An inter-laboratory comparison study of the ANSI/BIFMA standard test method M7.1 for furniture

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Summary

Five laboratories using five different test chambers participated in the study to quantify within- and between-laboratory variability in the measurement of emissions of volatile organic compounds (VOCs) from new commercial furniture test items following ANSI/BIFMA M7.1. Test items were wood framed chairs produced as a single lot. Within- and between-lab relative standard deviations were determined for the sampling and analysis procedure, measured emission factors at days three and seven, and predicted emission factors at day 14 by power-law model. Results obtained were comparable to the lower bound of uncertainty ranges in previous round-robin studies of VOC emissions for individual dry materials. The study also identified areas for improvement of the test method.

KEYWORDS
Volatile Organic Compound (VOC), Emission Test Method, Office Furniture, IAQ

INTRODUCTION

ANSI/BIFMA M7.1 (2007) is a standard test method for the determination of VOC emission rates of office furniture and seating. Because the tests may be conducted at different labs, it is important to understand and determine the uncertainties involved so that test results can be properly interpreted and compared with respect to relevant acceptance criteria.

Table 1 Summary of Chair Test Conditions

	Lab A	**Lab B**	**Lab C**	**Lab D**	**Lab E**
Chamber	mid-scale	mid-scale	full-scale	full-scale	full-scale
Chamber air volume, V (m^3)	5.14	6.13	28.71	29.8	28.3
# of Chairs	1	1	6	6	6
Temperature, T (C)	23	23	23.4	23	23
Relative humidity, RH (%)	50	50	52.6	49.9	50
Air change rate, ACH (1/h)	0.67	1	1.07	0.97	0.5
Loading ratio, L (unit/m^3)	0.19	0.16	0.21	0.20	0.21
Unit specific flow rate, N/L (m^3/unit-h)	3.44	6.13	5.12	4.82	2.36

METHODS

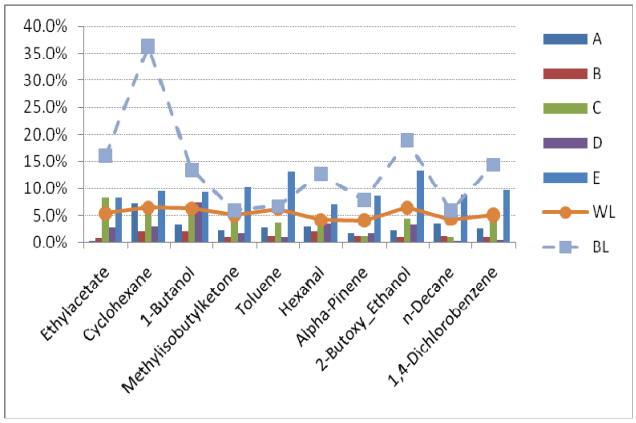
Five labs participated in the study (Table 1). The test item consisted of a wood framed chair with vinyl-wrapped foam seat cushion and back produced as a single lot. BEESL collected the chairs at the manufacturer, packaged each chair in a multi-layer Mylar bag, and shipped them to participants. Duplicate sequential tests were conducted at each lab. The tests were coordinated among the labs to start on the same dates. Chamber air samples for VOCs and

aldehydes were collected at 72, 168 and 336 hours. These samples were analyzed by thermal desorption GC/MS for total VOCs quantified as toluene (TVOCtoluene), for individual VOCs (IVOCs), and summed VOCs (TVOCsum--the sum of the mass of individual VOCs with concentrations no less than the M7.1 target LOQ of 2 μg/m^3, quantified by the reference compound response factor for the corresponding chemical class, ANSI/BIFMA M7.1-2007). Formaldehyde and acetaldehyde were sampled by DNPH cartridges and analyzed by HPLC.

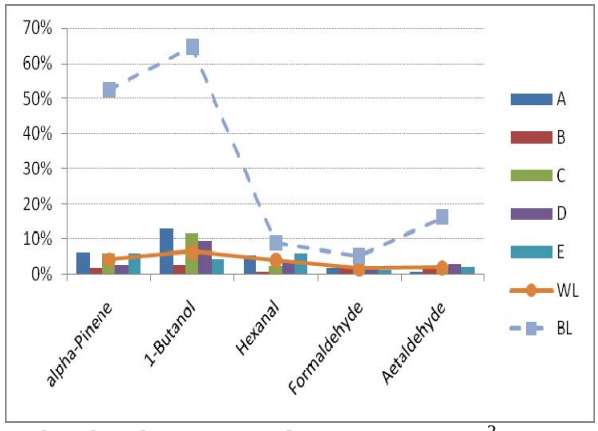
Prior to the chair tests, each lab established a quality assurance plan for the project and validated the operation of its chamber. Preliminary assessments were also conducted. These consisted of the analysis of three sorbent tubes spiked by BEESL with unknown amounts of ten representative IVOCs in the M7.1 (Figure 1a) and the analyses of three VOC and three aldehyde samples taken during an office workstation test at BEESL. A blank Tenax tube and DNPH cartridge was also analyzed with each batch of samples for quality control.

