Odour management tools – filling the gaps

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Abstract In many countries the approach to odour management and regulation is increasingly based on quantitative techniques and criteria for acceptable exposure to odours in the living environment. A range of tools exists for implementing this approach, from emission measurement to assessment of effects. Some of these tools are well developed and validated, such as the use of olfactometry in laboratories operating according to international standards (EN13725:2003) and applying quality control and assessment systems under strict supervision by accreditation bodies. But other tools, while widely used, which are really still in the development stage, without standardisation or adequate validation. And then there are those that are still on the “wish list” of methods we would like to have in our toolbox. This paper contains a gap analysis that aims to provoke discussion on the needs for concerted R&D, standardisation and validation.

Keywords Dynamic olfactometry; nuisance; odour; odour management; standardisation

Introduction
Odour management is typically driven by the reality that some processes cause unpleasant odours, which can cause “offence to the senses” of the people living in the vicinity. Complaints arise, and are the trigger for intervention by authorities and implementation of some form of odour management.

The authorities have been involved in keeping the worst-smelling activities separated from residents, and odour nuisance regulations have existed for a very long time indeed. Early European legislation regulated smelly activities, such as slaughtering and tanning of hides, on a local level, typically by deciding that this should be done outside of the town, or downstream on the river. Europe was nevertheless a very smelly place, until quite recently. Imagine the smell of the first cities to house large numbers of people, such as Paris and London. Well before sewers and sanitation became commonplace in the second half of the nineteenth-century, London surpassed 100,000 inhabitants in 1600, while the second census of 1811 put the population of London at over 1 million for the first time. There was no sanitation to speak of, and the waste of all those people was discarded in the same river that provided most of them with drinking water, resulting in outbreaks of disease, such as cholera, claiming many lives. It was, after all, not until the mid-nineteenth century that the link between water and disease was made by Dr Snow in London (1854) and Louis Pasteur in Paris. Until then, bad smells and “vapours” were associated with disease.

It was actually not the disease, but rather the smell of the polluted Thames River, that caused the UK Parliament to decide, after the “big stink” of the summer of 1858, to allow the construction of the main London sewers, creating a bypass along the Thames to the sea. In those days the curtains and drapes of the Houses of Parliament, were treated with “chloride of lime” to combat the odours. In spite of these attempts, Parliament was closed in 1858 because of the unbearable smells from the river. For a vivid description of the smells of Paris in the pre-sanitation times I can suggest reading the book of historian Alain Corbin (1988) that inspired the even more fascinating novel The Perfume (Süskind, 1989).

The issue of nuisance caused by smells was traditionally regulated by commonsense regulations. Very smelly processes were to be located away from where people lived. If
conflicts arose, the situation was assessed by the relevant authority. More general principles were included in a Nuisance Law, which was established in many countries in the late-nineteenth century, when industrialisation led to larger-scale processes and increasing urbanisation, and hence more residents affected. The details of these legal developments and the differences between countries are beyond the scope of this paper.

The principles of Nuisance Law are used until today, especially in countries with a legal system based on Common Law. However, society increasingly demands transparent and uniform environmental regulations, with the aim to achieve a uniform level of risk and protection for all citizens. Industry requires a predictable and clear set of performance criteria, to be able to plan their investments in environmental management. Recently, as a result of the common market in the European Union, there is a movement to achieve convergence of environmental protection, with the economic objective of ensuring uniform regulatory pressure, and hence uniform competitive conditions throughout the EU. These developments have led to a gradual introduction of regulations and guidelines that increasingly depended on quantification of impacts and criteria for “acceptable exposure” to odours (Mahin, 2001; Van Harreveld, 1991). Examples of such regulatory frameworks, or draft frameworks, are provided below:

- Western Australia. New draft guidance published in April 2000.
- New Zealand. Since 1995 New Zealand has a guideline for managing odour to make this general legal requirement operational: the *Odour Management Under the Resource Management Act (1995)*. The implementation in regional air quality plans appears to progress slowly, however. A review of the policy appears to be under way, and we hope to learn more in this conference.
- Japan. Regulations have been applied for a number of years, based on a list of limit values for odour for specific compounds. In addition, more general criteria are given that are based on olfactometry. A well established method for olfactometry exists, called the T&T Triangle Method, which produces results that are remarkably compatible with those obtained using modern dynamic olfactometry according to EN13725.
- United Kingdom. The Environment Agency is has published a draft national guideline for odour licensing under IPPC, for consultation, that is available on [www.environment-agency.gov.uk](http://www.environment-agency.gov.uk) (EA, 2002a,b). Scientific background documents have been commissioned by the Environment Agency, and provide a broad overview of odour assessment tools and odour abatement techniques.
- Republic of Ireland. The Irish EPA is taking an active interest in licensing procedures where odours are an issue. A baseline report for livestock odours has been prepared for the Irish EPA (EA, 2001), and a similar sector specific approach for the mushroom substrate production sector is ongoing. Information: [www.epa.ie](http://www.epa.ie)
- Belgium. Currently a policy review is under way to establish a concerted policy on odours in Flanders, the northern part of Belgium (Van Broeck, 2001). The *Flemish Environmental Policy Plan 2002–2006* contains an initiative to define odour exposure standards for 16 sectors of economic activity.
- The Netherlands. Industry-specific guidelines are published to provide guidance for regulators in the licensing process at the local authority and provincial level (InfoMil, 2000). In 2001, new specific guidelines were proposed for air-quality criteria for specific areas dedicated to livestock production.

