Characterisation of VOC emissions released from furniture products

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SUMMARY
Limited data are available to determine emissions from furnishing products and their contribution to indoor air pollution. As a result, a specific study was carried out to characterise volatile organic compound (VOC) emissions from 29 furniture products. The study included different kinds of furnishing products and a large panel of materials from the French and European markets or from import. Emission tests were carried out according to the ISO 16000 Standard series (parts 3, 6, 9 and 11). In all, 135 compounds were characterised. Formaldehyde was the most commonly identified compound emitted by wood-based panels and upholstered furniture: it was detected in 21 of 29 products and emission rates were quantified between 11.5 and 381 $\mu g.unit^{-1}.h^{-1}$. Other VOCs were quantified and discussed according to the nature of furniture components.

PRATICAL IMPLICATIONS
This work has provided new data on volatile organic compound (VOC) emission from furniture products. These data were used by the French Agency for Food, Environmental and Occupational Health and Safety (ANSES) to help French ministries draft a short list of substances to include in mandatory labelling on VOC emissions from furniture products, like the current list for building materials in France (JOFR, 2011a and 2011b).

KEYWORDS
Furniture, VOC, formaldehyde, emissions, emission test chamber

1 INTRODUCTION
Like building materials, furniture products are known to contribute to indoor environmental pollution by emission of volatile organic compounds (VOCs). To reduce VOC exposure and the potential health impact, the French authorities mandated ANSES to provide an expert assessment on VOC emissions from furniture products. For the French authorities, the aim was to implement potential future labelling, like that in place for building materials. ANSES and the FCBA (the French Institute of Technology for Forest-based and Furniture Sectors) therefore carried out a specific study to characterise volatile organic compound emissions from 29 furniture products. Without a specific methodology for furniture products, emission tests were carried out according to the ISO 16000 Standard series (parts 3, 6, 9 and 11) used for building products by the FCBA in order to contribute to the inventory of substances of interest for this labelling (FCBA, 2015). These measurements are presented and can be used to estimate consumer exposure.

2 MATERIALS/METHODS

Sampling plan

In this study, the aim of the sampling plan was to select furniture products for emission tests that have not previously been tested in French studies about pre-school and school furniture (FCBA and CSTB, 2011) or domestic children's furniture (FCBA and CSTB, 2013). Therefore, 29 furniture products were selected arbitrarily from the French and European markets or from import, with priority given to upholstered furniture for household use and contract furniture. The 29 furniture products are listed in Table 1 with associated materials.

Table 1: Furniture products selected for emission tests

Place	n	Product	Main material	Market
Household furniture (n=12)	6	Cabinet units	Wood-based panel(1)(2)	Fr/EU/I
	2	Countertop	Synthetic resin or polymer	I
	1	Table	Wood-based panel, solid wood (2)	I
	3	Chair and upholstered chair	Wood-based panel, metal(3), plastic(4), fabric/ textile(5)	I/ns
Office furniture (n=5)	1	Office chair/upholstered chair	Wood-based panel, fabric/ textile, foam(6), plastic	Fr/EU
	1	Desk	Wood, metal	Fr/EU
	2	Cupboard curtain	Plastic	Fr/EU
	1	Pedestal cabinet	Metal	Fr/UE
Contract furniture (n=4)	4	Chair and upholstered chair	Wood-based panel, solid wood, metal, foam, plastic	Fr/EU
Upholstered furniture (n=8)	3	Mattress	Foam, plastic, fabric/ textile	Fr/EU
	1	Box springs	Solid wood, foam, fabric/ textile	Fr/EU
	4	Armchair	Wood-based panel, solid wood, foam, fabric/ textile	Fr/UE/I
	1	Padded chair	Wood, foam, fabric	I

Fr: France, EU: Europe, I: Import

(1) Wood-based panel: Particleboard, veneered boards, medium-density fibreboard (MDF), melamine faced boards, plywood, or chipboard, etc. (2) Wood can be lacquered/varnished or not (3) Metal: chromed metal or lacquered/varnished aluminium, etc. (4) Plastic: polycarbonate (PC), acrylonitrile butadiene styrene (ABS), polyurethane (PU), polyamide, polyvinyl chloride (PVC), polypropylene, or polyethylene, etc. (5) Fabric and/or textile with treatment or not: cotton, viscose/polyester, or leather, etc. (6) Foam: polyurethane foam, polyester foam, or latex foam, etc.

