

# Laboratory evaluation of volatile organic compounds emissions from coated and uncoated oriented strandboard

A. Bartekova  
C. Lungu  
R. Shmulsky\*  
P. Huelman  
J.Y. Park

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## Abstract

Emissions of volatile organic compounds (VOCs) from oriented strandboard (OSB) samples were measured. The OSB samples were from a new house constructed using structural engineered panels. The OSB samples were tested: 1) uncoated; 2) coated with oil-based primer; 3) coated with topcoat latex; and 4) coated with both. The highest total VOC emissions were measured from the primer-coated OSB samples. The laboratory results indicate that terpenes were found mainly in the uncoated OSB samples (9.5% of total VOC emissions represented alpha-pinene) while N-decane (18%) and N-undecane (36%) are the most abundant components in the oil-based primer used as coating. The water-based latex was found to contain mainly benzene derivatives (30%). The experimental results and information from relevant studies were combined for the toxicological evaluation of the OSB and coatings. The uncoated isocyanate-bonded OSB had very low VOC emissions through the 28-day test period. All tested materials met the "very low emitting materials" benchmark of widely referenced total VOC evaluation procedure after 3 and 28 days.

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The influence of different building materials on indoor air quality (IAQ) and subsequently on human health has been documented in various studies. Previous studies (Tshudy 1995, Salthammer 1999) showed that 96 percent of the volatile organic compounds (VOCs) found in buildings result from the materials used to build and furnish the buildings. For this reason, some countries have implemented criteria for classifying building materials according to VOC emissions using various labeling systems (Wolkoff 2003). The best known are the Finnish, Danish, German, and voluntary United States labeling systems (IAQ 2004). Builders are trying to prevent IAQ problems by increasingly using low toxicity building materials. For this reason, building materials and furnishings are tested and only those found to meet the low emission requirements are considered acceptable for the indoor environment.

One of the most popular building and construction materials in single-family residential construction is oriented strandboard (OSB). Today, OSB consumption exceeds that of plywood since all building codes in the United States and Canada recognize OSB panels for the same uses as plywood. OSB is being extensively used in the Pilot House Demonstration

Project in St. Paul, Minnesota, for the construction of new "affordable, energy-efficient, and healthy houses." This is a new application. The OSB is part of a novel wall system. The thickened OSB panel provides both the structure and interior

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The authors are, respectively, Post-Doctoral Associate, Div. of Environmental Health Sciences, Univ. of Minnesota, Minneapolis, MN (barte034@umn.edu); Assistant Professor, Div. of Environmental Health Sciences, Univ. of Alabama, Birmingham, AL (clungu@uab.edu); Associate Professor, Dept. of Forest Products, Mississippi State Univ., Mississippi State, MS (rshmulsky@cfr.msstate.edu); Associate Professor, Dept. of Bio-based Products, Univ. of Minnesota, St. Paul, MN (huelm001@umn.edu); and PhD student, Div. of Environmental Health Sciences, Univ. of Minnesota (park0697@umn.edu). The financial support for this study by J.W. Fulbright Commission, Institute of International Education and Cold Climate Housing program at the Univ. of Minnesota is gratefully acknowledged. We also thank Gabriela Ventura Alves da Silva from the Univ. of Porto, Portugal and our other colleagues helping in the laboratory. This paper was received for publication in November 2004. Article No. 9961.

\*Forest Products Society Member.

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Forest Prod. J. 56(2):85-90.

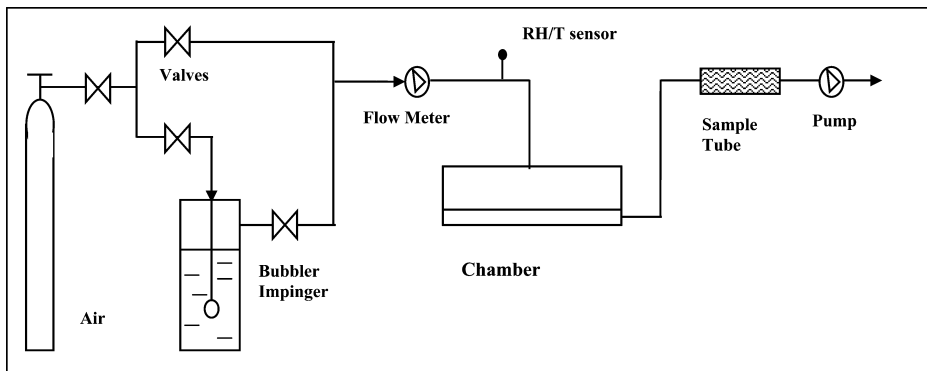


Figure 1. — Set-up of the test with an environmental emission chamber.

