Developing a new passive tracer gas test for air change rate measurement

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ABSTRACT
Ventilation is critical in interpreting indoor air quality (IAQ), yet few IAQ assessments report ventilation rates; even when they do, the measurement method is often not fully described. Most ventilation assessments use a tracer gas test (TGT) to measure total air change rate. In a TGT, the indoor air is marked with an easily identifiable gas (tracer) and the air change rate (ACH) is inferred by monitoring the tracer’s injection rate and concentration. Passive sampling (adsorptive/absorptive samplers) is mostly preferred to monitor tracer concentration for its simplicity, practicality and affordability. Such samplers are commercialized by a range of companies and are widely used in IAQ studies to assess pollutants levels. Currently used passive TGTs present three major limitations: (1) disconnection from IAQ analysis (providing ACH data in a different time-scale than IAQ data), (2) employment of inadequate substances as tracers and (3) tendency to bias arising from the perfect-mixing assumption. Thus, this paper proposes a new approach on the passive TGT method, employing as tracer a suitable gas that can be co-captured and co-analysed using commercial passive samplers employed in common IAQ studies and which includes a more careful planning phase to account for imperfect mixing. A literature review was carried out in pursuit of such a gas, and the gases considered as possible tracers were the volatile organic compounds (VOCs) capable of being captured by the samplers commercialized by Radiello®. Radiello® samplers are composed by activated charcoal, which captures all VOCs in the targeted molar mass range by adsorption. The info-sheets for these samplers were consulted. Two options for alternative tracer gas are currently under consideration: 2-butoxyethyl acetate (EGBEA) and deuterated decane (D-decane). Both present low-reactivity, usually negligible background indoor concentration, generally low toxicity and no links to chronic health effects. A preliminary field test was carried out in order to check EGBEA’s measurability, and results showed insignificant background EGBEA concentration and good measurability by the Radiello® sampler. A total of six chamber tests were performed to evaluate the behaviour of EGBEA and D-decane under standard conditions and to optimize a source design: three in stainless steel chambers (TCP1, 2 and 3) and three in glass chambers (GCP1, 2 and 3). Results from these chamber tests indicate emission rates stability and enabled incremental enhancements to the source design. Further chamber tests will be performed to evaluate the behaviour of the potential tracers under varying conditions and to further optimize the source design. Future work also includes simulation of TGTs in imperfectly-mixed zones to study the effects of source/samplers positioning on the accuracy of the resulting ACH calculations.

KEYWORDS
Ventilation, air change rate, indoor air quality, tracer gas test, passive sampling.

1 INTRODUCTION

Air pollution in indoor environments has become a great concern in the last decades. People tend to spend the majority of their time indoors, where numerous known sources of substances with high potential to cause adverse effects to human health are present. A crucial factor in determining the accumulation of pollutants in indoor environments is ventilation, and its impacts on the health and comfort of occupants have long been recognized in standards and regulations. Simultaneously, ventilation is closely related to the energy efficiency of a building (Persily, 2015): the higher the building airtightness, the higher is its insulation, saving heating/cooling costs. However, increased airtightness can lead to lower total ventilation rates, ultimately representing a health concern.

Although ventilation is critical in interpreting indoor air quality (IAQ) measurements, only few IAQ field studies report measured ventilation rates; and even when they do, the measurement methods are often not described in sufficient detail to evaluate their quality or applicability (Persily,
Given the importance of ventilation in estimating pollutant sources impact and proposing remediation actions, it is crucial that IAQ assessments report actual ventilation rate values, measured by means of a reliable and reproducible method.

Methods currently used for measuring ventilation rates either involve direct flow rate measurements at vent holes combined with pressurization tests, or a tracer gas dilution/dispersion test (TGT). The first type is used only under very specific circumstances, such as in extremely airtight buildings where all airflows occur mechanically in ductwork. Thus, most ventilation assessments use TGT as a method to measure the total air change rate (ACH) of a building/indoor space (Persily, 2015). In a TGT, the air is marked by the injection of an easily identifiable gas and the ACH is then inferred by monitoring the tracer emission rate and room concentration. TGT is the only method capable of measuring the actual airflow between building zones and the outdoors (Lunden et al., 2012). Although the TGT approach may yield less precise ACH data, its higher degree of uncertainty is compensated by its greater simplicity, convenience and compatibility to be executed during normal occupancy, allowing to account for the large effect occupancy has on a building’s ACH (Lunden et al., 2012). TGTs are especially suited for large-scale ventilation surveys, in which a lower degree of individual data precision is acceptable in favor of increased amount and representativeness of data.