The relative standard deviation (RSD), defined as the standard deviation among the quantities of interest (concentrations or emission factors) divided by the mean of the quantities was used to quantify the variability within and between labs. The overall within-lab repeatability was calculated as the root mean square of the RSDs within individual labs.

RESULTS AND DISCUSSIONS



a. Spiked sorbent tubes (64 μg/m^3 for 5-L sample)



b. Chamber air samples (2 to 75 μg/m^3)

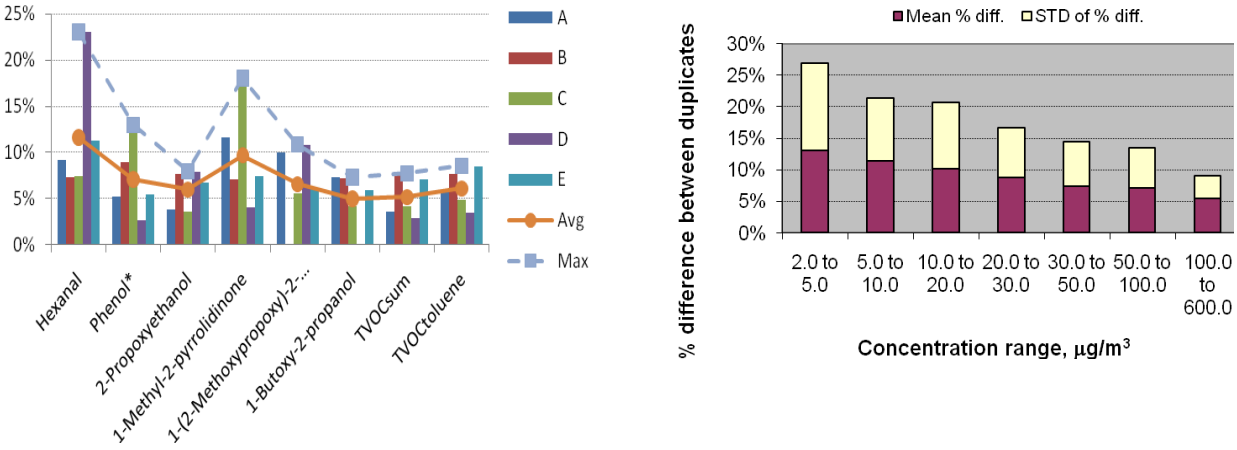
Figure 1. Relative standard deviation (RSD, %) within an individual lab (A,B,C,D,E), overall within-lab (WL) and between-labs (BL) for spiked tubes (a) and chamber air samples (b)

Preliminary assessments.

For the 10 spiked IVOCs, the overall within-lab RSD was 5% ± 1% (mean ± standard deviation), and the between-lab RSD was 14% ± 9% (Fig. 1a). For the chamber air samples, analysis reported here is limited to the five compounds included in the 10 spiked VOC mixture plus formaldehyde and acetaldehyde (Fig. 1b). For these compounds, the overall within- and between-lab RSDs were 4% ± 2% and 29% ± 24%, respectively. The between-lab variations were relatively high (> 50%) for alpha-pinene and 1-butanol, where concentration levels ranged from ~3 to 14 μg/m^3 (i.e., close to the LOQ of 2 μg/m^3). For formaldehyde, within- and between-lab RSDs were 2% and 5%, respectively. Acetaldehyde had the same within-lab RSD as formaldehyde, but had a somewhat higher between-lab RSD (15%). These results show that for selected IVOCs that were calibrated per ANSI/BIFMA M7.1 requirement, the labs achieved reasonable within-lab repeatability and between-lab reproducibility where concentrations were approximately five times greater than the M7.1 target LOQ. There was less variation in HPLC than GC/MS analysis.

Chair emission tests.

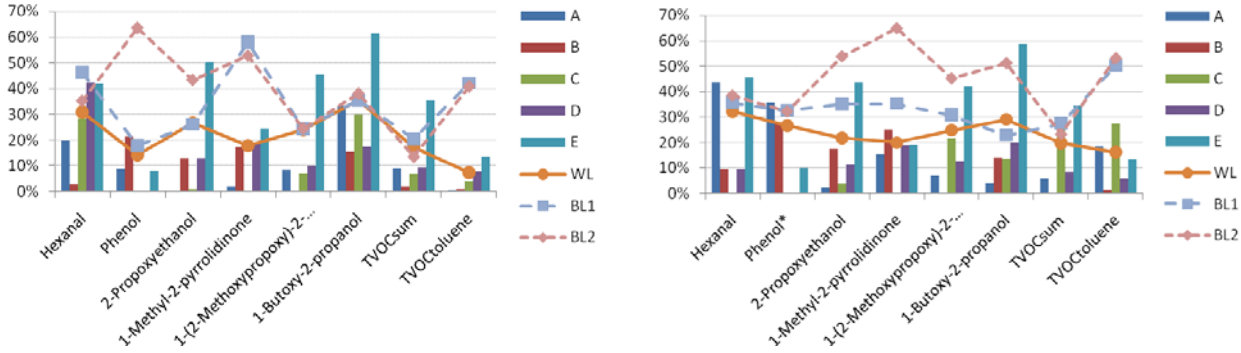
VOC concentrations. First, we consider the six IVOCs that were identified by at least four of the five labs and had concentration levels larger than the M7.1 target LOQ of 2 μg/m^3. The average relative difference between duplicate air samples was 15% and all duplicate air sample analyses for the six selected IVOCs were well within the sample acceptance criteria of 45% of the M7.1 (Fig. 2a). Precision improved with increasing concentration (Figure 2b). Formaldehyde and acetaldehyde concentrations were below the LOQ in a majority of air samples and hence were excluded from comparison analyses.



