New developments in odour testing: Adapter connects emission test chamber and funnel

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Abstract. Healthy and energy efficient buildings must be free from disturbing odours. Odour emissions from building materials can be measured with the well-known and accepted standard ISO 16000-28 “Indoor air – Part 28: Determination of odour emissions from building products using test chambers”. For commonly used emission test chambers the sample air is collected in containers (bags) and presented to a group of panel members for the purpose of evaluating the odour. A standard sets requirements for the on-demand presentation in detail. These include the validation procedure for container materials, pre-treatment of bags, details on storage of filled bags and how to carry out the measurements. However, although these measures are proven in practice, incorrect measurements are still possible. Also errors can occur due to a very complex measurement procedure. So, there is a great need for research into how the odour samples are presented.

The proposal planned to be presented will introduce a new development in sample provision by using an adapter which enables collection and provision of sample air without storage or transport of bags. The adapter is a sample container which is permanently positioned on the emission test chamber´s outlet and continuously filled with sample air flowing through it. The flow is briefly interrupted at the time when a sample is taken by a panel member for the test.

The size of the container is sufficient to provide enough sample air for evaluation by at least one panel member via a funnel. Since sampling and presentation are technically connected, it means you can almost do away with storage or transportation and thus it can be presented almost unchanged to the panelmembers. The aim is to reduce measurement errors in the odour samples provision process and the improvement of measurement reproducibility. The paper presents the construction of the adapter as well as the results of emission and odour tests carried out so far.

Keywords. Building materials, odour, emission, test chamber, perceived intensity, bags, sample provision system, adapter.
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1. Introduction

Building products used indoors such as floor coverings, paints and adhesives should be low-emission and hardly noticeable in terms of odour. This protects the health and well-being of those people who spend time in these rooms. Unfortunately, odour nuisance and the associated health complaints, e.g. irritation of the eyes or headaches, are among the most frequently mentioned impairments of indoor spaces [1]. The resulting dissatisfaction in office buildings can also lead to lower productivity [2, 3].

The use of low-emission and low-odour products is becoming increasingly important, as the European Union's goal of achieving greenhouse gas neutrality by 2050 [4] also focuses on the energy efficiency of buildings. With buildings accounting for 40% of the total annual energy demand, Member States have committed to enhancing building renovation. New should be constructed to the nearly-zero energy standard [5, 6]. Due to energy-efficient construction, accompanied by better thermal insulation of façades and tightly closing windows and doors, the building envelope is becoming increasingly airtight. If users try to ventilate unpleasant odours out of the room, e.g. by frequently opening windows, the building's heating energy demand inevitably increases [7]. In addition, the users’ comfort can decrease due to falling room temperatures or undesirable drafts, which in turn can lead to health problems [8]. The testing and use of low-emission and low-odour products is therefore essential for healthy indoor air and energy-efficient building operation. The ISO 16000-28 standard for odour testing has been available since 2012. It comprehensively describes the odour testing options for building products using an emission test chamber [9]. The building product to be tested is measured under standard conditions (23°C, 50% relative humidity and an air exchange rate of 0.5 h-1). The sample air from the emission test chamber is then evaluated using the criteria acceptability or perceived odour intensity Π. The perceived intensity describes the strength of an odour perception and is evaluated with the help of a reference. For this purpose, different acetone concentrations in air are set on the so-called comparative scale and offered for comparison to a specially trained group of panel members. The hedonic note, i.e. how pleasant or unpleasant an odour is perceived, can be added to the evaluation as a further measurand. The olfactory measurands and the comparative scale have been described in detail in various publications [10, 11].

To evaluate the sample air, it must be ensured that a sufficient and constant air flow rate of 0.6 to 1.0 l/s is made available to the panel members. This prevents ambient air from mixing with the sample air during smelling. Another requirement according to EN 16516 is to establish an air exchange rate of 0.25 to 2.0 h-1 in the emission test chamber [12]. Due to these requirements, sample provision on a funnel directly connected to the emission test chamber is only possible with very large test chambers (from a size of 3 m^3) and is thus rather the exception. In the smaller test chambers normally used, sample containers are filled with sample air from the emission test chamber and presented to the panel for odour evaluation. The tested and ISO 16000-28 approved materials polyvinyl fluoride (brand name: Tedlar®) and polyethylene terephthalate (brand name: Nalophan®) serve as sample containers [9].

