From odorant formation to odour nuisance: new definitions for discussing a complex process

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Abstract  The process leading from odorant formation to individuals filing a complaint is complex, involving many steps and factors. A flow chart is proposed. The definitions that describe elements of this process, such as annoyance, nuisance, propensity of a population to experience nuisance, the “unpleasantness” of an odour, as used in odour literature, are often imprecise and confusing. A set of definitions is proposed to identify the issues involved and suggest a more precise use of terminology. A new definition for “annoyance potential” as an attribute of an odour is proposed. The concepts were developed for a study into the feasibility of developing a standardised method for measuring annoyance potential, funded by the programme “Improvement of the Quality of Environmental Measurements”, funded by the Ministry of Public Planning and the Environment in The Netherlands. The programme is expected to lead to a development programme, which will be outlined.

Keywords  Annoyance; annoyance potential; epidemiology; hedonic tone; nuisance; nuisance potential; odour

Introduction

The process leading from odorant formation, to release, to dispersion, to exposure, to annoyance of individuals, to nuisance in an exposed population is complex. The use of words that describe elements of this process, such as annoyance, nuisance, propensity of a population to experience nuisance, the “unpleasantness” of an odour, as used in published literature on odours, are often imprecise and confusing.

This lack of a suitable set of terms and definitions was highlighted in the course of a study entitled “Feasibility study for the development of a standardised method for assessment of odour annoyance and odour annoyance potential” (Van Harreveld et al., 1999). This study into the feasibility of developing a standardised method for measuring “annoyance potential”, was research project PD207 of the programme “Improvement of the Quality of Environmental Measurements”, funded by the Ministry of Public Planning and the Environment in The Netherlands.

This first phase of the project was carried out during 1999. This involved a critical review and inventory of existing methods that aimed to characterise one or more elements in the chain that lead from odour emission to odour annoyance, which could ultimately cause odour nuisance:
The relationship between exposure to ambient stressors such as malodour and effects in a human population is not straightforward. Odour nuisance involves a long-term intermittent exposure to malodours that can cause a detrimental effect by giving rise to odour nuisance. This process is poorly defined, both in scientific terms and in its management in the regulatory framework. Even the central concept of nuisance lacks a clear definition, in the scientific, as well as legal, usage. To address this problem of definition in scientific discussion, a focused attempt has been made within the study to define the operational concepts required to describe the effects and its contributing factors. These concepts distinguish between annoyance potential, which is an attribute of a particular odour, and the much broader concept nuisance potential that describes the probability of annoyance and/or nuisance occurring in a particular situation. This involves among others, a source, a receptor population, weather and terrain. The broader concept of nuisance potential covers a large part of the chain leading from emission to effect, including annoyance potential, exposure characteristics and characteristics of the exposed population that can contribute to perception and appraisal of odour as an ambient stressor.

The set of definitions that was proposed to identify the issues involved and the flow chart describing the process that leads from odorant production to the symptom of odour complaints is presented in this paper. This includes a new definition for “annoyance potential” as an attribute of an odour, to be added to the existing four attributes available to characterise the sensory perception of odorants:

- detectability (CEN prEN13725, 1999);
- intensity (VDI/DIN 3882 part 1:1997);
- hedonic tone (VDI/DIN 3882 part 2:1997);
- odour quality.

The development phase for such a method is now funded by the Ministry VROM in The Netherlands and is expected to lead to a validated method to be reported in December 2001.

Methods

The feasibility study involved a critical review and inventory of existing methods that aimed to characterise one or more elements in the chain (set out above) that led from odour emission to odour annoyance, which could ultimately cause odour nuisance.

The study used the driving principle behind radical changes in regulatory approach of odours in The Netherlands in 1995 as a starting point:

“The character of the odour is a factor in determining the amount of nuisance caused.”

The relevance of existing methods in the initial inventory and review was assessed against this background, with a view to developing a method to assess nuisance potential. The review of methods focused on their ability to “distinguish a bakery from a rendering plant” in terms of its results, at relevant exposure levels or intensity levels that are experienced in the environment. Because of this perspective, the feasibility study has searched specifically for those methods that have the potential to characterise and distinguish between different odours, with the aim to determine their relevance for assessing nuisance potential.

The requirements for the method were outlined in precise terms at the onset of the feasibility study:
The method that is to be developed shall be suitable for standardisation and shall comply with a number of requirements:

1. The method must be suitable for development of a standard protocol and it shall be possible to validate the method.
2. The method shall be applicable for assessing a wide range of odours with different character.
3. The results of the method must be simple and easy to understand and interpret.
4. The development of a suitable standard reference material shall be feasible, with a view to achieving traceability of the results to such a standard.
5. The uncertainty of the results of the method must be known, approximately.
6. The cost of applying the method must be acceptable.
7. The method shall be suited for implementation in the current framework of regulations in The Netherlands and shall provide sufficient flexibility to allow the consideration of an acceptable level of odour annoyance by local authorities in the licensing process.

