Odor Regulation and the History of Odor Measurement in Europe

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Keywords
Olfactometry, standardisation, odour

Abstract
The concentration of people in cities in Europe has led to considerable odour problems, which were addressed by a variety of regulations for many hundreds of years. In the past 30 years there is a trend to move away from using the judgement of an environmental health officer, and to rely on quantitative measurements of odour instead. Pioneered in The Netherlands, the trend is towards quantitative odour management based on measurement of emissions, dispersion modelling to define exposure and criteria derived from dose effect studies to define a level where no 'reasonable cause for annoyance' exists. These criteria may be specific to an industry, depending on the offensiveness of the odour. A reliable method for odour concentration measurement is an indispensable tool required for this approach, and such a method is now available is the European standard EN13725:2003. An initial comparison of results shows a remarkable agreement of results between this method and the Japanese Triangle method. The rigorous selection of assessors for the panel is likely to be the critical operational parameter that contributes to this agreement.

Odor nuisance is a matter between neighbours. It occurs whenever people concentrate their lives, homes and activities in cities and towns, as has been happening in Europe in the past 3-4 centuries. It is not surprising, therefore, that even the earliest written legislation in European countries addresses nuisance, including that caused by smells

Early European legislation on a local level, regulated smelly activities such as slaughtering and tanning of hides, 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 19th century. London had over 100,000 inhabitants in 1600 and 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 19th 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 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[1] that inspired the even more fascinating novel The Perfume, by Patrick Süskind[2].

The issue of nuisance caused by smells was traditionally regulated by common sense 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 Nuisance Law, which was established in many countries in the late 19th 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. Also, 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 odors[3].

The first sector to be regulated on a national level specifically for odour impacts was the intensive livestock sector. In the Netherlands, with a very large pig production sector, a practical guideline was imposed in 1971 on new and existing livestock operations, which determined the minimum distance between residential housing and livestock housing facilities, depending on the capacity as counted in number of pigs[4].

This regulation was initially based on experience of public health inspectors. However, it led to research into methods to quantify odour emissions. In the Netherlands, with its high population density, industrial and agricultural activity and high economic level, the need for managing odour impacts was felt. In 1984 a quantitative air quality guideline for odours from industrial sources was introduced[3].

The guideline was based on measurement of odour emissions using olfactometry, followed by dispersion modelling to predict frequency of exposure to hourly average concentrations in excess of a certain limit value. In 1984 the Ministry of Public Planning, Housing and the Environment in the Netherlands set two exposure criteria, a more lenient one for existing facilities and a tougher limit for new installations:

- The odour concentration at the location of 'sensitive objects', such as residential housing, shall not be higher than 1 ge/m^3 as a 99.5 percentile of hourly average concentration, new industrial facilities ($C_{99.5,\ 1\text{-hour}} < 0.5\ ou_E/m^3$)
- The odour concentration at the location of 'sensitive objects' shall not be higher than 1 ge/m^3 as a 98.0 percentile of hourly average concentration, for existing industrial facilities ($C_{98.0,\ 1\text{-hour}} < 0.5\ ou_E/m^3$)

These regulations were applied between 1984 and 1995, and were found effective in reducing annoyance among the population leaving nearby regulated industries. However, a number of problems were identified in the years after introduction:

- The regulations did not take into account differences in offensiveness, and regulated a bread factory in the same way as a rendering factory
- The regulations were perceived to be too protective, too strict, and too rigid in their approach
- The measurement techniques available were not capable of providing sufficiently accurate data for enforcement

These issues have been addressed in the following years, and a more flexible approach has been introduced in 1995, and now formalised in the Netherlands Emission Guidelines of 2000[5].

Of course it was absolutely essential that the methods of measurements were improved so that they could be used in court. This requirement was recognised and led to development of standards, which will be described in more detail below.

The approach in the Netherlands was typical for a trend in other Northern European countries, such as Germany and Denmark. More recently, Belgium has started a systematic programme to develop a regulatory framework for managing its environmental odours, and the Irish Environmental Protection Agency has moved to define criteria for specific sectors, e.g. the livestock production sector (pigs)[6] and the mushroom growing substrate composting sector. A description of the history of odour related regulations in different European and non-European countries can be found in a recent research document that was prepared for the UK Environment Agency [7].

