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Limitations of FIDOL Factors for Odour Impact Assessment: Potential Ways of Improvements

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FIDOL factors that represent five dimensions (Frequency, Intensity, Duration, Offensiveness and Location) are tools for odour impact assessment. If the four factors (F, I, D, O) are clearly identified parameters, the fifth one (L) can be interpreted in different ways. Some recent communications are based on FIDOR (R as Receptor) or FIDOS (S as Sensitivity) to integrate larger impact than only the location (L). For location, the perception is not the same at work place or in a residential area, but the difference also depends on the considered period (workday, weekend or holidays) and also on sensitivity caused by tiredness or on any other "aggressive" perception (noise, very bad weather…). Therefore, two approaches are eligible: adding new dimensions (R and/or S) to obtain six/seven factors or considering the fifth one (L) as a multidimensional factor (LRS). All factors describe a characteristic of odour impact and for each of them; a scale has to be defined to give a value representing/describing its impact. Thus, what is the more acceptable and representative scale for each factor? After such a choice, the potential weight of each factor on the global perception is also a real question?
Global odour perception is, in fact, subjective due to the interpretation of perceived smells in a context. Therefore, factors must integrate the subjectivity for all dimensions they represent. That means it could be interesting to keep the subjective feeling avoiding interference by objective external quantitative measurement like chemical or physical sensors (for example estimating exposure time or intensity based on pollution detection by sensors).

1. Introduction

Air quality is a wide domain and generally, measurement are based on chemical or physical approaches. The case of pollution by odorous compounds can be characterised in a chemical point of view by classical analytical tools like GC/MS or with specific detectors for chemical families. But, the characterisation of global odour (and not the chemical composition) is linked to sensorial measurement. The human odour perception and its impacts on wellbeing must also be assessed with sensorial approaches and/or methodologies based on feelings. Because environmental odours had impacts on population, regulations were developed worldwide (Bokowa et al., 2021) but these regulations needs tools to measure and/or estimate emissions, methodologies to quantify concentrations, impacts…(Capelli et al., 2013).
Environmental odour characterization can be characterised using different complementary approaches often linked to standards like EN standards developed by European Committee for Standardization. At the emission, the EN-13725:2022 standard describes the way to quantify odour determining odour concentration by dynamic olfactometry and odour emission rate. In ambient air, the determination of odour can be carried out by using field inspection with the grid method (EN-16841-1:2016) or with the plume method (EN-16841-2:2016). If these standards describe efficient methods to characterise environmental odour in terms of concentration at the emission site, exposure and presence or absence in a defined area, other parameters generate the impact on population. To try to integrate all dimensions, FIDOL factors for Frequency, Intensity, Duration, Offensiveness and Location are cited to assess the impact and also to propose odour regulation (Nicell, 2009). In regulation context, objective odour limits are fixed. The objective approach is common and even logical in physical or chemical measurement but for a sensorial perception, with a wide variability between persons, it's typically more complex due to subjectivity. For example, when a doctor asks a patient to rate his pain on a scale from 1 to 10,

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it's the real feeling of the patient and not temperature, cardiac rhythm or another factor that describe the pain. So, it is important to explain limits of FIDOL factors and to propose how a full subjective approach could be another way to assess impact on populations.

2. Limits of the FIDOL factors

FIDOL factors are pertinent and efficient indicators to assess an impact. But, even if such an approach defines a way to manage environmental odours, these five factors present some limits and the following paragraphs describe these limits by factors but also on a global view. It must be noticed that FIDOL approach is quite specific in environmental assessment. Generally, pollution is mainly characterised by concentrations, flows, accumulations and compared with values defined in regulation texts. So, analytical results can be easily compared with references values to not exceed. In environmental approach, a more complex assessment could be life cycle analysis (LCA) because for complex products, input data is very numerous. FIDOL factors can be considered as a less complex approach than LCA but need knowledge on odours to be understood.