surface of the exterior walls. It can also be used for interior partitions. This application eliminates the studs and associated cavity insulation. Instead, a 60-mil membrane followed by rigid insulation is installed on the exterior surface of the OSB panel. This provides a continuous insulation layer that improves thermal performance and reduces the risk of moisture accumulation. However, the raw OSB was determined to be an unacceptable interior finish for the walls. Rather than the cost and additional thickness associated with a more traditional gypsum drywall covering, it was desirable to directly finish the OSB surface. The panel manufacturer provided recommendations for the preparation, primer, and paint formulation. The interior paint was applied toward the end of the construction cycle similar to traditional construction.

This composite represents a more sustainable and cost-effective approach to residential construction than other similar building materials. However, information is needed about the emissions from coated and uncoated OSB and any impact that they may have on the future air quality.

Additionally, coatings, varnishes, and paints used to cover these OSB-based materials and products may release large amounts of VOCs. This may result in exposure of building occupants to various VOCs at higher than acceptable concentrations. The first priority in controlling an indoor pollutant is to identify the compounds and reduce their source. Generally, the best solution is to replace a polluting source with an alternative non-polluting product, but this is not always economically feasible.

The objectives of this study were to: 1) identify the VOC sources in the new pilot house by testing OSB samples and coatings in a laboratory test chamber; 2) evaluate both total VOC (TVOC) and individual VOC emissions from OSB and coatings based on laboratory testing; 3) categorize OSB and coatings using an available literature evaluation procedure.

### Material and methods

OSB specimens for laboratory chamber testing were chosen and taken from material remnants from the pilot house construction project. The OSB, produced by J.M. Huber Company, was manufactured no more than 6 months prior to sample collection and testing. Information about the product (manufacturer and resin type) was obtained at the time of panel sample collection. However, information about manufacturing specifics such as day, time, shift, technological conditions, and material composition were not available. All tested panels were bonded with an isocyanate-based resin. Material samples were cut (approximately 0.25 by 0.25 m)

from the large remnant panels and packaged in aluminum foil until they were tested. The samples were divided into four groups and each group contained primary samples (A) and secondary duplicate samples (B). The first group contained pure, uncoated OSB (OSB 1). The second group (OSB 2) contained OSB coated with primer and topcoat latex paint. An alkyd primer (Preprite Pro Block, Sherwin Williams Co., OH) and topcoat (100% wall and trim interior eggshell latex, Valspar Comp, IL) were used as

coatings in this study. The coated samples were allowed to dry for 48 hours at normal laboratory conditions of 25°C and 50 percent RH. OSB coated only with primer (OSB 3) and OSB coated only with topcoat latex (OSB 4) were the other two groups. A set of matched samples, OSB coated with primer and topcoat, were shipped to the Chemistry Department, Faculty of Science, University of Porto, Portugal for a VOC evaluation using chamber testing.

All specimens were stored in their respective foil packages at room conditions before testing. To minimize edge emissions, the specimens were edge-sealed with emission free aluminum tape before introduction into the chambers. The time period between unpacking and placing the testing material in the pre-conditioned chamber was no longer than 30 minutes. All samples were tested in duplicate using the same procedure: A) primary samples; and B) secondary samples.