Recent regulatory developments in the United Kingdom are perhaps the most interesting to consider in some more detail. Until recently the regulation of odour emissions and nuisance was based on Local Authority Air Pollution Control legislation and the chapter on statutory nuisance in section 79 of the Environmental Protection Act 1990, stating: *"A Statutory nuisance includes any dust, steam, smell or effluvia arising on industrial, trade or business premises which are prejudicial to health or a* *nuisance"*. Ultimately, these regulations relied on Environmental Health officers to judge specific situations to decide if a statutory nuisance was present, in which case they could invoke measures to remove the causes. In practice, this led to wide variations in assessment. This is expected to change in the near future after publication of *Technical Guidance Note H4, Integrated Pollution Prevention and Control (IPPC), Horizontal Guidance for Odour* by the Environment Agency, in January 2003[8,9]

The H4 guidance provides a framework of assessment and regulation for processes as provided in the Integrated Pollution Prevention and Control directive of the European Union[10]. Specific processes that fall under IPPC are required to determine their impact on 11 criteria, one of which is odour impact. The sectors of industry involved are encouraged to define 'Best Available Technique' (BAT) on a European level to achieve greater efficiency in environmental management of these facilities.
With the H4 guidance the UK Environment Agency has provided a well defined framework for implementation of the IPPC directive for odours in the UK.It is to be expected that production facilities that fall under other regulatory frameworks, such as the local authority, will be assessed with the H4 guidance in mind. Planning procedures are similarly likely to consider principles laid out in the H4 guidance.

The H4 guidance provides a considerable degree of flexibility. It does, however, require a quantitative approach, based on quantification of emissions and dispersion modelling to determine if *'reasonable cause for annoyance'* exists at the location of residential property and other sensitive localities. It also recognises that differences in offensiveness, or annoyance potential[11], that can lead to differentiated exposure standards for specific sectors of industry. In Appendix 6 of Part 1 of the H4 guidance[8] an indication of possible criteria is provided, which range from $C_{98.0,\ 1\text{-hour}} = 1.5\ ou_E/m^3$ for more offensive odours to $C_{98.0,\ 1\text{-hour}} = 6\ ou_E/m^3$ for odours with a low annoyance potential. These indicative criteria are derived from a dose effect study conducted in the Netherlands for the livestock production sector[12], that were also used as a starting point to derive air quality criteria for exposure to livestock odours for the Irish EPA[6].

The H4 guidance explicitly states that sectors of industry can develop specific exposure criteria defining the level of exposure associated with *'reasonable cause for annoyance'*, by carrying out dose effect studies. In such a study, the effect is measured using a Standardised Telephone Questionnaire technique, where 100-250 people living in a delimited area are asked a number of questions, two or three of which are relevant to odour annoyance. They are not made aware that odour annoyance is the objective of the survey. Based on the answers given, each respondent is classified 'annoyed' or 'not annoyed. In this way a prevalence of 'odour annoyed' is obtained, for people exposed to a certain level of odours. A minimum of five exposure levels is surveyed in this way, and from the responses a correlation cure between the effect (annoyed) and the dose (odour exposure, $C_{98,\ 1\ \text{hour}}$) is obtained[9, 12, 13]

The uncertainty of the method is typically 3 percentage points, while in control areas a 'background' of 2-3% annoyed is observed. Therefore, at the background level plus two times the uncertainty, or approx. 10% annoyance, the annoyance effect is likely to be detected with sufficient statistical confidence.

The dose is measured by determining the emission of odours, using olfactometry, followed by dispersion modelling. This leads us to the central and crucial requirement for any quantitative method to reliably manage odour impacts: sufficiently accurate emission measurement. From the historical perspective of this paper it is notable that one of the earliest legal texts, he Magna Charta granted by King John of England and Ireland on June 5th 1215 recognised the need to use the same units for mass and length throughout the Kingdom:

There shall be one measure of wine throughout all our kingdom, and one measure of ale, and one measure of corn, namely the quarter of London; and one breadth of dyed cloth, and of russets, and of halberjects, namely, two ells within the lists. Also it shall be the same with weights as with measures.

The same basic requirements of reproducibility apply to odour measurement today, especially when its results are to be used in a legal context of licensing and enforcement. Olfactometry, the measurement of odour concentration using human subjects, has been practised for over a century now. The first reported odour thresholds are from 1848[14] with comprehensive studies appearing in the 1890's[15]. The early olfactometers were built by pioneers such as professor. Zwaardemaker, of the University of Utrecht, the Netherlands, as shown in figure 1. A more recent, but less portable model is shown in Figure 2.