However, there are three important shortcomings related to TGTs: 1) Most TGT techniques provide instantaneous results (due to the use of online monitors), whereas the concentrations of indoor pollutants are commonly measured using long-term sampling techniques that report time-averaged values, i.e. IAQ and ventilation data are not directly comparable due to their differing time-scales; 2) Most TGTs employ sulfur hexafluoride (SF₆) or perfluorocarbons (PFTs) as tracer gases, both being potent greenhouse gases with very long lifetimes in the atmosphere (IPCC, 2007), making it imperative to find alternative tracer gases; 3) Common TGT application assume that the air in the assessed indoor space has a homogeneous spatial distribution. However, a perfect-mixing situation is rarely observed in real life, meaning that the placement of the tracer source and samplers can greatly impact the measurements of tracer concentration, which can lead to severe bias in the ACHs measured by TGTs (Van Buggenhout et al., 2009; Lunden et al., 2012; Liu et al., 2018).

Thus, a TGT which provides ventilation rates in the same timescale as the pollutant concentration measurements, uses a more adequate substance as tracer and includes a more careful planning for placing sources/samplers to account for imperfect mixing would be more appropriate than the ones currently used. Furthermore, it is also important that the new method is suitable for use during normal occupancy, thus the TGT must not cause disturbance and the employed tracer must be scientifically proven harmless to the occupants’ health. Also, a highly desirable characteristic for this new method is the employment of purely passive techniques, which lowers the costs involved and broadens the range of buildings where it can be applied.

Taking all these desired characteristics into account, this project aims to develop a reliable and reproducible TGT using as tracer a substance that is safe for use during occupancy and that can be co-captured and co-analyzed with standard passive samplers used for common IAQ assessments. Additionally, this new method proposes the implementation of a pre-test planning phase in which the optimal physical placement of sources/samplers is determined by means of simulations, in an effort to minimize bias arising from imperfect mixing.

2 MATERIALS AND METHODS

2.1 Selection of a new substance for use as tracer gas

The first step to propose this new TGT consists of finding an adequate substance to be used as a tracer, alternatively to the currently employed SF₆ and PFTs. This initial step was done by means of a comprehensive literature review. The thought process through which the literature review was carried out is explained below.
Volatile organic compounds (VOCs) are among the most relevant contaminants in IAQ studies, as they are ubiquitous in indoor spaces and several are knowingly harmful to human health. Most researchers utilize passive sampling techniques to quantify time-averaged VOCs concentrations, for its accuracy, practicality and suitability for use during normal occupancy. If the tracer gas selected for this new TGT can be captured by commercial passive VOC samplers, the issue of time-scale difference between pollutants concentrations and ACHs is eliminated. This approach also saves time and resources, as only one passive sampler and one analysis provide all the information needed to infer both the ACH and the indoor VOCs level. Thus, the gases considered for use as tracer were the VOCs capable of being captured by the passive VOC samplers commercialized by Radiello®, i.e. VOCs in the range C2-C12 (Radiello, 2007).

Initially, paraffins were considered as candidates for their high stability, inertness and low toxicity. There is however a major setback regarding the applicability of paraffins as tracers. A tracer gas should be easily recognizable from all other constituents of air. Ideally, the background concentration should be negligible. A non-zero background concentration may be accepted provided that it is stable, that the additional concentration is significantly larger and that it is low, to avoid oversaturation of the passive sampler. Paraffins do not fulfill this criterion, as they typically present considerably high background concentration in most indoor environments. Thus, the use of paraffins as tracer gas is inadequate.

The second option considered for use as tracer gas is the solvent 2-butoxyethyl acetate (EGBEA). Although EGBEA is present in various household products, studies show that its presence in indoor environments is usually insignificant (Plaisance et al., 2008; Billionnet et al., 2011; Derbez et al., 2014). Regarding human health, EGBEA has generally low toxicity and has not been linked to any chronic effects (ATSDR, 1999; ECETOC, 2005; SCHER, 2006).

An alternative for EGBEA is the use of stable isotope labeling, more specifically using deuterated compounds, not naturally present in the atmosphere or in any household product. Stable isotopes are analytically distinguishable yet chemically and functionally identical to their original correspondent compounds (Wilkinson, 2016). This approach allows revisiting the initial idea of using paraffins as tracers. Thus, the second option currently under consideration is the use of deuterated paraffins in C8-C15 range. Deuterated decane (D-decane) is initially considered for its combination of lower flammability and higher volatility.