2.1 Frequency

With a sensor and a defined baseline, it is easy to count the number of values above this baseline. With permanent or regular recording, the frequency of exceeding baseline level can be easily calculated. Then, the percentile of exceeding or non-exceeding is recorded. This approach is typically developed for regulation based on percentiles 95% or 98% that express than 95% or 98% of the time, odour is absent because lower of 1 UO_E/m^3. Such a percentile is in fact a combination of frequency and duration so tries to represent these both factors. Considering a case where people are exposed twice a day (at 7h and 19h for example) to a strong odour peak for 12 minutes each, the calculation will give 2x12min/day so 0.4h/24h that is in fact 1,6% of the time. This case is compatible with a percentile of no exceeding for 98% of the time so can be considered very far from a potential nuisance but what is the real feeling of a person exposed each day and twice a day to a stench atmosphere ! Because of regularity, the perceived frequency is probably close to "often" for a subjective description when an objective description will propose no significant exceeding. Such an example clearly illustrate that an objective measurement cannot be representative of real feeling in some cases. It also exists the measurement of odour frequency with the protocol defined by German guide VDI3940 part 1 (2006) and used for odour exposure measurement with grid method EN16841. To synthetize the method for a single measurement in one point, the assessor (with normal sensitivity to n-butanol) sniffs the air every 10 seconds. He records the presence of odour (and the quality) on a record sheet or an application on mobile. After 10 minutes, he has assessed 60 breath of air for this period. The quotient of the number of positive assessments (odour detected) divided by the number of assessments in the cycle gives the percentage odour time so a representation of frequency. Defining a certain percentage of odour presence in advance, the percentage time reaching or exceeding the defined level is considered an odour hour. It's not well adapted for situations with very punctual peaks of odours like the specific case cited previously. Clearly, measurements with a chemical analysis, a sensor or even a sensorial method during a period can give an objective result about odour frequency but that could differ to subjective perception.

2.2 Intensity

The intensity seems easier to characterize because it's link to the concentration. With a chemical measurement, a concentration of an odorous compound can be determined and then with the odour threshold and the knowledge about the molecule, an estimation of odour intensity can be proposed. But, in reality, because odours are the results of perceived mixtures (odorants + non-odorant compounds), the intensity cannot be defined by chemical concentrations. So intensity is typically given by smelling the source or a sample collect from it. But, how precise must be the scale? Is it an open scale (just the feeling) or do we organize intensity measurement comparing odours with an odour from different solutions (or gas samples) of a reference scale? Such a scale, with n-butanol, exists in many countries and described in national standards like in France: NF X43-103 (1996) or in USA: ASTME E544-75 (1997). In this last American example, "Odor Intensity Referencing Scale" (OIRS) can be expressed with different scales:

- 12-point static scale starting at 10 ppm butanol with a geometric progression of 2;
- 10-point static scale starting at 12 ppm butanol with a geometric progression of 2;
- 8-point static scale starting at 12 ppm butanol with a geometric progression of 2;
- 5-point static-scale starting at 25-ppm butanol with a geometric progression of 3 given as example in Table 1.

Table 1: OIRS with 5 points and a geometric progression of three and potential intensity description

Reference Level	0	1	2	3	4	5
n-Butanol (ppm in air)	0	25	75	225	675	2025
Potential intensity description	None	Slight	Noticeable	Very Noticeable	Strong	Very strong

A scale with seven level from 0 to 6 is also describes in German guideline VDI 3882 part 1 (1992).

2.3 Duration

Duration is probably less complex to characterize comparatively to other factors. As mentioned in the paragraph about frequency, such parameter can be included in a percentile with an objective measurement. For subjective perception of duration, one parameter is the stability of odour. In case of stable odour, habituation can set in and then decrease the impact of real duration of exposure. Of course, variations of intensity (and/or quality) cannot lead to habituation and the weight of duration in the global impact could increase. As for the frequency, a chemical measurement with a sensor records a signal. If this signal exceeds the baseline level considered for odour presence, it's easy to count the time of exceeding, the duration of each peak, the global duration (sum of period of odour peaks). Once more, objective values can be obtained without total warranty to represent the real feeling of people exposed.