As various studies show, the type of sample provision can influence the result of the odour measurement. The results of the perceived intensities can be different in direct evaluation compared to those from sample container-based evaluation because the sample air changes in the sample container [13–16]. Overall therefore, there is a great need to preferably use direct sample provision. The adapter presented here offers this possibility.

2. Research Method

2.1 Development of the adapter

In sample container assessment, sample air is first collected in a sample container and then placed in a sample provision system for assessment by the panel (Figure 1).

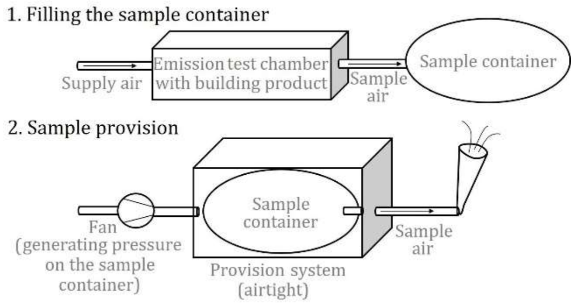


Fig. 1 - Sample provision setup using sample containers according to ISO 16000-28 (two sub-steps).

The adapter enables the collection and provision of sample air in only one step (Figure 2) by connecting the emission test chamber to the funnel. It is capable of buffering a sufficient amount of air for assessment by a panel member and providing it at the moment of sampling with a flow rate of 0.6 to 1.0 l/s.

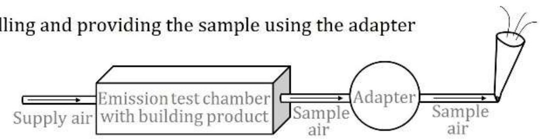


Fig. 2 - Sample provision setup using adapter (single step).

2.2 Adapter design and functioning

The adapter consists of a sample container (Tedlar or Nalophan bag) and the necessary accessories to allow alternating its operation between the filling process and sample air provision (Figure 3). During filling, the supply air valve is opened and the exhaust air valve is closed. As soon as the sample container is filled, the excess air flows to the funnel via the bypass. This prevents the flow conditions in the emission test chamber from being affected. The adapter is connected at least one hour before sampling to flush the sample container sufficiently with sample air. During emptying, i.e. at the time of sampling, the supply air valve is closed and the exhaust air valve is opened. The panel member can operate a blower with the help of a button, which exerts pressure on the sample container within the airtight box. This causes the sample container to empty towards the funnel. The blower speed can be controlled with the help of an orifice plate so that the desired constant volume flow rate (between 0.6 and 1 l/s) is provided at the funnel. The panel member can take sample air several times for evaluation. At the end of sampling, the exhaust valve is closed and the supply valve is opened to start the next filling process. During the emptying of the container, it must be ensured that the flow conditions in the emission test chamber are not influenced. This can be achieved by opening a sampling point to remove excess air.

The size of the sample container is about 15 l and is sufficient to provide sample air for evaluation by at least one panel member. Afterwards, the sample container is filled again ready for the next person to evaluate. The exact frequency of how quickly the adapter becomes available for the next panel member depends on the air exchange rate of the emission test chamber. For very small chambers, this may well take several minutes.

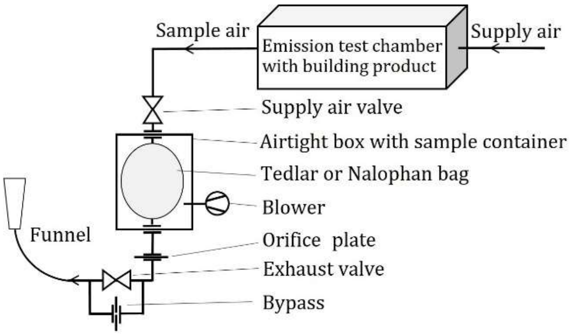


Fig. 3 - Adapter setup and positioning.