Storage and preparation

Specifications of Standard NF EN ISO 16000-11 were applied for furniture storage and preparation. Different sized emission test chambers were used depending on the size of the test samples: from 50.9 to 225 litres for furniture components, and larger test chambers from 1 to 30 m^3 for parts of furniture or whole furniture. Whole furniture and furniture in kits were collected. When possible, product samples were analysed in one piece, in order to reflect reality. When necessary, product samples were prepared to be analysed in a small test chamber to simulate emissions in "real" conditions. Furniture assembly or cutting was performed on the day of the test according to the requirements provided by the manufacturer (see Pictures 1 and 2). The items did not require use of adhesive or cleaning products. Only a non-emissive aluminium adhesive tape was used to seal cut portions. Finally, cupboards were tested with closed drawers and doors.

Picture 1: Foam mattress preparation

i) Preparation

ii) In the 225 litre test chamber

Picture 2: Chair

i) Unpacking chair

ii) Whole chair in 1 m^3 test chamber

The emission test started with introduction of items into the test chamber.

Determination of volatile organic compounds and aliphatic aldehydes of low molecular weight

The study involved measuring the release of volatile compounds from materials or furniture products according to Standard NF EN ISO 16000-9 (Indoor air - Part 9: Determination of the emission of volatile organic compounds from building products and furnishing - Emission test chamber method). Sampling was performed after 7 days in the emission test chamber at 23 ± 2°C and 50 ± 5% relative humidity. Two kinds of sampling and analysis were carried out:

- active sampling on 2,4-Dinitrophenylhydrazine-Impregnated Silica Gel (DNPH) and high-performance liquid chromatography with detection by ultraviolet absorption (HPLC/UV) according to Standard NF ISO 16000-3 for aliphatic aldehydes of low molecular weight;
- active sampling on Tenax TA® sorbent, thermal desorption (TD) and gas chromatography using mass spectrometry and flame ionisation detector (GC/MS-FID) according to Standard NF ISO 16000-6 for VOCs.

For upholstered furniture, specific sampling and analysis were applied in order to characterise 4 compounds: Toluene 2,6-diisocyanate (CAS number 91-08-7), Toluene 2,4-diisocyanate (CAS number 584-84-9), 4,4'-Methylenediphenyl diisocyanate (CAS number 101-68-8), and 1,6-hexane diisocyanate (CAS number 822-06-0):

- sampling on filters coated with 1-(2-pyridyl)piperazine and HPLC/UV according to FCBA internal methods derived from Métropol N°004, INRS (INRS, 2003)

The aim was to characterise emissions of volatile substances from furniture products qualitatively and semi-quantitatively (quantitation in toluene equivalents for VOCs according to the definition described in Standard NF ISO 16000-6). Substances were identified in the test chamber at a concentration greater than or equal to 2 $\mu g.m^{-3}$, according to the limit set by Standard NF EN ISO 16000-9.

3 RESULTS

Unit specific emission rates (SERu, in $\mu g.unit^{-1}.h^{-1}$) of 135 volatile substances were characterised quantitatively or semi-quantitatively from 29 furniture products.

The occurrence of major volatiles identified from furniture products was calculated. This corresponds to the number of times that the volatile substance was identified at a higher SERu than 10 $\mu g.unit^{-1}.h^{-1}$. This threshold was determined arbitrarily in order to select only major volatiles higher than an exposure concentration of 0.7 $\mu g.m^{-3}$ in a reference room. This was calculated by analogy to the reference room defined in the French Regulation for the labelling of construction products (JOFR, 2001b): the furniture product is placed in a room of 30 m^3, with an air exchange rate of 0.5 h^{-1}.

Twenty-three substances were identified at least twice (Table 2). As expected, formaldehyde was widely detected, in 21 of 29 tested furniture products. Hexanal, alpha-pinene, acetaldehyde, and acetic acid were also detected from at least 7 products. Higher SERu was observed for formaldehyde. On average, higher SERu was observed for toluene (n=3) with a mean of 139.4 $\mu g.unit^{-1}.h^{-1}$. In addition, 28 substances were identified once, but are not presented in this paper. SERu for these VOCs were quantified between 10 to 787.9 $\mu g.unit^{-1}.h^{-1.}$