2.4 Offensiveness

The offensiveness criteria, which is characteristic to the hedonic, tone i.e. the appreciation as good/bad or eventually neutral. By definition, such a classification good/bad is typically subjective and differs from people because related to education, life, quality of life... So it's probably with this factor that heterogeneous answers can be obtained. This fact must be integrated because it's an important part for acceptability (pleasant/unpleasant). Of course, the odour quality is important for acceptability because the probability to appreciate a perfume is higher than the appreciation of odours from wastes (wastewater, organic wastes in putrefaction). But the intensity has also an impact on such appreciation because an increase can move the perception from pleasant to just acceptable or acceptable to unpleasant. A perfume at very high level of concentration so high intensity can be perceived as unpleasant. A scale from very unpleasant (-4) to extremely pleasant (+4) is proposed in German guideline VDI 3882 part 2 (1992). This hedonic approach is completed by the concept of odour profile based on pairs of opposite adjectives (VDI 3882 part 2, 1992 and VDI 3940 part 4, 2010). This last concept implies more data treatment and generally, only a scale unpleasant/Pleasant is kept for offensiveness description.

2.5 Location

The fifth factor described as Location is in fact a multidimensional factor. Some alternatives of FIDOL are FIDOR or FIDOS for Receptor or Sensitivity respectively. These difference of definitions have the objective to describe a vulnerability to the odorous stimuli depending not only on the place (work place, shopping area, house…) but also on the receptor itself (the human body during a work day, a week-end or holidays…) with its sensitivity (tiredness, illness, busyness, stress…). So this factor represents more the person than the odour episode and the level of complaint for this factor is linked to the ability to manage the odour event and its impact on his/her life. If this fifth factor must represent all sensitivities not considered by other factors, it must integrate physiological and psychological health, age, social level…

2.6 Not studied interactions

Because odour perception is complex, FIDOL/FIDOR/FIDOS describe a situation. Sometimes, it can be difficult to understand results for example for both following cases: unknown synergistic effects and unknown masking/inhibition effects. In the first situation, the impact is increased when it's decreased in the second one. Of course, FIDOL factors will describe the real situation and the exact feeling that is the most important but punctual interactions with such unknown effects will complexity data analysis. Also because perception with FIDOL approach describes a situation, when many odorous sources are responsible, the result depend on the perception of the global mixture and cannot be correlate with one specific source.

2.7 Studied interactions

With the description of each factors, it was clear that some of them are in strong interaction with each other. A study (Griffiths, 2014) propose models based on intensity and frequency to characterise annoyance and odour impact criteria. If the combination of intensity and frequency can be linked to annoyance, a single percentile

odour criteria cannot reflect the complexity of factor interactions to predict nuisance. The need is then more complex with, as example, multi-percentile approach.
These factors are often found in Odour Impact Criteria (OIC) with the objective to integrate several parameters. In such a criteria, the combination of an odour concentration threshold (expressed in OU_E/m3) and a probability of exceedance (in %), lead to percentile (Brancher et al., 2017; Sommer-Quabach et al., 2014).

2.8 Global limits

These factors are based on perception but the boundary between perception and judgment is very narrow in odorous situations. By definition, a judgment involves a cognitive process and hedonic tone, integrated in offensiveness, is clearly more than a simple perception and a typical judgment. Without considering if the answer is rational or irrational when a factor is assessed, the observation is subjective because depending on each observers at a specific time in some conditions… So, the acceptation of a subjective answer allows to consider both perception and judgement in the same assessment.
If each factors show some limits, the combination of all factors in order to obtain a global assess of the situation is complex. Can we consider that all factors present the same weight? If not, how a ponderation can be proposed? The real need could be a global description based on integration of factor responses.
With OIC and a percentile, hedonic tone (Offensiveness), living quality and psychosocial situation (Location, Sensitivity, Receptor) are not taken into account. With FIDOL, qualitative description is not developed because offensiveness concerns mainly pleasantness or unpleasantness. Qualitative descriptors like in odour wheel (Suffet et al., 2004) are not included.

3. Proposal of a full subjective approach

As shown in previous paragraph about limitations, a key point is to choose between objective or subjective criteria. The possibility to mix both objective and subjective criteria seems incompatible with data treatment in order to express a real feeling and to be in a frame of “psychometric measurement”. Firstly, a number of levels must be selected and these levels must be qualified by descriptors accessible for everybody and that ca represent their feeling. Secondly, a mathematical treatment must be proposed to integrate recorded level of each factor in an odorous situation. Both aspects are described in following paragraphs.