A small (55 L) environmental test chamber was used for VOC emission testing from OSB with or without the coatings. The environmental test chamber description, sample collection, and analysis were carried out in accordance with standard testing procedures (ASTM 1997). The air concentration and emission factors were determined in the chamber under specific test conditions that influence results (surface area: 0.102 to 0.283 m<sup>2</sup>; area-specific airflow rate: 0.207 to 0.578 m<sup>3</sup>/m<sup>2</sup>h; air exchange rate: 1.06 h<sup>-1</sup>). General procedures for testing at combinations of product-loading ratios and at air-exchange rates typical of the indoor environment were used. The temperature in the test chambers was 23 ± 0.5°C, the relative humidity was 50 ± 5 percent, and the air exchange rate in the test chambers was one change per hour. The chamber was supplied with air from the laboratory compressed-air outlet. The air was passed through a battery of filters containing a drying column, an activated carbon column, and a HEPA filter to obtain a clean, dry airflow. The desired relative humidity was obtained by combining dry air with water-saturated air prepared by passing air through a water-filled impinger. The airflow through the chamber was controlled by a mass flow controller. Inside the chamber, a temperature-relative humidity sensor attached to a data logger continuously monitored these parameters. The diagram of the experimental set-up is presented in **Figure 1**.

The VOCs emitted from the test materials were determined by sampling at the chamber outlets. Activated charcoal tubes (226 to 01 Coconut Charcoal, SKC, Eighty Four, PA) attached to personal sampling pumps (Airchek 50 and 52, SKC, Eighty Four, PA) using a flow rate of 70.7 to 105.8 mL/min were used for all VOC sampling. The sampled air volumes were between

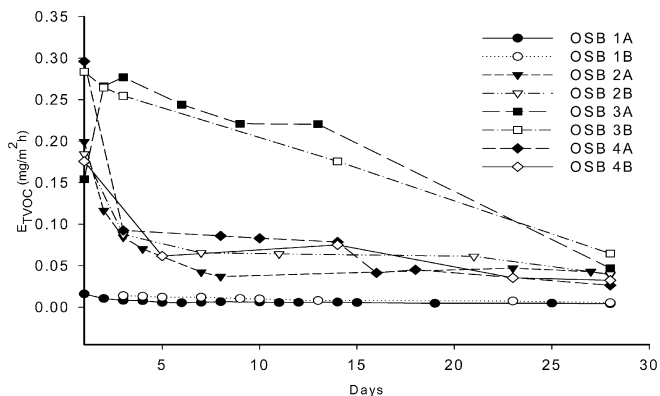


Figure 2. — Emission factors ( $E_{TVOC}$ ) of TVOCs measured during 28 days of testing; OSB 1 = uncoated OSB; OSB 2 = coated with both primer and latex; OSB 3 = coated only with primer; OSB 4 = coated only with latex; A = primary samples; B = secondary duplicate samples.

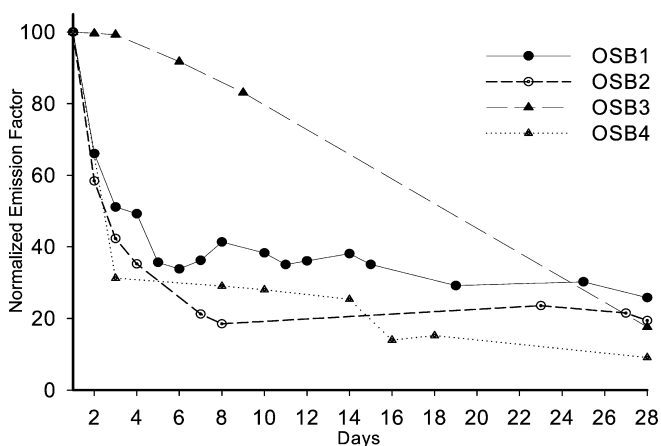


Figure 3. — Reduction of average TVOC emission factors with time, normalized to 24 hours for tested material; OSB 1 = uncoated OSB; OSB 2 = coated with both primer and latex; OSB 3 = coated only with primer; OSB 4 = coated only with latex.

20.26 and 36.1 L. The charcoal tubes were stored in the refrigerator before being analyzed. Maximum storage time was 2 weeks. The sampling time interval was chosen according to the Occupational Safety and Health Administration (OSHA) and the National Institute for Occupational Safety and Health (NIOSH) sampling method for VOCs (NIOSH 1996). VOCs were desorbed from the charcoal tubes using 1 mL carbon disulfide (Sigma-Aldrich, St. Louis, MO).