Table 2: Occurrence and unit specific emission rates (SERu) of major volatiles identified from furniture products

n/29	**CAS number**	**Name**	**SERu $\mu g.unit^{-1}.h^{-1}$** (mean)	**Material**
21	50-00-0	Formaldehyde	11.5 to 381.3 (67.4)	Solid wood and fabric/ textile
				Wood-based panel (n=8)
				Upholstered furniture (n=12)
10	66-25-1	Hexanal	13 to 258.4 (52.3)	Solid wood and fabric/ textile
				Solid wood-based panel (n=4)
				Upholstered furniture (n=5)
9	80-56-8	Alpha-pinene	10.5 to 223.8 (73)	Solid wood and fabric/ textile
				Wood-based panel (n=4)
				Upholstered furniture (n=4)
8	75-07-0	Acetaldehyde	11 to 45.6 (23.4)	Solid wood and fabric/ textile
				Wood-based panel (n=5)
				Upholstered furniture (n=2)
7	64-19-7	Acetic acid	15.5 to 258.4 (83.5)	Solid wood and fabric/ textile
				Wood-based panel(n=3)
				Upholstered furniture (n=3)
4	475-20-7	Longifolene	11 to 140.5 (51.6)	Wood-based panel

n/29	CAS number	Name	SERu $\mu g.unit^{-1}.h^{-1}$ (mean)	Material
				Upholstered furniture (n=3)
4	68-12-2	N, N Dimethylformamid	16.5 to 159.1 (56.3)	Upholstered furniture (n=4)
4	123-38-6	Propanal	12 to 136.4 (52.3)	Wood-based panels (n=2)
				Upholstered furniture (n=2)
3	149-57-5	2-Ethylhexanoic acid	11.1 to 60.8 (34.5)	Wood-based panel
				Upholstered furniture (n=2)
3	78-93-3	Butanone	14.5 to 45.5 (28)	Wood-based panel (n=3)
3	138-86-3	Limonene	10.5 to 15.4 (13.7)	Wood-based panel
				Upholstered furniture (n=2)
3	108-88-3	Toluene	24 to 287.9 (139.4)	Wood-based panel (n=3)
2	280-57-9	1,4-Diazabicyclo(2.2.2)octane	12 and 50	Upholstered furniture (n=2)
2	13475-82-6	2,2,4,6,6-Pentamethylheptane	25.1 and 30.3	Wood-based panel
				Upholstered furniture
2	111-76-2	2-Butoxyethanol	30.4 and 120	Wood-based panel (n=2)
2	104-76-7	2-Ethyl-1-hexanol	10.7 and 16.6	Wood and fabric/ textile
				Upholstered furniture
2	108-65-6	2-Methoxy-1-methylethyl acetate	25.5 and 30.4	Wood-based panel (n=2)
2	123-86-4	n-Butyl acetate	15.5 and 45.6	Wood-based panel (n=2)
2	127-91-3	Beta-pinene	12 and 63.9	Wood-based panel
				Upholstered furniture
2	110-82-7	Cyclohexane	30.3 and 75.8	Wood-based panel (n=2)
2	71-36-3	n-Butanol	10.4*	Upholstered furniture (n=2)
2	124-19-6	Nonanal	10 and 30.4	Wood-based panel
				Upholstered furniture
2	108-95-2	Phenol	12.5 and 27.8	Upholstered furniture (n=2)

* 10.4 and 10.4

4 DISCUSSION

Results confirm that formaldehyde, and to a lesser extent, hexanal, alpha-pinene, acetaldehyde, and acetic acid, are principally emitted by wood-based panels and upholstered furniture.

Several VOCs can be linked with the nature of furniture components. For example, N,N dimethylformamid, used especially as a solvent in the manufacture of synthetic leather, was quantified in 4 upholstered furniture products, of which 2 were coated with leather. Toluene was quantified only in wood-based panels due to the main use of the substance as a solvent for paints, varnishes etc. As expected, plastic or metal furniture is not listed in Table 2, because VOC emissions were lower than 10 $\mu g.unit^{-1}.h^{-1}$.

It should be noted that results cannot be considered completely representative of the emissions of furniture products available on the French market, since only 29 samples were tested. However, VOCs were quantified in toluene equivalents according to Standard NF ISO 16000-6. Unit emission specific rates (SERu) were therefore difficult to compare. However, this kind of experimental study is clearly relevant because, according to hearings conducted by ANSES, manufacturers do not know the exact composition in their furniture products defined as articles in the REACH regulation.

5 CONCLUSION

In this study, 135 volatile substances were identified as furniture product emissions. As expected, formaldehyde was detected in a large number of products mainly in wood-based panels but also in upholstered furniture. Metal and plastic furniture was analysed and results confirm the very low VOC emissions for these products.
This study helps to address the lack of available data and can be used to estimate consumer exposure.

For information, these results were used to propose a short list of relevant substances for future labelling on VOC emissions from furniture products. With this aim, a ranking method based on emission data and chemical hazard was performed. Twenty-one substances were proposed by ANSES to the French Ministry for inclusion in the future legislation (ANSES, 2015, Leroux *et al.* 2015).

6 ACKNOWLEDGMENTS

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