurement – reverse modelling – long-term dispersion calculations” should be necessary; however this need discords with the variety of dispersion models and limit values used in practice in different European countries or regions.

6. Conclusions

It can be concluded that measuring odour with the dynamic plume method, as now described in the prEN16841-2 is a very valuable instrument, complementary to other instruments as dynamic olfactometry or chemical analyses.
The main advantages exist in its simplicity, the measurement of the actual perceptibility, the inclusion of diffuse or moving sources, and the link with the observations by the neighbours. On the other hand, this method is not able to attribute emission strengths to different subsources. The execution of a measurement cycle can be disturbed by bad meteorological circumstances or inaccessible terrain.
The use of dispersion models to back-calculate the emission strength of a source can give rise to an additional uncertainty. Further rigid standardization of this chain with a unified dispersion model would be an important step forward.
In Flanders, odour policy is based on measurements with this method. Since the same model is used in calculating the odour impact, this insecurity is implicitly built into the applicable odour standard.

References

Bilsen, I., De Fré, R. & Bosmans, S., 2008, Code van goede praktijk: bepalen van de geurverspreiding door middel van snuffelploegmetingen. VITO, expertisecentrum milieumetingen 2008/MIM/R/022, 47p.

CEN, 2015, prEN 16841-2. Determination of odour in ambient air by using field inspection: plume method. CEN TC264 WG27.

Guillot, J-M., Bilsen, I., Both, R., Hangartner, M., Kost, W.J., Kunz, W., Nicolas, J., Oxbol, A., Secanella, J., van Belois, H., Van Elst, T. & van Harreveld, T., 2011, The future European standard to determine odour in ambient air by using field inspection. In Proceedings of the 4th IWA specialized conference on odours and VOCs, Vitoria, Brazil, 17-21 October 2011.

Moortgat, M., Schamp, N., Van Langenhove, H., 1992, Assessment of odour nuisance problems in Flanders: a practical approach. In: Dragt, A.J, van Ham, J. (Eds.), Biotechniques for Air Pollution Abatement and Odour Control Policies. Elsevier Science Publishers BV, the Netherlands.

Nicolas, J. & al, 2011, Quatrième campagne de mesure des odeurs sur le CET "Champ de Beaumont" à Monceau-sur-Sambre Estimation et monitoring des nuisances olfactives. Rapport ISSEP.

Nicolas, J., Guillot, J.M. & Sironi, S., 2013, Comparison of hood techniques to sample odour from passive area sources. Paper prepared for the CEN TC264 WG2, document N302.

Odometric, 2015, Etude de l’impact olfactif. Personal communication, client details are hidden due to privacy reasons.

Tuymans, A. , 1999, Snuffelploegmetingen als basis voor de beoordeling van geurproblemen. Scriptie Universiteit Gent, FLTBW, 119p.

Van Broeck, G., Van Langenhove, H. and Nieuwejaers, B., 2001, Recent odour regulation developments in Flanders: ambient odour quality standards based on dose-response relationships. Wat. Sci. Tech., 44 (9), 103–110.

Van Langenhove H. and Van Broeck G., 2001, Applicability of sniffing team observations: experience of field measurements. Wat. Sci. Tech., 44 (9), 65-70.

VDI, 2006a, Guideline 3940-Part 1, Measurement of odour impact by field inspection - Measurement of the impact frequency of recognizable odours - Grid measurement.

VDI, 2006b, Guideline 3940-Part 2, Measurement of odour impact by field inspection - Measurement of the impact frequency of recognizable odours - Plume Measurement.