The project has been completed in three phases:

1. Inventory and review of existing expertise and methods, both in The Netherlands and abroad.
3. Feasibility assessment.

**Figure 1** From odour formation to complaint
Results and discussion

From odorant formation to complaint: a complex process

Odour studies are often undertaken to address a specific regulatory issue, or from an environmental engineering perspective. This practical view tends to obscure the wider picture on the process as a whole, seen from an environmental health viewpoint. The chart in Figure 1 attempts to show and name the various elements in the process that leads to nuisance, and its symptom of odour complaints that eventually may prompt regulatory action.

The process is far from straightforward, and few of the relationships involved are well understood. Odour nuisance can develop after long-term intermittent exposure to odours that cause a negative appraisal in the individual concerned. It has to do directly with the way we value our environment. It is not a straightforward process. Our attitudes towards the source, the inevitability of the exposure and the aesthetic expectations regarding our residential environment are some of the less tangible factors that are relevant to the probability of experiencing nuisance. Once the balance tips, and an environmental stressor, such as a livestock odour, becomes a nuisance to an individual, it is very difficult to reverse the process. What used to be a faint odour has now become a signal for annoyance. Once the first complaint has been made, the problem is much more serious for all those affected than before.

The mechanism that leads from an emission of odorants to atmosphere to actual odour nuisance is quite complex. It involves the following main factors:

- The characteristics of the odour that is released (detectability, intensity, hedonic tone, annoyance potential).
- Variable dilution in the atmosphere through turbulent dispersion (turbulence or stability of boundary layer, wind direction, wind speed, etc.).
- Exposure of the receptors in the population (location of residence, movement of people, time spent outdoors etc.).
- Context of perception (i.e. other odours, background of odours, activity and state of mind within the perception context).
- Receptor characteristics (exposure history, association with risks, activity during exposure episodes, psychological factors such as coping behaviour, perceived health and perceived threats to health).

In the inventory of literature, many publications dealt with parts of this process. Very few considered the issues involved in a broader epidemiological or environmental health perspective. In the course of the inventory it also became apparent that a number of essential words, such as nuisance and annoyance were used loosely and lacked definition for a sound scientific discussion. Some concepts, such as nuisance, were defined in a legal sense in a variety of interpretations, but not in a way suitable for scientific use. This led to development of a tentative list of proposed definitions, presented below. The definitions are related to the flowchart in Figure 1 and are open to discussion and further development. This presentation is an invitation to critical review of these definitions.

Proposed definitions

**Nuisance.** Nuisance is the cumulative effect on humans, caused by repeated events of annoyance over an extended period of time, that leads to modified or altered behaviour. This behaviour can be active (e.g. registering complaints, closing windows, keeping “odour diaries”, avoiding use of the garden) or passive (only made visible by different behaviour in test situations, e.g. responding to questionnaires or different responses in interviews). Odour nuisance can have a detrimental effect on our sense of well-being, and hence a negative effect on health. Nuisance occurs when people are affected by an odour they can perceive in their living environment (home, work environment, recreation environment) and:
• the appraisal of the odour is negative;
• the perception occurs repeatedly;
• it is difficult to avoid perception of the odour;
• the odour is considered a negative effect on their well-being.

Annoyance. Annoyance is the complex of human reactions that occurs as a result of an immediate exposure to an ambient stressor (odour) that, once perceived, causes negative cognitive appraisal that requires a degree of coping.

Annoyance potential. Annoyance potential is the attribute of a specific odour (or mixture of odorants) to cause a negative appraisal in humans that requires coping behaviour when perceived as an ambient odour in the living environment. It is an attribute of an odour that can cause annoyance or nuisance. Annoyance potential indicates the magnitude of the ability of a specific odorant (mixture), relative to other odorants (mixtures), to cause annoyance in humans when repeatedly exposed in the living environment to odours classified as “weak” to “distinct odour” on the scale of perceived intensity (VDI 3882: 1997, part 1).

Nuisance potential. Nuisance potential is the characteristic of an exposure situation, which describes the magnitude of the nuisance that can be expected in a human population when exposed to an odour intermittently, but over an extended period of time, in their living environment. Nuisance potential is a function of many factors, such as the attributes of the odorant (mixture) in question, the frequency and dynamics of variation of the exposure (caused both at source and as a result of atmospheric dispersion) and attributes of the specific population that is exposed.

Nuisance sensitivity. Nuisance sensitivity is an attribute of a specific population (or an individual) that indicates the propensity, relative to that of other individuals or populations, to experience nuisance when exposed to an odour intermittently, but over an extended period of time, in their living environment.