2.2 Preliminary test

A preliminary test was carried out in order to test EGBEA’s measurability by Radiello® samplers in simplified field conditions. Radiello® samplers were used to measure this compound’s concentration in one room before and after the placement of a recipient containing the solvent. The room used was an unoccupied, fully furnished office (two desks with two chairs, two PCs, one wall cabinet and plastic blinds in the windows). Three sampling cartridges were used in total: one as a lab blank (no exposition); one to measure the background EGBEA concentration; and one to measure the air concentration of EGBEA after the placement of a source of this solvent in liquid phase. The source consisted of a simple glass beaker filled with approx. 11 ml of EGBEA (9.54 g) left uncapped so the solvent could freely volatilize into the room, acting therefore as a completely passive source. Both these samplers were exposed in the room for a period of 4 consecutive days. Figure 1 shows the setup of the experiment.

2.3 Chamber tests

To this date, a total of 6 chamber tests have been executed, 3 of them (TCP1, 2 and 3) using steel chambers and 3 of them (GCP1, 2 and 3) using 62 dm³ glass chambers (due to limited availability of the steel chambers). In these chamber tests, different source designs were tested to evaluate the behavior of EGBEA and D-decane when released to the air under standard and constant conditions. From that baseline, it will then be possible to compare the substance’s behavior under
varying conditions and circumstances in future chamber tests. Testing under standard/constant conditions also enables the determination of the concentration curve of the tracer, allowing to know when it will reach steady state.

Figure 1: Preliminary test setup

2.3.1 TCP1 (Test chamber phase 1)

The first chamber test was the Test Chamber Phase 1 (TCP1), in which liquid phase EGBEA was added to a glass recipient with an adjustable cap and then used as tracer source inside the chamber. The test chamber was a 117 dm³ steel chamber, with temperature, relative humidity and ACH set to constant standard conditions (23°C, 50% and 0.5 h⁻¹, respectively, according to ISO 16000-9). EGBEA concentrations in the chamber were simultaneously monitored by passive sampling (Radiello® tubes, solvent desorption), active sampling (Tenax® tubes, thermal desorption) and online monitoring (flame ionization detector - FID). Figure 2 shows the chamber setup at the beginning of the experiment. TCP1 had a whole duration of 8h for FID and active sampling monitoring, and of 3 days for passive sampling.

The FID measures the air concentration of total hydrocarbons (THC). In TCP1, since the airflow provided to the chamber was completely clean of THC and there was no other source of VOCs inside the chamber, the THC concentration measured was equivalent to the EGBEA concentration originating from the source. In order to determine specifically the absolute EGBEA concentration, Tenax® tubes were used to collect one air sample each hour, and 2 Radiello® samplers were placed together inside the chamber. Both Tenax® and Radiello® samplers were analyzed by means of gas chromatography with mass spectrometry detection. Tenax® samples were taken in 8 moments (the first before the source placement), one per hour, for a period of around 30min each (sampling period determined by the sampling pump flow and the maximum volume of air that can be sampled by the tube). The Radiello® samplers were placed inside the chamber at the same time as the source and remained there until the chamber was opened, 3 days later.

2.3.2 TCP2 (Test chamber phase 2)

After TCP1, second phase of chamber testing was executed as a repetition of TCP1, under the same conditions. It was called Test Chamber Phase 2 (TCP2) and its planning took into account some shortcomings observed in TCP1. The setup of TCP2 is shown in Figure 2.

There were four main differences between TCP1 and TCP2: 1) the glass recipient used as source in TCP1 was substituted by a different one in TCP2 (Figure 2), in an attempt to lower the tracer emission rate; 2) a bigger chamber was used in TCP2 (WEISS chamber, 1000 dm³), to enable an increase in the airflow rate (to dilute more the tracer, in case the emission rate from the new source remained high) while still maintaining the same ACH from TCP1; 3) the FID monitor yielded results below the detection limit due to a misconfiguration, thus no continuous FID data is reported for TCP2; and 4) two tracer options were tested, first EGBEA and then D-decane (n-decane was used as a proxy for D-decane, as an economy measure).
The EGBEA source was tested first, and then the n-decane source. Each test lasted 3 days, with 8 Tenax® samples taken. In the EGBEA test, 1 sample was taken as blank, the following 6 were taken one per hour on the first day, and 1 was taken after 72h. In the n-decane test, 1 sample was taken as blank, the following 5 were taken one per hour on the first day, 1 was taken after 51h and 1 was taken after 70h. One Radiello® sample was taken per test, for a period starting with the tracer source placement and until the reopening of the chamber.

