Odour assessment as a necessary complement to chemical evaluation of building products

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ABSTRACT
Evaluation of emissions from building products is mainly focused on comparison between exposition concentrations of identified individual organic compounds and health criteria. No adequate integrated criterion is available for interaction and mixture effects. Besides, everyone performs daily evaluation of perceived air quality. Human beings through their senses, for example, olfaction and chemesthesis, are able to achieve a synthetic response to a global mixture of compounds. It is thus essential to perform sensory tests complementing chemical analysis to take into account the impact of the whole emission of sources. Two related questions remain to be answered: the kind of sensory test and the type of sensory information and criterion to be used in the evaluation procedure.

INDEX TERMS
Odour; Material emission; Sensory; Source control; Chamber study

INTRODUCTION
Characterization of gaseous emissions from building products has become increasingly necessary in order to control and decrease possible impacts on indoor air quality (IAQ). Chemical analysis of volatile organic compounds (VOCs) emissions in test chambers is a powerful tool that allows identification and quantification of substances to which people may be exposed. However, this information is not enough to determine the possible impact on IAQ. Material emissions also need to be assessed as a whole because people are exposed to a ‘global’ emission not to a single substance. In this paper, the use of integrated criteria to evaluate material emission, whether through modelling or sensory assessment, is discussed giving in detail the advantages and the disadvantages, the information type and its representation regarding health and well-being, from technical and practical points of view.

INTEGRATED CRITERIA
All evaluation procedures of building materials require VOC emission testing in order to identify the absence or presence of hazardous substances subject to national legislation and potentially harmful compounds, for example, classed or suspected carcinogenic substances (for a review, see Wolkoff, 2003). Other VOCs have tolerance limits which they must not exceed in order for the material to be accepted in the accreditation or labelling process. These limit values are usually based on national threshold limit values from occupational health or directly derived from toxicological data. This VOC-by-VOC approach does not provide information about the whole emission. Therefore, most of the protocols include at least one integrated criterion, with the most simple one being TVOC (sum of individual VOC concentrations). Its simplicity is only apparent because of variations in the analytical definition from laboratory to laboratory (Mølhave *et al.*, 1997). Non-sensory integrated criteria from selected national labelling schemes are presented in Table 1.

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Table 1 Non-sensory integrated criteria in selected national labelling schemes

Integrated criteria	Country	Labelling scheme
TVOC Σ(carcinogens)	Finland	Finnish Classification Label http://www.rts.fi
TVOC $\Sigma(C_i/LCI_i)$ Σ(VOC without LCI)	France	Derived from European collaborative action procedure (ECA-IAQ, 1997) in complement to fitness for use properties (in preparation)
TVOC Total aromatic hydrocarbons	Germany	GuT (Association for Environmentally Friendly Carpets) http://www.gut-ev.de
TVOC	Germany	EMICODE® (Society for Emission Control of Adhesives) http://www.emicode.de
TVOC Σ(SVOC) $\Sigma(C_i/LCI_i)$ Σ(VOC without LCI)	Germany	AgBB (Committee for Health-related Evaluation of Building Products) (AgBB, 2002)
Σ(VOC 50–250°C) Σ(VOC > 250°C) Σ(CMT substances)	Germany	Blauer Engel Wood Products (RAL-UZ 38) http://www.blauer-engel.de
TVOC	Sweden	Swedish National Flooring Trade http://www.sp.se
TVOC Total aldehydes	USA	Greenguard http://www.greenguard.org

TVOC, total volatile organic compounds; SVOC, semi-volatile organic compounds; LCI, lowest concentration of interest; CMT, carcinogenic, mutagenic and teratogenic.

TVOC alone cannot be considered as a risk indicator for health and well-being (Mølhave *et al.*, 1997; Wolkoff and Nielsen, 2001; Mølhave, 2003). Thus, along with TVOC, other criteria based on the sum of selected VOCs per chemical family or toxicological data relevance are used. But the power of these criteria is limited by the performance of analytical methods and systems that are focused on easily measurable compounds. Besides, toxicological data are not always available for all identified VOCs. Moreover, these criteria do not provide any information on how building material emission will be perceived. There is thus a need to implement this approach by global criteria that take the whole emission into account without applying an analytical filter.

SENSORY CRITERIA

By now, only sensory evaluations can provide part of this information. Everybody performs daily assessments of IAQ whenever they enter closed spaces by means of their senses, particularly those involving nose, eye and overall olfaction. The last one is generally the first sense to be triggered and thus the first to provide information at the lowest VOC concentrations (Ruth, 1986). Furthermore, irritation tests are difficult to be performed routinely in an emission testing laboratory. Expert persons are needed to conduct such tests with volunteers bound by ethical restrictions. Olfaction, therefore, represents a more usable tool to assess first and immediate perception of air and emission quality. Olfactory criteria are thus included in several emission labelling schemes (Table 2).