2.3 Carrying out experimental tests

To test and prove the applicability of the adapter, analytical and olfactory tests were carried out.

Analytical measurements

The aim of the analytical measurements was to check whether the sample air provided to the panel members when using the adapter had the same composition as when sampling directly. Figure 3 shows the measurement setup for sampling the air from the adapter. For the measurement, the adapter was connected to a 1 m^3 chamber that contained a varnish sample with various volatile organic components added artificially and operated with an air exchange rate of 1.1 h-1. An approx. 15 l Tedlar bag was used, which was baked out at 80 °C for 4 hours according to the requirements of ISO 16000-28. The bag was then rinsed with sample air for 12 hours. For sampling, another completely empty Tedlar bag, which had also been baked at 80 °C for 4 hours, was placed over the funnel and an emptying procedure was then carried out with the help of the blower (as described in 2.2). Thus the sample air flowed out of the bag in the adapter into the second Tedlar bag and filled it with sample air. Directly afterwards, a Tenax tube was loaded both from the emission test chamber and from the bag filled with sample air. The sampling volume was 1 l each at a flow rate of 100 ml/min. The substances were determined using thermodesorption and gas chromatography coupled with mass spectrometry measurements (TDS/GC/MS).

Olfactory measurements

Olfactory measurements have the aim of checking whether similar results have been achieved in an evaluation using the adapter as in the direct evaluation. Several tests were carried out, of which an investigation of a varnish sample artificially doped with additional VOCs is presented here as an example. The emission test chamber used was the 44 l CLIMPAQ (Chamber for Laboratory Investigations of Materials, Pollution and Air Quality), which is widely used in Northern Europe and is supplied with conditioned air (temperature and humidity according to ISO 16000-28) by an air conditioning system. The chambers comply with the requirements of ISO 16000-9 [17]. Loading was selected so that a distinct odour could be detected. All components that come into contact with sample air are made of glass or stainless steel. For direct evaluation, the air from the CLIMPAQ is fed directly to a glass funnel at a flow rate of 0.9 l/s.

For an evaluation using the adapter, the air flow is diverted and channelled to the adapter. The sample container made of Nalophan was rinsed with sample air for one hour before the test. The flow rate at the funnel was also set to 0.9 l/s for the sampling.

The study comprised the determination of the perceived intensity and the hedonic note by 9 trained panel members based on ISO 16000-28. The minimum size of 12 panel members required by the standard could not be met when performing the measurements due to the Corona pandemic. For the evaluation, the arithmetic mean was calculated from the individual values determined by the panel members. The 90% confidence intervals prescribed by ISO 16000-28 were ± 2.0 pi for perceived intensity and ± 1.0 for hedonics. The bag was filled for approx. 30 s after sampling. This time is sufficient for a 15 l sample container and a flow rate of 0.9 l/s.

3. Results

Analytical measurements

Table 1 shows the results of the analytical measurements.

Tab. 1 - Air composition in the emission test chamber and in the Tedlar bag filled via the funnel. Substance-specific determination of the components.

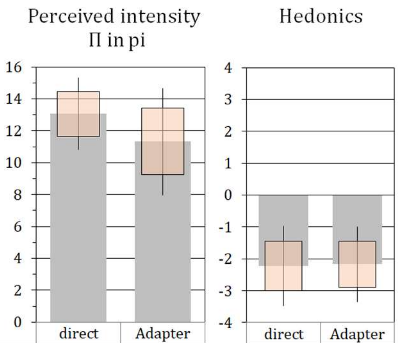
Components *(CAS number)*	Emission test chamber	Tedlar bag
	Concentration in µg/m^3	
Toluene *(108-88-3)*	23	17
Propylene glycol *(57-55-6)*	980	860
Butyl acetate *(123-86-4)*	3	1
Styrene *(100-42-5)*	27	23
Camphene *(79-92-5)*	14	13
Benzaldehyde *(100-25-7)*	21	20
Phenol *(108-95-2)*	24	19
Decane *(124-18-5)*	5	3
Acetophenone *(98-86-2)*	24	21

The air in the Tedlar bag has the same qualitative composition as the air in the emission test chamber, only the concentrations are somewhat lower for all substances. It is generally known that the concentrations in sample containers are lower. Analytically, however, except for propylene glycol, no significant distinction can be made between acetophenone concentrations such as 24 and 21 $\mu g/m^3$. The accuracy of the method in this measurement range is about 20%. Consequently, both values are in each other's uncertainty range.