Figure 2: Setup of TCP1 (left) and TCP2 (right)

2.3.3 GCPs (Glass chamber tests)

After TCP2, the chamber testing was transferred to glass chambers due to the lack of availability of the WEISS chamber. A series of three glass chamber tests was performed (GCP1, 2 and 3) with the primary focus of determining a more adequate source for the emission of tracer gas. The source design for the chamber tests after TCP2 was based on Shinohara et al. (2010). Although they used PFCs as tracers, the source design can be adapted for use as EGBEA and D-decane sources. For details on the source design, see Shinohara et al. (2010).

The GCPs were performed using 62 dm³ glass chambers in VITO lab. The ACH, temperature and RH for all chambers in all three GCPs were set to 0.5 h⁻¹, 23°C and 0%, respectively. Each glass chamber was equipped with a small fan to ensure a homogeneous concentration inside (ISO 16000-9). In each GCP, one tracer source and one Radiello® sampler were placed inside each chamber, which was then hermetically sealed. Tenax® samplers were used to monitor the concentration of tracer gas inside each chamber. The use of the FID monitor was discarded since it can only monitor one chamber at a time. Figure 3 shows an example of source used in the chamber tests after TCP2 and the basic setup of the GPCs.

In GCP1, two glass chambers were used to test one EGBEA source and one D-decane source. The sources used mimicked the source designed by Shinohara et al. (2010) using a 0.4 mm x 20 mm needle and a 9mm x 7.5 cm syringe, in which a manually cut disk of polyethylene (PE) sintered filter was placed. GCP1 ran for a total length of 48h. The sources were weighed before and after placement in the chambers for determination of the average emission rate.

GCP2 repeated GCP1, with 4 alterations: 1) the needle used to pierce the source was substituted for a larger one (1.2 mm x 40 mm); 2) The PE sintered filter disks were cut using a tool instead of manually, to increase the source design reproducibility; 3) The duration of GCP2 was increased to a total of 7 days, to check the source stability for a typical IAQ assessment using Radiello®; and 4) A total of 4 chambers were used, 2 duplicates for each type of tracer, in order to test the sources repeatability.

The GCP3 setup had two slight alterations from GCP2 setup, aiming to tackle the issues observed in GCP2: 1) the four pumps used for Tenax® sampling were re-adjusted to render the airflows more stable when connected to the Tenax® tubes; and 2) the PE sintered filter disks were removed from the source’s syringes (it was noted that one of the disks moved inside a syringe during of GCP2, with no effect to the source emission rate).
2.3.4 TCP3 (Test chamber phase 3)

After GCP3, the WEISS chamber was again available for performing TCP3. The source design was the same one from GCP3. Temperature, RH and ACH were 23°C, 50% and 0.5 h⁻¹ respectively. One source of EGBEA and one of D-decane were placed simultaneously inside the WEISS chamber, along with two Radiello®. TCP3 had a whole duration of 10 days. Tenax® samples were taken through the whole test (18 points in time, two duplicates per time). A different, recently calibrated flowmeter was used to determine the airflows provided by the Tenax® sampling pumps.

3 RESULTS AND DISCUSSION

3.1 Preliminary test

Results from the preliminary experiment are presented in Table 1.

<table>
<thead>
<tr>
<th>Sample</th>
<th>Sampling start</th>
<th>Sampling finish</th>
<th>EGBEA mass</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lab blank</td>
<td>-</td>
<td>-</td>
<td>0.067</td>
</tr>
<tr>
<td>Background</td>
<td>15/01 – 17h25</td>
<td>19/01 – 17h39</td>
<td>0.059</td>
</tr>
<tr>
<td>With EGBEA source</td>
<td>19/01 – 17h40</td>
<td>23/01 – 17h34</td>
<td>3.324</td>
</tr>
</tbody>
</table>

The background EGBEA concentration in the office was insignificant (the EGBEA mass desorbed from the background-sampling cartridge was very similar to the mass desorbed from the blank cartridge, even slightly lower, meaning that virtually no EGBEA was adsorbed). Furthermore, the relatively low volatility of EGBA (0.23 g evaporated in 4 days) did not hinder its measurability by the Radiello® sampler: the cartridge placed in the room after the addition of the EGBEA source adsorbed an EGBEA mass two orders of magnitude higher than the blank and background cartridges. The calculated average concentration in air corresponding to the adsorbed mass after 4 days exposure to the EGBEA source was 14.1 µg m⁻³. These results can be interpreted as clear indications of the potential suitability of EGBEA as tracer for a new TGT: its background concentration in the assessed room was negligible and it was successfully captured by a commercial VOC sample at a measurable level.