Initially the samples were analyzed using a gas chromatograph fitted with a mass spectrometer (GC/MS system with a Hewlett-Packard 5890 series II Plus GC and an HP 5972 MS detector) to identify the most prevalent VOCs. The sample extract (1  $\mu$ L) was injected into the HP-1 (30 m/0.25 mm ID/0.25  $\mu$ m film thickness) capillary column set with a temperature program from 50° to 250°C at 8°C/min. The individual VOCs were identified by their retention time from the analysis of calibration standards. TVOC concentration was determined for each individual air sample. The numerical value of this concentration was based on integrating all detected peaks during GC elution time starting at 5 minutes until the end of

the analysis (30 min). Benzene was used as the calibration response for TVOCs. Flame ionization detector (FID) gas chromatography analysis was used further to quantify the VOC compounds.

Sampling was conducted every 24 hours at the beginning of the experiment, followed by daily testing for the first 3 days, and occasional testing after that up to 28 days. Blank runs of the empty chamber were performed each time before material testing while clean, humidified air was flowing through the chamber.

The two basic measurement values needed to characterize the materials were the emission factor ( $Ea$ ) and the concentration ( $C$ ) in the 55-L environmental chamber. Once the chamber concentration data were obtained, the emission factors were calculated directly from individual concentration data points (Eq. [1]). Statistical analyses were performed using SigmaPlot version 8.0 for Windows (Systac Software 2004).

### Result and discussion

The emission factors for the TVOC emitted from the OSB with or without the coatings during the 28 testing days in the testing environmental chamber are shown in **Figure 2**. The TVOC concentration in the emission chamber as a result of emission from coated or uncoated OSB decreased rapidly during the first 14 days. For example, for OSB coated with primer, the decrease of the emission factor in this time period was from 0.293 to 0.047  $\text{mg}/\text{m}^2\text{h}$ . **Figure 3** shows the percentage time reduction of the emission factors with respect to the initial values for this time period. During the first 4 days, the decrease was 50 percent for uncoated OSB, 65 percent for coated OSB (primer and latex), less than 5 percent for primer-coated OSB, and 70 percent for topcoat-latex-coated OSB. After 28 days, the emission factor decreased by 75 to 90 percent for all tested materials. The TVOC emission factors for the entire testing period of the uncoated OSB were the lowest (from 0.016 to 0.005  $\text{mg}/\text{m}^2\text{h}$ ). TVOC emission factors of OSB were different when various coatings were used. The coating system altered the TVOC emission characteristics. The emissions from all tested materials generally decreased in time. The emissions from OSB covered with primer were the highest during the first 14 days. Because alkyd-based primer and latex are applied wet, and because they cover such a large area, they do release significant amounts of VOC into the air, which can be a strong irritant and could affect the residents. Primer is more volatile and has longer drying times than latex, so its emissions are higher in the first time period compared with latex.

As shown in **Figure 4**, the predominant VOCs emitted in the third day of testing from the OSB coated with primer and topcoat (OSB 2) are alkanes (N-undecane [25%], N-decane [17%], Nonane [9%], and N-benzene [8%]). Of these compounds, only nonane was found in the uncoated OSB, where the predominant VOCs are terpenes ( $\alpha$ -pinene most prominently). The most common VOCs reported in new buildings include alkanes (decane, undecane, nonane), and aromatic hydrocarbons (toluene) (Brown et al. 1994, Hodgson et al. 2000). We were interested to determine if the primer or the topcoat latex were the primary source of alkanes. As shown in **Figure 4**, decane and undecane are the most abundant in the primer (18% and 36%) and are found in the topcoat latex. From the same figure, it can also be seen that the topcoat latex