Table 2 Olfactory criteria in national labelling schemes for emission testing of building products

Olfactory property	Scale type	Tolerance value	Country	Labelling scheme
Intensity Acceptability	Continuous –1 to +1 0 to 5	Time to reach 50% olfactory/irritation threshold Intensity < 2 Acceptability > 0	Denmark Norway	Indoor Climate Labelling (Wolkoff and Nielsen, 1996) http://www.dsic.org
Acceptability	Continuous –1 to +1	Untrained panel (*n* = 5/15) Dissatisfaction < 15% (M1)	Finland	Finnish Labelling Scheme http://www.rts.fi
Intensity	Equal-attribute matching (butanol references) 0 to 2.5	Trained panel (*n* = 5–15) mean value < 2 (log Cppmv butanol) (Ramalho *et al.*, 2003)	France	Derived from European collaborative action procedure (ECA-IAQ, 1997) in complement to fitness for use properties (in preparation)
Unpleasantness	Category 1: no odour to 5: very unpleasant	Trained panel median value < 4	Germany	GuT (German Association for Environmentally Friendly Carpets) http://www.gut-ev.de
Recognized but no method chosen yet			Germany	AgBB (Committee for Health-related Evaluation of Building Products) (AgBB, 2002)

A large majority of people think that olfactory perception is totally subjective. This, however, is not completely true as it depends on the kind of sensory information, which depends also on the strategy beyond emission control. There are two different strategies:

- Diminution of source emission level to improve IAQ. The assumption here is: the lower the source emission, better the IAQ will be. Olfactory assessment is considered here as a complementary sensitive measurement that does not filter emission information. Basically, odour intensity measurement is required in this strategy. Building materials should, therefore, yield low VOC emission levels along with low odour intensity.
- Diminution of the perceived impact of source emission to improve IAQ. The assumption here is: the lower the annoyance, the better IAQ will be. Olfactory assessment is here no more a measurement tool, but the criterion that needs to be satisfied. Clearly, acceptability assessment is needed in this strategy. Building materials should provide low emission levels and satisfy population perception.

OLFACTORY ASSESSMENT METHODS

Acceptability assessment requires at least several dozens (>60) of untrained subjects ('customers') to provide exploitable results due to large inter-individual differences caused in part by education level and self-experience (AFNOR, 2000). Several labelling schemes use acceptability assessment as a criterion while always using a small-sized panel. The obtained data cannot be considered representative of population perception. Extrapolation of panel acceptance to population acceptance is not allowed in this case. The large number of subjects needed in the experiment is difficult to manage in a routine material emission test. These difficulties hinder the application of the second emission control strategy. The first remains more appropriate from a practical point of view.

Odour intensity measurements are far more objective especially when calibration occurs, by means of odourous standards (Moskowitz *et al.*, 1974) or use of master scales (Lidén *et al.*, 1997). Olfactometry through the dilution factor method (odour units) is sometimes considered as an intensity measurement method: this is not true. Despite being useful to determine the amount of clean air necessary to achieve odourlessness, this method does not give any response regarding perceived intensity. Moreover, it is based on detection thresholds that can be very different from one human to another (Punter, 1983).

Odour intensity is assessed by qualified subjects, that is trained persons (ISO, 1993), who give reliable and reproducible results. Thus, a small number of trained panelists (n = 5–20) is sufficient to perform an odour intensity assessment. Although, inter-individual differences in detection threshold (Punter, 1983) and power function (Berglund *et al.*, 1971) exist, intensity information remains consensual among people if proper calibration is used. Calibration is essential in order for the assessments to be comparable from one laboratory to another (ECA-IAQ, 1999). A simple continuous scale is not sufficient because what is perceived as a strong odour to one subject may not necessarily be perceived as strong by another. Besides, representations of semantic terms may not be identical from one person to another. At present, all the existing labelling schemes do not use calibrated scales (Table 2).

Standardized methods to assess odour intensity include calibration (ASTM, 1993; AFNOR, 1996). These methods rely on direct comparison of the sample odour with a series of an odorous reference (n-butanol). Perceived odour intensity is thus expressed in equivalent butanol concentration that provides the same level of intensity than the sample. Typically, the measurement is performed on a discrete scale with eight categories of n-butanol. In order to simplify the methods for routine use without hampering data quality, comparison of a discrete scale and a continuous scale with two references has been done (Ramalho, 2003). The observed results show no significant differences between the two scales. The continuous linear scale with two references represents an example of a simple yet calibrated method that could be used routinely to assess odour intensity from emission of building material.

Tolerance values are dependent on the method used, on the olfactory information assessed and on the time of the assessment, typically after 28 days most of the time. Some values are presented in Table 2. The tolerance value associated with the use of the continuous scale with two references is 2 log units of the equivalent concentration of n-butanol in the gas phase (100 ppmv). Beyond this point, odour is perceived as strong to very strong and a building product should be rejected.

LIMITATIONS

Evaluation is conducted at the laboratory with usually new manufactured building materials. No information on possible long-term secondary emissions, that is ageing effect, is provided (Salthammer *et al.*, 1999).

Odour assessment in an evaluation protocol provides immediate perception information but nothing on adaptation rate which is also relevant in occupant's perception of IAQ. Future studies and protocols should take this into account as irritative effects may appear over time.

Odour is generally not considered to be related to health criteria and, therefore, has not been taken into account in evaluation procedures. However, the World Health Organization considers well-being as being part of health (WHO, 1999). Besides, complaints about building material odour are more probable than real health risk.

CONCLUSION AND IMPLICATIONS

Odour assessment is needed as a complement to chemical analysis in the frame of building material evaluation. Intensity measurement represented the most consensual and objective evaluation tool, but needs to rely on calibrated methods, which should be used for a harmonized European labelling scheme.

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