A quantitative approach to odour management and regulation requires a range of tools to
quantify and characterise emissions to the atmosphere, to model their dispersion, to assess air quality at receptor level and to measure the effects of odours on health and well-being of residents. Operators of smelly processes require effective tools for odour emission mitigation, operational control of odour control equipment and effective guidelines on community communication in the event that odour annoyance episodes do occur.

**Methods**

A recent draft guideline for odour regulation and management under the European Integrated Pollution Prevention and Control (IPPC) directive has been published for consultation by the UK Environment Agency (EA, 2002a) and provides an extensive overview of tools for odour management, and their potential use (EA, 2002b,c,d). Similar overviews have been published in other jurisdictions (Freeman *et al*., 2000; Paduch *et al*., 1995). Are these tools complete, validated and effective? Do we lack the tools for effective odour management? These questions will be discussed in the gap analysis in the section that follows, reflecting the observations and experience of the author, with the objective of provoking discussion and initiatives for continued research and development into effective tools for odour management, and their validation.

**Discussion**

The past 25 years have seen a tremendous growth in available tools to support odour management. The key phrase “You can’t manage what you can’t measure” has been well understood in the odour management community. The cornerstone of odour management remains the measurement of odour concentration and emission rates: how much “odour” is released? The fundamental tool to provide the answer to this question is odour measurement or olfactometry.

Olfactometry is not such a new discipline as is often assumed. The first measurement of an odour threshold was reported more than a century ago by Fischer and Penzoldt in 1886. A dedicated instrument for olfactometry was developed, named an “olfactometer” (see Figure 1), and used in academic research in the nineteenth century by Hendrick Zwaardemaker Czn. (Haarlem, 1857–Utrecht, 1930). However, academic research puts less stringent requirements on reproducibility of results as a practical application in environmental management, where conclusions can cost or save hundreds of thousands, if not millions, of euros.

In academic applications olfactometry has produced a disconcertingly wide range of results, even for often repeated measurements of the odour threshold of one odorous component, such as H₂S or methylmercaptan. A range of several orders of magnitude is not uncommon, and exhaustive compilations of results have been published (Devos *et al*., 1990). The range of variation of results was, however, unacceptable and far too large for
providing management information, even when using national standards that were applied in some countries (VDI 3881: 1986 part 1, ASTM E679).

The need for a reliable method, with known uncertainty and reproducible results, became evident as soon as regulations were based on those results. Odour regulations, with quantitative limits, were introduced in the Netherlands in the early 1980s, immediately followed by initiatives to standardise measurements. The result was a Dutch national standard for olfactometry NVN 2820: 1990), that systematically addressed the causes of the notorious variability in olfactometry that had been identified by researchers (Dravnieks et al., 1980).

On the basis of this experience an international standard for dynamic olfactometry has been developed more recently by CEN, the European standardisation committee, titled: EN 13725: 2003 Air Quality – Determination of Odour Concentration by Dynamic Olfactometry, that is currently applied in many countries. Standards Australia have published a very similar standard (AS/NZS 4323.3, 2001). An increasing number of laboratories are working under the rigorous demands of accreditation for their QA/QC management system, under the auspices of the European Accreditation organisation, with the ISO 17025 quality management standard as the accreditation benchmark. These developments have brought tremendous improvement to the reproducibility of olfactometry results (Van Harreveld, 1998).

Methods for measuring effects of exposure to odour in populations have been developed and applied, and relevant standards have been published (LAI, 1998; VDI, 1993; Sucker et al., 2001). The link between dose and effect has been established using dispersion models to predict exposure, which can be linked to the effect of odour nuisance in the population (Miedema et al., 2000). Some validation has become available, linking the various methods for characterising “odour exposure” and assessing its potential to cause “offence to the senses” (Sucker et al., 2003).

Does that mean we now have a well equipped toolbox, which provides the odour management practitioner with all the tools to do their job of balancing the interests of the operators of the odour source and the surrounding community? Not quite. In theory, the tools are there, but in practice a considerable task lies ahead of our professional community to develop and validate methods, before odour management becomes a fully established and predictable activity. What are the gaps in our structured toolbox? The following discussion highlights the gaps that have been identified in the daily practice of odour consultancy.