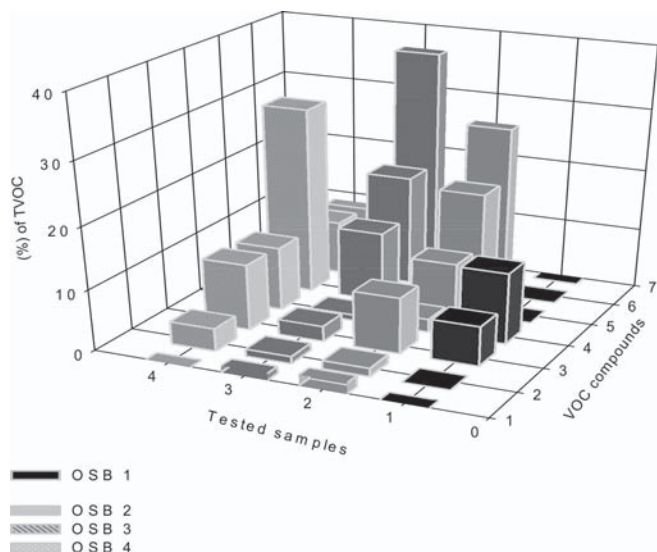


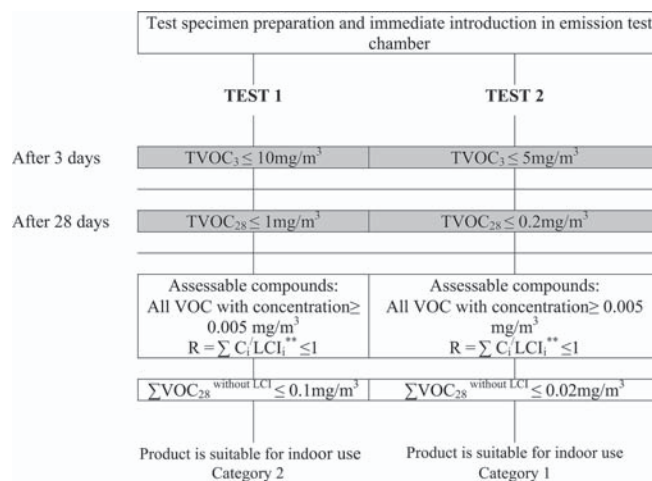
Figure 4. — Predominant VOC emission factors from tested materials given as percentage of TVOCs; tested samples: 1 = uncoated OSB; 2 = OSB coated with primer and topcoat latex; 3 = OSB coated with primer; 4 = OSB coated only with topcoat latex; VOC compounds: 1 = hexanal; 2 = xylene; 3 = N-nonane; 4 =  $\alpha$ -pinene; 5 = N-benzene; 6 = N-decane; 7 = N-undecane.

has a higher percentage of N-benzene concentration (30%) than any other tested sample. The percentage of  $\alpha$ -pinene concentration (11%) from the latex-coated OSB was comparable with that from the uncoated OSB. Only the most predominant individual VOC compounds are discussed here. Because we studied only some small OSB samples, it is not possible to conclude that the data are representative of the entire OSB production. The evaluation of VOC emissions from OSB and coatings (alkyd primer and water based topcoat latex) was based on laboratory testing and available literature information (ECA 1999, AgBB 2003).

According to Equation [1], the indoor air concentration  $C$  for a surface-emission source depends on the area-specific emission factor  $Ea$  [ $\mu\text{g}/(\text{m}^2 \text{ h})$ ] of the product, the air exchange rate [ $\text{h}^{-1}$ ] and the ratio of product surface area  $A$  [ $\text{m}^2$ ] to the room volume  $V$  [ $\text{m}^3$ ]. The parameters  $n$ ,  $A$ , and  $V$  are combined into the parameter  $q$  [ $\text{m}^3/(\text{h m}^2)$ ] called the area-specific airflow rate.

$$C = \frac{Ea \times A}{n \times V} = \frac{Ea}{q} \quad [\mu\text{g}/\text{m}^3] \quad [1]$$