3.1 Proposed levels for factors

To characterise the feeling, the table 2 gives an example of subjective data for the different factors.

Table 2: Example of five qualitative levels for each factor based only on perception

	Frequency	*Intensity*	*Duration*	*Offensiveness*	*Location, Sensitivity of Receptor*
(5 qualitative levels)	Very often	Very strong	Very Long	Very unpleasant	Very high
	Often	Strong	Long	Unpleasant	High
	Sometimes	Medium	Medium	Neutral	Medium
	Rare	Weak	Short	Pleasant	Low
	Very rare	Very weak	Very short	Very pleasant	Very low

Five levels are retained, in Table 2, to estimate the difference between feelings. If a scale presents too many levels (10 for example), it’s then difficult to choose between too close level. By reducing the number of level, the precision seems lower but the stability for the same situation must be better.
These factors are based on perception at a period of time and because the boundary between perception and judgment is very narrow, the answers are probably more reflecting the feeling of the human exposed to malodorous atmosphere.

So, within the frame of this full objective approach, the methodology must define if the five levels are sufficient to quantify each factor. Then, it is necessary to identify if the methodology for aggregating factors to give a global answer can be limited to five levels (as example shown in Table 3) or must be placed on a more defined scale with higher number of levels.

Table 3: Global answer integrating the five factors to describe impact assessment with five integrated qualitative levels

	Lowest global Impact				*Highest global impact*
Integrated levels	*Mild*	*Moderate*	*Severe*	*Very severe*	*Extremely horrible*
Numerical levels	*1*	*2*	*3*	*4*	*5*

3.2 Proposed methodology to combine answers

The problem of identifying the global assessment of a situation based on multiple factors has been studied for years (Fishburn, 1970; Mardani et al., 2015) and refers to multi-criteria decision making. Many methods can be used (Mardani et al., 2015) to identify such overall assessment function. Lots of them are based on utility function which will capture a customer's preference or measure the customer's level of pleasure with a choice. These utilities will differ from one customer to another. This is why the chosen factors do not express a physical dimension but how the customer feels about this dimension and then can express the customer's utility for that dimension. The utilities have then to be aggregated to obtain the overall assessment. This overall assessment too may vary from one customer to another, especially if the set of criteria is not sufficient to represent the overall assessment (which means that the final decision also depends on other criteria). Considering that it is not the case, we intend to interview a group of people to find out their feelings on a set of situations, giving both their evaluation on each of the criteria and their overall evaluation. From this data set, we will find the multi-criteria decision technique that best fits the data. Using statistical methods we can also identify conflicts and deduce whether there are one or more aggregation operators, and then whether they all have a similar decision method or wether we need to define groups of people according of their decision type. If several groups exist, we then should investigate in order to identify what are the specifics of each group. As the set of criteria and qualitative values are not so important, the result could be a 5-dimensional matrix giving the overall assessment for each possible values of each criteria (i.*e.* one for each identified decision type).

4. Conclusion

Potential odour annoyance and especially environmental odour characterization is still complex to assess. The approach based on FIDOL/FIDOR/FIDOS factors was developed to characterise the multidimensional feeling caused by odour perception. By definition, odour perception is variable from one subject to another one and so this perception is very dependent on how a subject considers the feeling for all FIDOL dimensions. This difference of perception between people can be characterise by subjectivity that is in opposition to objectivity. Measurements of chemical pollution with analytical devices is objective but odour perception and its complexity must consider subjectivity. That is the reason why, the global odour assessment based on multiple factors must be the result of aggregation of utilities that are expressed for all dimensions.

This work is a first step of a process to propose a global assessment. This first step is based both on matrix definition (description of levels for factors) and on data treatment methodology. The proposed matrix with five levels for five factors and integration of results to propose also a global answer (potentially five levels as well) are key points of data collection and data treatment to try to cover odorous situations. This first step is made with five levels that can be clearly distinguished by a population. It is always possible to propose a scale with more levels (up to ten for example) but in such a case, it becomes hard to find a quantitative descriptor for each of them. This limitation in vocabulary is also based on the fact that subjective measurement placed on a scale with many levels do not give warranties of reproducibility.

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