Results of inventory and assessment of the feasibility of developing a method for assessing “annoyance potential” from existing methods

An extensive review of over 400 literature references on existing assessment methods for the assessment of odours and their effects led to the following results.

The available methods for determining annoyance potential can be classified into categories: (a) relative, comparative methods, and (b) methods to determine the relation between odour concentration and an odour attribute scale, e.g. hedonic tone, intensity or “nuisance scale”.

(a) The methodology for comparative sensory methods are available, in the international standards for “triangle testing”, typically used in product evaluation work. The main problem is the lack of suitable reference odours that can be used as reference in such comparative measurements. A major advantage of comparative methods is the simplicity of the task of the assessors, reducing the need for training and selection to the point where enlargement of panels becomes a possibility, e.g. a few dozen instead of panels consisting of less than ten people as is currently typical.

(b) The method for hedonic tone testing is well defined (VDI 3882:1997, part 2). The advantage of the method is that results are obtained on a continuous scale as opposed to a discrete number of categories. Reference odours would be required for validation purposes to achieve traceability of the results. The complexity of the assessor’s task...
implies that trained assessors must be used, which causes difficulties in attaining increased panel sizes. There are indications that the relation between hedonic tone and odour concentration can be predicted from the more simple relation between perceived intensity and odour concentration. If this predictive ability can be confirmed experimentally it would create the possibility of using the results of this straightforward and well documented, standardised method to predict “annoyance potential”. If this approach proves successful, the advantages of hedonic tone measurement would still apply, but with the added advantage of using larger assessor panels, with a reduced need for training. This would achieve the practical option of using larger panel sizes, with the objective to reduce concerns over non-representative small samples of the population being used to arrive at general statements.

The advantages and disadvantages of the use of a “nuisance scale” in laboratory testing are similar to those for the hedonic tone measurement. An additional disadvantage is that no standard protocols have been developed for this method. Also, the assessor task of imagining the aesthetic impact of the odour in the field, as a result of long-term intermittent exposure, on the basis of a laboratory test, is very demanding.

Assuming that reference materials for odours can be developed, specifically for the purpose of annoyance potential assessment, the feasibility of developing a method for annoyance potential using elements of the methods described above, is confirmed by this study. It was not possible to exclude any of the methods mentioned above from further consideration in the development phase. The differences in relevance and feasibility were insufficient to reduce the number of options any further.

Proposed framework for differentiated assessment of “acceptable annoyance” level in licensing

The development of a generally applicable predictive model for the odour nuisance sensitivity of a particular population, the influence of perception context and the influence of socio-economic factors poses a problem. The feasibility study has not identified any indication of quantitative relationships between these factors and nuisance. The number of variables is apparently large, which complicates the issue. The development of a predictive, quantitative model for the impact of these factors on nuisance potential is not considered feasible, as a result of this review. This may be possible in the long term, but not within the limitations of time and budget that exist and within the requirements used as criteria for a possible method set out in this study. Given this conclusion, the study proposes a framework on the basis of “hard” quantitative measurement of annoyance potential that can be translated in differentiated values of well known exposure measures as the 98th-percentile of an odour concentration. In addition to this “hard core” of quantitative assessment data, the framework allows consideration of identified qualitative factors, in a transparent and quantified manner, using weight factors. Using this framework, the licensing authority can consider the qualitative factors and apply corrections on that basis, using the outcome of the quantitative result of annoyance potential measurement of the emitted odour at source as a starting point. In the Dutch regulatory environment, the judgement of which qualitative factors are relevant, whether their effect on nuisance potential is positive or negative and the relative weight of the correction for their effect, would be left to the licensing authority, usually on a local level.

A review of previously established epidemiological dose-effect relationships between odour exposure and percentage of population annoyed, has provided an indication that adding an annoyance potential factor would lead to a better prediction of annoyance caused by a variety of environmental odours.
A method for measurement of annoyance potential is now being developed, with funding by the Ministry of Public Planning and the Environment in The Netherlands, to enable implementation of such a licensing framework that would not judge the smell of a bakery in the same way as the smell of a renderer in terms of annoyance potential.

Conclusions
1. The understanding of the process leading to odour nuisance requires an overall view of the chain leading from odorant formation to complaint.
2. Existing terms and definitions, including those for central concepts such as “nuisance” and “annoyance” require improvement to allow clear scientific discussion of the processes leading to odour complaints.
3. Annoyance potential would be a useful attribute to differentiate odours in terms of their ability to cause nuisance.
4. Developing and validating a method for measuring annoyance potential is feasible.
5. Describing all relations between factors in the processes leading from odorant formation to complaints is not within reach yet. To attain an operational method that can be used for licensing, a method that combines quantitative information on exposure and annoyance potential with a transparent set of indicators describing nuisance potential in qualitative terms is considered feasible in the regulatory framework of The Netherlands.

References
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