In order to use coated or uncoated OSB as an interior surface, the material must satisfy certain health criteria with respect to VOC emissions. Procedures were developed to evaluate building materials (Yu and Crump 2002) but none of them has been specifically used for OSB evaluation. In this study, we used two evaluation procedures (Test 1 and 2) for VOC emissions from OSB with or without coating. Using these procedures, OSB and coatings were divided in two categories: *low emitting* (if the TVOC concentration after 3 days ( $\text{TVOC}_3$ ) was  $\leq 10 \text{ mg}/\text{m}^3$  and after 28 days ( $\text{TVOC}_{28}$ )  $\leq 1 \text{ mg}/\text{m}^3$ ) and *very low emitting* (if the TVOC concentration after 3 days ( $\text{TVOC}_3$ ) was  $\leq 5 \text{ mg}/\text{m}^3$  and after 28 days ( $\text{TVOC}_{28}$ )  $\leq 0.2 \text{ mg}/\text{m}^3$ ). Figure 5 shows the diagram of the evaluation procedure. The evaluation procedure starts from



\*\* LCI (lowest concentration of interest) is defined as the lowest concentration of a certain substance, which according to present knowledge at continued exposure in the indoor air will not cause damaging impact on humans.

Figure 5. — Toxicological evaluation diagram procedure (Test 1 and Test 2) for VOC emissions from building products.

the time the OSB sample to be tested is unwrapped and placed into the test chamber. Typically 4 to 24 hours are allowed for the sample to equilibrate. VOCs for which an LCI (lowest concentration of interest) is reported (Table 1) are called assessable. An individual  $\text{VOC}_i$  is supposed to have no effect if risk index  $R_i$  (obtained by comparing the exposure concentration and LCI) does not exceed the value 1. Relevant VOCs for which no LCIs exist are called non-assessable compounds  $\text{VOC}_{ni}$  (ECA 1999). Exposure concentration  $C_{ni}$  of these compounds should be lower than  $100 \mu\text{g}/\text{m}^3$  (category 2) and lower than  $20 \mu\text{g}/\text{m}^3$  (category 1).

As shown in Table 2, all tested materials have successfully passed the toxicological evaluation of TVOC emissions after 3 and 28 days of testing following the procedure shown in Figure 5 and can be categorized as *very low emitting* materials. A material passing the used evaluation procedure (under the condition of the selected exposure scenario) may not cause health effects.

OSB samples were evaluated at the University of Minnesota, and duplicate samples were sent for comparison to the University of Porto in Portugal. An example of a comparison of VOC emission measurements from OSB coated with primer and topcoat after 3 days between University of Minnesota and University of Porto is shown in Table 1. Because of different chamber conditions at the testing facility in Portugal (surface area:  $0.13 \text{ m}^2$ , chamber volume:  $0.26 \text{ m}^3$ ; area-specific airflow rate:  $1.25 \text{ m}^3/\text{m}^2\text{h}$ ; air exchange rate:  $0.63 \text{ h}^{-1}$ ) only emissions factors can be readily compared. The TVOC emission factor from Portugal is higher because of a different air-sampling technique. Although the University of Minnesota TVOC emission factor is lower, all predominant individual compounds were found in both laboratories at comparable values. For the analysis of VOC in indoor air, various sampling techniques and different adsorbing materials are generally used, depending on the boiling point of the VOCs (Augustin et al. 2000). As a common adsorbent, activated charcoal tubes are regularly used for VOC determination and were used in our study. At the University of Porto, Tenax TA adsorbent was used to collect contaminants from

Table 1. — Example and comparison of VOC emission measurements from OSB coated with primer and topcoat after 3 days: University of Minnesota versus University of Porto.