**Sampling**

Sampling of point sources is relatively well developed. However, the decay of odour concentration (and character?) during transportation and storage of bag samples is a concern.

The sampling of area sources is, however, the main “blank spot” in terms of validation. Hood sampling methods are most frequently used, but differences in measured outcome prevail. Discussions on the best method, providing “credible results” are ongoing, particularly focusing on the perceived advantages and disadvantages of the “Lindvall hood” method (Bliss et al., 1995) and the USEPA “dome” method (Witherspoon et al., 2002).

However, what remains a gap waiting to be bridged is comparison of area sampling methods with “open-top” real-world experiments, looking at mass transfer of low-concentration water-soluble compounds under different conditions (turbulence, solar radiation, temperature), in direct comparison with readings obtained by various types of hoods.

**Methods for measuring annoyance potential**

To enable tailoring of odour exposure criteria to the offensiveness of the specific odour in question, a measure of “annoyance potential”, which could be derived through a laboratory measurement, would be very useful (Van Harreveld et al., 1999, 2001). How far do odours differ in their annoyance potential? Indications to answer that question can be found in data collected on the hedonic tone of various environmental odours. Another indication of the
The magnitude of the spread of values can be derived from the exposure criteria that have been set for specific types of sources in the Netherlands Emissions Guidelines (InfoMil, 2000). These criteria are defined on the basis of a combination of dose–effect study results, attainable solutions using best available technology and, in the Dutch tradition, some degree of negotiation between industry and regulator. The different values are summarised in Table 1. From these values, we can see that the differences can be expected to not exceed one order of magnitude. The standard for coffee roasting, on the relatively pleasant end, is $C_{98} < 3.5$ OUE/m$^3$, while the criterion for slaughterhouses is $C_{98} < 0.55$ OUE/m$^3$. ($C_{98}$ is the limit concentration for the 98-percentile of hourly average concentrations).

A validated method to assign a quantitative parameter for “odour annoyance potential” is still elusive, however. Ideally, such a method would produce results that would be validated by predicting differences in actual dose–effect relations for odours with distinct annoyance potentials. A method to predict such differences in the laboratory would be very valuable in tailoring exposure criteria to reflect the “offensiveness” of the odour. Initiatives to look into the feasibility of such a method exist, and have led to efforts in development, mainly focusing on hedonic tone assessments, according to German standard VDI 3882: 1994 Part 2. Validation of this approach is, however, still unavailable, as are criteria for panel size, panel selection, panel instruction, etc.

### Table 1 Industry specific air quality criteria for odour in the Netherlands, National Emission Guidelines (NeR, 2000)

<table>
<thead>
<tr>
<th>Industry/Activity</th>
<th>Target $C_{98,1\text{ hour}}$ OUE/m$^3$</th>
<th>Limit $C_{98,1\text{ hour}}$ OUE/m$^3$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bakeries/bread</td>
<td></td>
<td>No limit value, $&gt;&gt; 10$ OUE/m$^3$</td>
</tr>
<tr>
<td>Bakeries/pastry</td>
<td>5</td>
<td>Target value for existing sites</td>
</tr>
<tr>
<td>Breweries &gt; 200 000 hectolitre</td>
<td>1.5</td>
<td>Target value for existing sites</td>
</tr>
<tr>
<td>Slaughterhouses</td>
<td>0.55</td>
<td>1.5</td>
</tr>
<tr>
<td>Meat processing</td>
<td>0.95</td>
<td>2.5</td>
</tr>
<tr>
<td>Grass dryers</td>
<td></td>
<td>2.5</td>
</tr>
<tr>
<td>Coffee roasters</td>
<td></td>
<td>3.5</td>
</tr>
<tr>
<td>Animal feed production</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Flavours and fragrances</td>
<td>2</td>
<td>3.5</td>
</tr>
<tr>
<td>Green waste composting</td>
<td></td>
<td>Distance table for buffer zones</td>
</tr>
<tr>
<td>GFT composting, new facility</td>
<td>0.5</td>
<td>1.5</td>
</tr>
<tr>
<td>GFT composting, existing facility</td>
<td>1.5</td>
<td>3.0</td>
</tr>
<tr>
<td>Waste water treatment (domestic), new</td>
<td>0.5</td>
<td>for urban domestic residences</td>
</tr>
<tr>
<td>Waste water treatment (domestic), new</td>
<td>1.5</td>
<td>for rural areas or commercial sites</td>
</tr>
<tr>
<td>Waste water treatment (domestic), existing</td>
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<td>3.5</td>
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</tr>
</tbody>
</table>

Lack of dose–effect data

It is a handicap that reliable dose–effect studies are only available for a limited number of activities and their odours. Much of this work was done in the Netherlands (Miedema et al., 2000) and in Germany (Sucker et al., 2001). A notable study of the dose–effect relationship between odour exposure and prevalence of annoyance in the community for pig production housing odours was conducted in the Netherlands (Bongers, 2001). The results have been used to underpin limit and target values for livestock odours that provide guidance to the Environmental Protection Agency in Ireland when assessing license applications (EPA, 2001).