3.2 Chamber tests

3.2.1 TCP1

Figure 4 shows the results measured by the FID monitor during TCP1. Results measured by the FID monitor presented a noisy signal, most probably due to the fact that the sampling flow from the chamber to the FID had to be combined with another (clean) airflow in order to reach the
working FID inlet flow. Nevertheless, the FID measurements followed the theoretical concentration trend quite well.

Figure 4: Results measured by the FID monitor during TCP1.

The theoretical concentration ($C(t)$) of an emitted substance in a test chamber is given by:

$$C(t) = C_0(1 - e^{-Nt})$$

(1)

In which $C_0$ is the substance concentration when it reaches steady state and $N$ is the ACH. Thus, even though the FID response was noisy, it can be considered realistic.

The Tenax® and Radiello® tubes used for sampling were oversaturated. The Radiello® samples were diluted for reanalysis (results should be considered with care), revealing a very high 3-day average EGBEA concentration in the chamber (1690 µg m$^{-3}$). The Tenax® samples could not be diluted due to the destructive nature of the thermal desorption. These high adsorptive sampling results, along with the also high FID results (> 13000 µg m$^{-3}$), indicate that the emission rate of the source was too high for a TGT. Thus, planning of TCP2 included the substitution of the source.

3.2.2 TCP2

Figure 5 shows the results obtained with the Tenax® samplers in both tests of TCP2.

The concentration levels reached inside the chamber were much lower than in TCP1. However, the EGBEA concentration curve deviated considerably from the expected pattern, and it is not possible to determine if a steady state was reached. Since the WEISS is designed to eliminate sink effects and the same problem was not observed in the n-decane test, it is deduced that the recipient used as EGBEA source was not able to hold a constant emission rate.

The Radiello® samplers yielded average 3-day concentrations of 71.8 and 949 µg m$^{-3}$ for EGBEA and n-decane, respectively. The EGBEA result is consistent with the last Tenax® sample. On the other hand, the n-decane concentration was extremely high compared to the Tenax® results, indicating a possible contamination of the Radiello® sample. Moreover, the analysis results from the GC-MS showed that the Radiello® samples yielded peaks with areas above the linearity range of the calibration curve, meaning that the calculated concentrations should be considered with care, similarly to TCP1. To address these issues, a different tracer source, with lower, more stable and reproducible emission rate, should be used. Moreover, actual D-decane instead of n-decane as a proxy should be employed to avoid possible contamination. These measures were taken into account in the following chamber tests.
3.2.3 GCPs

The results obtained in GCP1 with the Tenax® samplers for the chamber with the EGBEA source are displayed in Figure 6. The samples taken from the chamber with the D-decane source had no D-decane adsorbed onto them, i.e. the D-decane concentrations reached were too low for the applied sampling conditions (total air volume sampled).

After 2h, the EGBEA concentration stabilized at about 2 µg m⁻³ for the next 5h of the experiment. During the night between the first and second day, the mixing fan inside the chamber detached from the lid and fell, tipping over the EGBEA source. The Tenax® samples taken after the fan fell are considered invalid.

The Radiello® samples yielded an average concentration of 21.7 µg m⁻³ of EGBEA and 6.11 µg m⁻³ of D-decane in their respective glass chambers. The EGBEA result is close to the results yielded by the Tenax® samples taken after the source was tipped over. The D-decane result shows that in fact the source did emit some D-decane, although resulting in a low average concentration, explaining why the Tenax® sampling was unable to capture the tracer.