Compound name	CAS <sup>a</sup> number	University of Porto		University of Minnesota		LCI
		C <sub>VOC</sub> (µg/m <sup>3</sup> )	E <sub>TVOC</sub> (µg/m <sup>2</sup> h)	C <sub>VOC</sub> (µg/m <sup>3</sup> )	E <sub>TVOC</sub> (µg/m <sup>2</sup> h)	
Hexanal	66-25-1	3.80	4.74	27.00	6.15	640
m/p-xylene	1330-20-7	2.95	5.12	27.89	6.36	4400
Nonane	111-84-2	9.20	11.48	48.56	11.07	--
Nonane,4-methyl	17301-94-9	3.25	3.68	25.46	5.80	640
Nonane,2-methyl	871-83-0	3.55	5.68	19.42	4.43	640
α-pinene	80-56-8	4.55	4.87	31.25	7.12	2000
1-ethyl-benzene	100-41-4	3.15	4.06	29.11	6.63	4400
Benzene,1,2,3-trimethyl	526-73-8	6.70	4.43	19.80	4.53	1000
1,3,5-trimethylbenzene	108-67-8	3.85	8.36	18.76	4.28	1000
Decane	124-18-5	11.25	3.93	16.45	3.75	--
Decane,2-methyl	6975-98-0	5.85	4.37	19.20	4.38	--
Decane,3-methyl	13151-34-3	34.40	7.55	22.37	5.10	--
Decane,4-methyl	2847-72-5	4.85	14.04	27.17	6.19	--
Cyclohexane	110-82-7	3.50	4.80	17.56	4.00	7000
Undecane	1120-21-4	6.05	23.90	107.33	24.46	--
Undecane,3-methyl	1002-43-4	4.35	7.30	26.46	6.03	--
Undecane,2,6-dimethyl	17301-23-4	5.05	6.09	19.53	4.45	--
Dodecane	112-40-3	19.15	5.43	23.45	5.34	--
Texanol	25265-77-4	166.60	207.89	na <sup>b</sup>	na	--
Other	--	--	--	--	--	--
TVOC	--	373.70	466.33	526.80	120.10	--
TVOC (except Texanol)	--	207.10	258.44	526.80	120.10	--

<sup>a</sup>Chemical Abstract Service.

<sup>b</sup>na = not available.

Table 2. — Toxicological evaluation of TVOC emissions from tested materials after 3 and 28 days following the procedure in Figure 5.<sup>a</sup>

	Condition to be fulfilled for		TVOC concentration after 3 and 28 days ± σ (mg/m <sup>3</sup> )			
	Very low emitting	Low emitting	OSB 1	OSB 2	OSB 3	OSB 4
3 days	≤5 mg/m <sup>3</sup>	≤10 mg/m <sup>3</sup>	0.119 ± 0.073	0.454 ± 0.118	0.597 ± 0.017	0.3987 ± 0.024
28 days	≤0.1 mg/m <sup>3</sup>	≤1 mg/m <sup>3</sup>	0.063 ± 0.034	0.172 ± 0.003	0.184 ± 0.062	0.118 ± 0.045

<sup>a</sup>OSB 1 = uncoated; OSB 2 = coated with both primer and latex; OSB 3 = coated only with primer; and OSB 4 = coated only with latex.

the test materials. Activated carbon is suitable for aromatics, aliphatics, terpenes. However, this type of adsorbent is not as sensitive and suitable for the detection of high boiling point compounds such as Texanol (255° to 260°C) typically emitted from latex. On the other hand, a lot of debate is going on that Texanol (glycol ether) is not included in the VOC definition in the field of indoor paint and varnish (Bio Intelligence Service S.A. 2002). The samples tested in Porto also successfully passed the toxicological evaluation of TVOC emissions although a more sensitive sampling and analytical technique was used.

### Conclusion

Some products used in new buildings are responsible for contributing to higher levels of VOCs in the indoor air environment. Testing OSB samples and coatings in the laboratory, the VOC sources were identified. OSB coated with primer had the highest TVOC emission factor during the entire sampling period.

Both TVOC and individual VOC emissions from OSB and coatings were evaluated. The dominant classes of compounds detected from coated and uncoated OSB were aromatics, alkanes, terpenes, and ketones. The laboratory results indicate that terpenes were found mainly in the uncoated OSB samples, while N-decane and N-undecane are the most abundant components in the oil-based primer used as a coating. The water-based latex was found to contain mainly benzene derivatives. All tested materials successfully passed the toxicological evaluation of TVOC emissions after 3 and 28 days.

This study also shows that the overall emissions from the uncoated OSB are much smaller compared with emissions from the coated material. At the beginning of the experiment the TVOC emission factors for the uncoated OSB were approximately 14 times smaller than primer coated OSB respectively 9 times smaller than latex coated OSB. The emission factors remained still much reduced for the uncoated OSB after 28 days compared with the coated OSB, but the difference was much smaller due primarily to the reduction in the emission from the coated samples. This fact leads to the conclusion that OSB itself is not a significant source of VOC compared with materials coated with primer, topcoat latex or both.

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