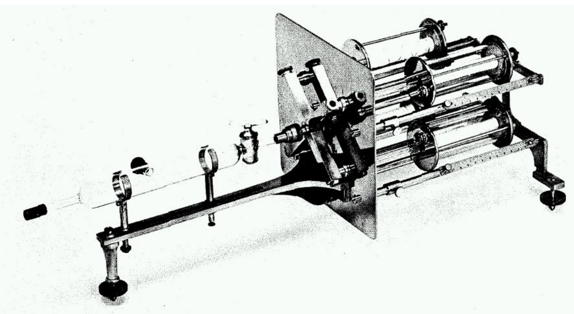

Fig 1: Zwaardemaker olfactometer, The Netherlands,1886

Fig.2 Modern olfaktomat olfactometer, OdourNet, UK, 2000

A remarkable volume of published data from the early years of the 20th century exists on odour detection thresholds for compounds. Unfortunately, the differences in results of odour thresholds in literature are very considerable. Compilations that have been published[16, 17] typically show a range of several orders of magnitude. When olfactometry was taken out of academic research, and increasingly drawn into the arena of environmental management of odours, standardisation was a logical step. A number of standards appeared such as VDI3881 (Germany)[18]. However, these failed to address the *'significant operational variables'* that had been accurately identified by Dravnieks in 1980[19]. The main issue was that no reference odours were defined, and no 'agreed reference values' for these odours agreed that could be used to 'calibrate' panels through selection of assessors for a specific olfactory acuity. As we now know, the variability of olfactory acuity between individuals is too large to accurately form a representative sample of the population, at practical panel sizes (e.g. n<10). Other issues were of a more technical nature, such as instrumental calibration, materials of construction and ensuring sufficient flow of odorous stimulus presented to avoid dilution with ambient air during inhalation (>20 l/min).

The significant operational variables, as identified by Dravnieks, were addressed in standards that included a form of assessor selection using reference odours such as AFNOR[20]. The Dutch NVN2820:1990 standard, in addition to panel selection, set a reference level of 20 ppb/v n-butanol for 1 'Dutch odour unit', or ge/m^3, and added statistical QA/QC procedures[21, 22].

These national standards of EU countries will now be replaced by the EN13725:2003 standard, that has been introduced in April 2003, after close to 10 years of preparation[23]. This standard defines the EROM, or a mass that is just detectable when evaporated into 1 m^3 of neutral gas, as equivalent to 123 μg n-butanol. In other words: 1 $ou_E/m^3 \equiv 40$ ppm/v. Strict panel selection procedures, using n-butanol as a reference odour, are used as a form of 'span adjustment'. Statistical QA/QC procedures are integrated in the measurement protocol. These measures have resulted in a marked improvement in the performance of olfactometry, which has been verified in an increasing number of blind interlaboratory tests. These developments, which were driven by a regulatory demand, have been described in more detail in a paper published in the AWMA journal[24]. It is satisfying that Australian Standards have published a standard AS/NZ4323.3 that closely resembles EN13725.

Table 1		**Odor detection thresholds in ppm**		
Compound	Odor quality	NL	Japan	Factor Japan/NL
Acetone	Sweet/fruity	28.0		
Benzene	Aromatic/sweet	1.7		
n-Butylacetate	Sweet/banana	0.076		
n-Butanol	Sweet/alcohol	0.040	0.038	0.95
Ethyl Alcohol	Sweet/alcohol	0.370		
Hydrogen Sulfide	Rotten eggs	0.0005	0.000495	0.99
Isobutyl Alcohol	Sweet/musty		0.012	
Methyl Ethyl Ketone	Sweet/sharp	3.1		
Methyl Mercaptan	Rotten cabbage		0.000102	
Styrene	Sharp/sweet	0.025	0.033	1.32
Toluene	Sour/burnt	1.6	0.9	0.58

It is very interesting to note that the key 'significant operational parameter' of panel selection is so elaborately addressed in the Japanese Triangle Method. Maybe that explains why, in spite of a very different technical approach on the instrumental level, the results obtained in Japan appear to be very close to those obtained using the NVN2820 method, that is compatible with the European EN13725 standard. The odour thresholds (or EROM's) for a limited number of compounds, that could be found in available papers, are compiled in table 1. The agreement between the methods is quite good, with differences of less than 50%.

With this promising indicative review in mind, it will be very interesting to learn of the results of more elaborate comparisons of the Triangle method and the EN13725 method.

The aim, after all, is that odour measurements all over the world can be compared and used to add to our combined knowledge on how odour emissions can be characterised, with the ultimate purpose of managing odorous impacts and avoiding detrimental impacts of offensive odours on the enjoyment of life.

Conclusions

- In Europe there is a trend towards quantitative air quality criteria for odours, using dose-effect studies to determine a level where 'no justified cause for annoyance' exists
- A precondition for this approach is the availability of odour measurement techniques with a known uncertainty, that is sufficiently small for use in a legal framework
- Selection of assessors appears to have been the main 'critical operational parameter' causing the lack of reproducibility in olfactometry
- The detection thresholds obtained using the Japanese Triangle Method appear to be in close agreement to those obtained using EN13725.

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