The emission rates from the sources could not be determined by gravimetry (mass differences were too small), thus they were calculated indirectly using the following equation:

\[ G = VqC_s \]  

In which G is the source emission rate (µg h⁻¹), V is the chamber volume (m³), q is the ACH (h⁻¹) and C_s is the steady-state tracer concentration, here considered equal the Radiello® result (µg m⁻³). In GCP1, the emission rates yielded by the proposed source design were very low (0.7 µg h⁻¹ for EGBEA and 0.2 µg h⁻¹ for D-decane). Such emission rates, if applied to a real room, would result in too low indoor concentrations (<0.05 µg m⁻³) to be accurately measured by passive sampling. The alterations applied to the GCP2 setup (see section 2.3.3) had thus the aim of increasing the source emission rate.

Results obtained in GCP2 are displayed in Figure 7. The shapes of the concentration curves for EGBEA and D-decane measured with the Tenax® samplers in GCP2 were closer to the theoretical shape than in GCP1. The maximum concentrations reached indicate a higher volatility and thus a higher emission rate for the D-decane sources compared to the EGBEA ones. The emission rates calculated from the Radiello® results (Equation 2) were 0.6 µg h⁻¹ for EGBEA and 3.2 µg h⁻¹ for D-decane (average), indicating that increasing the needle diameter was effective in increasing the emission rate for D-decane. Also, the PE disk was significantly dislocated inside the syringe of the chamber 1 EGBEA source. To enhance repeatability, its use was discarded for GCP3.

Figure 8 displays the results obtained in the four glass chambers during GCP3. In GCP3 the Radiello® results were slightly higher than the corresponding Tenax® final results. The issues in Tenax® sampling observed in GCP2 and 3 was due to airflow meter used to check the sampling pumps airflows, which was uncalibrated. Such de-calibration was not significant for airflows above approx. 100 ml min⁻¹, but was significant for lower airflows (measurements were highly overestimated in that range). Consequently, the absolute concentration values of the Tenax® samplers should be considered as indicative.
Figure 7: EGBEA and D-decane concentrations over time measured in GCP2 (issues in the sampling process affected the Tenax® results: corrected results are shown for chamber 3, invalid results not shown for chamber 2).

Figure 8: EGBEA and D-decane concentrations over time measured in GCP3 (chamber 2 Radiello® discarded due to contamination; issues in the sampling process affected the Tenax® results of chambers 2 and 3, similarly to GCP2).

Still, the shapes of the concentration curves observed in GCP3 are consistent with the expected trend and overall similar to GCP2. The Radiello® results show that removing the sintered filter disk from the source increased the emission rate for D-decane (from 3.2 µg h⁻¹ to 4.8 µg h⁻¹). For EGBEA, the emission rate remained the same for the 3 GCPs (0.7 µg h⁻¹).

3.2.4 TCP3

After GCP3, TCP3 was executed in the WEISS chamber. Figure 9 displays the results obtained in TCP3.

Figure 9: EGBEA and D-decane concentrations over time measured during TCP3.
From the emission rates calculated in GCP3, the final concentrations in the WEISS chamber were expected to be approx. 1.4 and 9.6 µg m⁻³ for EGBEA and D-decane, respectively. As can be seen in Figure 9, the final concentrations were close to these predicted values.

TCP3 results are consistent with what was observed during the GCPs. The emission rates calculated from the Radiello® results were 1.0 µg h⁻¹ and 5.2 µg h⁻¹ for EGBEA and D-decane, respectively, values only slightly higher than the calculated for GCP3, suggesting that the difference in relative humidity did not alter the behavior of the sources.

4 CONCLUSIONS

This paper describes an ongoing project dealing with the development of a new TGT, with the motivation of providing an ACH measurement method as simple, practical and accurate as possible. The ultimate goal is to provide a method so convenient that it will encourage researchers to include ventilation assessments in their IAQ studies. This new TGT focuses on tackling 3 major issues commonly related to TGT applications: differing timescale between ACH and IAQ data, inadequate substances used as tracers and perfect-mixing-assumption bias. Until the present, efforts have been focused on the pursuit of a new adequate tracer gas and of a suitable source design. Extensive literature review, a preliminary field test and a total of six chamber tests have been executed so far, with results indicating an overall good applicability of two substances as tracers (EGBEA and D-decane) and with incremental enhancements to the source design. Work will be continued with further chamber tests to evaluate the behaviour of the potential tracers under varying conditions and to optimize the source design (to increase emission rates and stability). Future work also includes simulation of TGTs in imperfectly-mixed zones using CONTAM software coupled to CFD to study the effects of source/samplers positioning on the accuracy of the resulting ACH calculations.

5 REFERENCES