Olfactory measurements

Figure 4 shows the results of perceived intensity and hedonics for direct evaluation and evaluation using an adapter.

The calculated mean value of the perceived intensity is 11.3 pi for the adapter i.e. lower than 13.1 pi obtained in direct evaluation. The difference of 1.8 pi shows that the results, compared with each other, are within the measurement uncertainty of the method. Despite the low number of panel members (9), the required 90% confidence interval has been met by the direct evaluation and just missed by the method using an adapter. The number of panel members and the standard deviation influence the confidence interval. Having the same number of panel members, the standard deviation is significantly greater in the adapter method since the values recorded by the individual panel members are very different: they are between 7 and 15 pi. Hedonics is rated the same at -2.2 in the direct evaluation and in the test using the adapter. The 90% confidence interval of the hedonics is also almost the same for both tests: 0.7 and 0.8.



	direct	Adapter	direct	Adapter
Mean	13.1	11.3	-2.2	-2.2
90 % confidence intervall	1.4	2.1	0.8	0.7
Standard deviation	15.3	14.7	-1.0	-1.0

Fig. 4 - Perceived intensity and hedonics – directly determined and using an adapter.

4. Discussion

The results of the analytics show, as expected, that the sample air has a very similar composition at the funnel as in the emission test chamber and that the adapter is a suitable device in terms of analytics. The measurements will be repeated in the course of the study with a sample that emits higher substance concentrations that will help the system to achieve the more accurate measuring range of the GC/MS method. The Tedlar bag, which is placed over the funnel, should also be rinsed with sample air beforehand to increase accuracy. The measurements will also be carried out using Nalophan sample containers.

The results of the olfactory measurements, one of which was presented here as an example, show overall that the intensities determined using the adapter are often reported as lower and the standard deviations are higher. Further investigations have shown that an air backflow via the funnel into the sample container of the adapter may be the cause. As soon as a panel member stops pressing the button for the blower, air flows back because the emptied sample container exerts a suction effect. The sample air is thus provided in different compositions for the individual panel member. The adapter is currently being optimised so that a non-return valve can be installed between the funnel and the sample container. The measurements will be repeated after the modification and a larger number of panel members will be employed.

Overall, it can be assumed that all sampling systems without mechanical backflow prevention can lead to sample air dilution. The smaller the sample containers are and the more frequently the fan is operated by the testers to empty the bag, the more noticeable this becomes in the olfactory measurements.

The adapter should be used on test chambers from approx. 250 l size as the exhaust air volume at these chambers is still sufficiently large to fill a bag within an acceptable time. With a 15 l bag, an air exchange rate of 0.5 h-1 is achieved and after being completely emptied by a panel member, a bag can be completely refilled in approx. 8 minutes.

The advantage of the adapter over the commonly used sampling systems is that the air in the bags does not remain for a longer period of time and thus experiences little change. The procedure can be carried out in laboratories where odour assessment is feasible in close proximity to the emission test chamber. When planning the measurement, the filling time of the bags must be taken into account. If several samples need to be evaluated on one day, a fresh adapter must be available for each sample.

The adapter can help to further develop the odour measurement method according to the ISO 16000-28 procedure and reduce the influence of the type of sampling inasmuch as results comparable to direct evaluation can be achieved using the adapter. Overall, this will further increase the acceptance of ISO 16000-28. As a result, the dissemination of odour measurements for indoor building products can be further advanced for the benefit of health and energy-efficient building operation.

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The datasets generated during the current study are not publicly available because the study is still ongoing but will be available after the study is completed.