# The future of passive techniques in air change rate measurement

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**SUMMARY**
Current methods used to measure ventilation rates are either expensive, unpractical or disconnected from IAQ measurements. This paper proposes the use of different substances as tracers in the classic tracer gas method, prioritizing their safety to occupants, possibility of sampling by commercially available passive samplers and low background indoor concentrations. The use of 2-butoxyethyl acetate as tracer gas is evaluated as a first possibility.

**KEYWORDS**
Ventilation; tracer gas test; IAQ assessment

## 1 INTRODUCTION

Ventilation is critical in interpreting indoor air quality (IAQ), but only 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) approach to measure total air change rate, which consists in marking the indoor air with an easily identifiable gas (tracer) and then inferring the air exchange rate by monitoring the tracer's injection rate and concentration (Persily, 2016). For this monitoring, two sampling options can be used: active samplers, costly and complex, or passive samplers (which work by absorption/adsorption without electricity use), overall more advantageous: cheaper, smaller, lighter, simpler and silent. Affordable passive samplers are commercialized by a range of companies and are already widely used in IAQ studies to analyse the presence of several gaseous pollutants (Stranger et al., 2008). However, currently employed TGTs in IAQ assessments are either active or not conceived to be executed together with common IAQ analysis, providing ventilation rates in a different time-scale than the pollutant concentrations. Thus, this paper proposes a new approach for the TGT method, using as tracer a substance that can be co-captured and co-analysed using commercial passive samplers commonly used in IAQ studies.

## 2 METHODS

Most TGTs use sulfur hexafluoride ($SF_6$) or perfluorocarbons (PFTs) as tracers. Despite being non-toxic, PFTs and $SF_6$ are potent greenhouse gases (IPCC, 2013). The pentIAQ® is a commercially available passive system for ventilation assessment, in which the customer acquires the source and samplers along with specific usage procedures. This system is essentially disconnected from IAQ analysis and the TGT method employed is not verifiable or reproducible, as even the tracer gas employed is unknown. The key to propose this new TGT is to first find a substance better suited for use as tracer, initiating with a thorough literature review. An ideal tracer is non-reactive, insensitive, unique, measurable and safe (Sherman, 1990). Also, it should be possible to capture/analyse this substance passively, preferably using the same commercial samplers employed in IAQ studies. Thus, the literature review focused on verifying, among the gases that can be sampled by such samplers, which ones present the best combination of desired characteristics. A preliminary field test was carried out in order to check 2-butoxyethyl acetate measurability: Radiello® samplers were used to measure its concentration in one room before and after the placement of a recipient containing the solvent.

## 3 RESULTS AND DISCUSSION

Considering that the most relevant compounds in IAQ studies are volatile organic compounds (VOCs), and that such gases are sampled separately from inorganic pollutants due to their different characteristics, the gases considered as possibilities for use as tracer were the VOCs capable of being captured by the VOC samplers commercialized by Radiello®, 3M and Gradko. These samplers are composed by activated charcoal, which captures VOCs by adsorption. This process is non-specific, i.e. any VOC in the targeted molar mass range may be captured and later analysed in lab using the adequate analytical process. Also, a good tracer gas must be suitable to use during normal occupancy (as occupancy greatly affects IAQ), thus the substance must be safe for occupants. The information sheets for the commercial passive VOC samplers were consulted: Radiello® and 3M samplers capture VOCs in the range C2-C12; Gradko samplers capture compounds up to C28. Initially, paraffins C8-C15 were studied as possible tracer gas candidates. However, their typical background concentration is too elevated in most indoor environments, hindering their applicability as tracers. The option currently under consideration is the solvent 2-butoxyethyl acetate (EGBEA, CAS 112-07-2), mentioned by Radiello® in the VOC $CS_2$-desorption sampler info-sheet. Although EGBEA is present in various household products (ATSDR, 1999), its background indoor concentration is usually very low. A national survey for IAQ in 490 French dwellings found EGBEA concentrations below the detection limit in 97% of the assessed houses (Billionnet et al, 2011). More recent similar assessments, also in France, found no trace of EGBEA in any of the studied houses (Derbez et al., 2014; Plaisance et al., 2008). Regarding human health, EGBEA has generally low toxicity and has not been linked to any chronic effects (ECETOC, 2005; SCHER, 2006). Results from the preliminary field test showed insignificant background EGBEA concentration in the room (EGBEA mass desorbed from the cartridge placed before the recipient placement was lower than from a blank cartridge). The relatively low volatility of EGBA (0.23 g evaporated in 4 days) did not hinder its measurability by the Radiello® sampler, which measured a 4-days average EGBEA concentration of 14.1 µg $m^{-3}$. Further tests are being performed to determine the sampler's accuracy in measuring known EGBEA concentrations.

## 4 CONCLUSIONS

A TGT employing as tracer a harmless gas which can be passively emitted and then co-captured and co-analyzed along with common IAQ pollutants is close to an ideal method to measure ventilation. After careful consideration, EGBEA solvent stand out as possible candidate: it can be captured by commercial VOC passive samplers, presents no relevant effects on human health and has a typical very low presence in indoor environments. A preliminary field test indicates good measurability. Further test chamber and field tests should be carried out in order to determine the actual applicability of this substance as tracer in TGTs.

## 5 REFERENCES


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