a. Within lab relative difference between duplicates b. Dependence on the concentration level

Figure 2. Relative differences between duplicate air samples taken at 72 h and 168 h

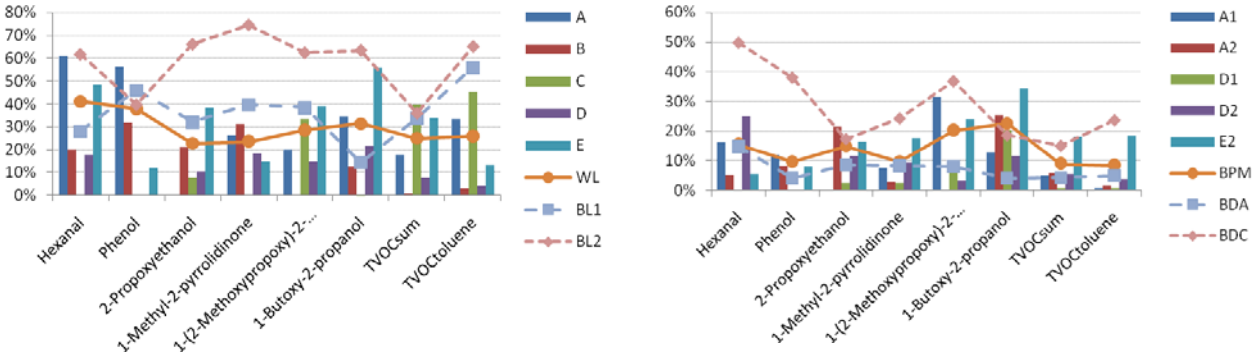
Measured emission factors at t = 72 h and t = 168 h. The overall within-lab RSD for the six IVOCs was 25% ± 8% and 26% ± 5% for 72 h and 168 h, respectively, indicating no appreciable differences between the two sampling times (Fig. 3). In average, the between-lab RSDs for chair one and chair two were about 10% and 20% higher than the within-lab RSDs, respectively. The higher between-lab RSDs in chair two than chair one were likely due to more test specimen heterogeneity due to longer test delay. The between-lab variability is comparable to the lower bound of RSDs found in previous inter-laboratory studies (20% to 100%) for individual dry materials (Howard-Reed and Nabinger, 2006). TVOCsum and TVOCtoluene had comparable within-lab RSDs, but the between-lab RSDs were higher for TVOCtoluene than TVOCsum (Fig. 3). However, determining TVOCsum required substantially more effort.



a. t = 72 h b. t = 168 h

Figure 3. Within-lab and between-lab RSD in measured emission factors for two chair tests at 72 h and 168 h

Predicted emission factors at t = 336 h (day 14): For the six compounds, the overall within-lab RSD was 31% ± 7% (Fig. 4a). The between-lab RSDs for chair one and two were 33% ± 11% and 61% ± 12%, respectively, again indicating higher variations among labs than within labs and more variation for chair two than for chair one. Note that the between-lab variation in the predicted emission factor at t = 336 h was only slightly higher than the variations in the measured EFs at 72 h and 168 h (Fig. 3). Emission factors at t = 336 h were measured only by Labs A and D for chair one and two, and by Lab E for chair two. The RSDs between the predicted and measured EFs were 15% ± 5% for the six IVOCs, which was about twice the RSDs between duplicate air samples (8% ± 4%), but only one half of the RSDs between duplicate chair tests (31% ± 13%) (Figure 4b). The results suggest that variability of the power-law model predictions were comparable to variability of the measurements.



a. RSDs of predicted EF between two chair tests b. RSDs between predicted and measured EF

Figure 4. Evaluation of power-law predicted emission factors (EF) at t = 336 h

CONCLUSIONS

1) Better precision can be achieved when measuring VOC concentrations that are at least 5 to 10 times the LOQ (2 μg/m^3). For target and selected IVOCs, the labs were able to achieve very good within-lab repeatability (± 5% in RSD). Between-lab reproducibility was about 3 to 5 times larger, ranging from ± 15% to ± 25% in RSD.
2) The overall mean within-lab repeatability in measuring emission factors of the chair was about ± 25% in RSD, and the between-lab reproducibility ranged from ± 35% to ± 45% in mean RSD. These values are comparable to the lower bound of variation ranges found in previous interlaboratory emission studies of individual dry materials.
3) On average, the day 14 emission factors predicted by the power-law model were within ± 15% of the measured value for selected IVOCs, and the variability in the power-law model predictions was comparable to the variability of measurements.

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