However, to derive credible ambient air-quality standards for odours, specific data for a particular jurisdiction are the preferable starting point. If the objective is tailoring of such criteria, to reflect offensiveness, this requires valid, large data-sets to derive dose–effect relations for a variety of odours, suitably located on the scale of offensiveness or “annoyance potential”. Such validated data-sets are currently insufficiently available.
Many ambient air-quality criteria for odour, based on modelling, are proposed in (draft) regulations while omitting the indispensable effort of validating these criteria using a suitable dose–effect relation. Like most health effects, exposure limits should be based on solid epidemiology linking cause and effect. There is a gap to bridge in this area.

**Continuous measurement of odour concentration for process control**

A major disadvantage of current tools for odour source testing, using olfactometry, is that these are limited to grab samples. Continuous or semi-continuous olfactometric measurement is not feasible. This is a considerable drawback, especially for process operators who would like to monitor and control the emissions from their processes and the effectiveness of odour control assets.

Electronic nose applications have been described for this purpose, but examples of effective application in stack testing applications are very rare indeed. Where surrogate parameters are proposed, validation against olfactometry is usually insufficient.

**Ability to predict odour from chemical constituent compounds**

Using surrogate parameters, such as marker compounds, could provide a perspective to obtain continuous measurement. To achieve this, the relation between the surrogate parameter and the odour in question, for the concentration range that is relevant, needs to be validated (JRC, 2002). The use of marker compounds to predict odour is limited to situations where one odorant is clearly dominant, as is the case for hydrogen sulphide in concentrations of approx. 10 ppm and upwards. However, at these concentrations the odour is in the order of 20,000 OUE/m³, which would imply that further treatment is indicated to bring the emission within best available techniques.

Prediction of odour concentration of more complex mixtures remains elusive, probably due to odorant compounds that contribute to the odour of the mixture at concentrations that are below the limits of detection of even sensitive methods such as GC–MS (Van Harreveld and Stoaling, 2002).

**Validated short-range dispersion models**

The Gaussian dispersion models most commonly used to predict odour exposure are typically designed and validated for emissions from high stacks, with an averaging period of one hour or more. Odours typically cause impacts within hundreds of metres, if that. Odours can be detected in each intake of breath, say on a five-second timescale.

The application of dispersion models for odours would imply a need for models that take into account local flow conditions, caused by buildings, valleys and hills, and that would model fluctuations in a time-frame of seconds. Although puff models promise to satisfy these requirements to some degree, the extensive data input required is still a major practical stumbling block.

It would, however, be useful to start looking at innovative modelling techniques. Detailed discussion on issues such as extrapolating hourly Gaussian model calculations to seconds averaging intervals using peak to mean values, while of great interest, will in my opinion do little to improve the fit of the curve established through dose–effect studies. The goodness of fit of the dose–effect curve is ultimately the measure of success or failure of suggested improvements to exposure modelling.

**Systematic approach to community relations, including remedies for the persistent frequent complainant**

The practical use of community relations has been demonstrated in practice in cases where things went wrong. Most practising odour consultants will be able to tell anecdotes of
situations where a clumsy initial approach to community relations muddied the waters, and raised the emotional stakes. Very often, lateral issues, such as health concerns over perceived exposure to chemicals, find an expression in a conflict over odours. After all, anybody can smell, while only specialists can assess exposure to otherwise unperceivable chemicals.

Protocols for improving community relations are currently a matter of common sense, rather than a well honed tool for odour annoyance mitigation. That is a gap to bridge for the odour management community. A special case is the approach for “persistent complainants”, who, in some cases, are so profoundly disturbed by smells that are quite acceptable to the general public, that a therapeutic psychological intervention could be indicated. Such therapy is now, still, beyond the gap.

Conclusions
The gap analysis of odour management tools provided in this paper is aimed at provoking discussion and innovation initiatives and to close the gaps in the odour management toolbox. While the cornerstone of odour management, odour concentration management using olfactometry, is now well developed and validated, limitations in its application remain.

Gaps in the toolbox for odour management are identified, concerning:

- sampling of odours
- methods for measuring annoyance potential
- lack of dose–effect data
- continuous measurement of odour concentration for process control
- ability to predict odour concentration from chemical constituent compounds
- validated short-range dispersion models
- systematic approach to community relations, including remedies for the persistent frequent complainant.

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