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Volatile organic compounds emissions from North American engineered wood products

Abstract

Although formaldehyde emissions from interior wood products have been extensively studied, emissions of other volatile organic compounds (VOCs) have received less attention, and engineered products are seldom study. Thus, thirteen commercially–bonded engineered wood products (structural plywood, oriented strandboard, structural composite lumber, I–joists, and glued–laminated timber) from North America were evaluated for VOCs using methods developed for interior bonded wood products. The dominate volatiles for the different products were greatly dependent on wood species and bonding process used preventing a universal conclusion. In fact, the volatiles from the adhesives seem to play a minor role. For example, the volatiles of Douglas fir plywood, and southern pine plywood and oriented strandboard are all quite different from each other. These data provide a basis for any future studies on bonded structural engineered wood products.

Keywords: volatile organic compounds, engineered wood products, commercially bonded products, laboratory testing

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Background

Volatile organic compounds (VOCs) are a wide–ranging group of chemicals that contain carbon plus other atoms, such as oxygen and hydrogen, and exist in the gaseous phase at ambient indoor temperature due to their vapor pressures. Most VOCs around the world are from natural sources such as plants and animals, but some VOCs are also emitted from manufactured products, including wood products.[1] At high enough indoor concentrations, some VOCs may lead to human discomfort or health issues, especially for high–risk groups such as infants or elderly individuals with compromised respiratory systems.[2] Most of the research has been focused on formaldehyde emissions from urea–formaldehyde adhesives used in interior wood products, although the VOCs from particleboard have been studied.[3] Thus, this study was to developed background VOC emission data on commercially available engineered wood products manufactured in North America.[4] Data collected from this research are strictly emission data from these products and do not indicate the quantity of VOCs that end up in the indoor environment.

Engineered wood products include structural plywood, oriented strandboard, structural composite lumber, I–joists, and glued–laminated timber. These products are widely used as structural elements of residential and commercial buildings and in the manufacture of industrial goods. Standards for structural engineered wood products establish the suitability of strength properties and adhesive bond durability properties. Engineered wood products are required to be made with moisture–resistant adhesives to meet applicable standards in North America and thus do not involve any type of urea–formaldehyde adhesives. Due to the nature of these adhesives, the products have relatively low emission rates of formaldehyde, a common VOC of concern. As a result, the products are exempt from formaldehyde emission testing and regulations in the United States, such as those required by the California Air Resources Board[5] and similar regulations for formaldehyde from composite wood to be implemented by the U.S. EPA in 2017.[6] Studies have shown that heating wood can cause an increased level of formaldehyde that are transient in nature compared to those from urea–formaldehyde emissions.

The health and comfort of occupants in indoor spaces are influenced by environmental conditions, such as temperature and moisture, and also by indoor air components, such as carbon dioxide and VOCs. The many sources of VOCs include interior furnishings (such as furniture and cabinets), wall coverings (such as wallpaper and window curtains), floor coverings (such as wood flooring, rugs, and carpets), household items, consumer items, and even plants.[1,7–9]

Elevated VOC concentrations from newly manufactured products tend to diminish over time as some VOCs react to form other chemical compounds, including air dilution and being absorbed into indoor materials (such as drywall) that act as a "sink." Code changes to promote energy efficiency have led designers to take measures to reduce natural air exchange rates, which tends to decrease the dilution rate of indoor air concentrations of VOCs.

There have been studies on the presence and root sources of VOCs that may exist indoors.[7,8] Most studies have focused on interior surfaces and furnishings as primary sources of VOCs. Recent studies have examined construction materials that may be sources of VOCs.[6] The contribution of wood building materials to indoor air VOC concentration is a function of type and rate of VOC emissions from the products.

This research is a pilot study to examine type and concentration of VOC emissions from engineered wood products in North America. This study used the testing principles of the "*Standard Method for the Testing and Evaluation of Volatile Organic Chemical Emissions from Indoor Sources Using Environmental Chambers, Version 1.1*" from the California Department of Public Health, also known as CDPH 01350,[10] because no standard VOC test method applies to structural products.

The CDPH 01350 evaluation method applies to products used within the envelope of enclosed indoor environments, which can be tested whole or by representative sampling. The method is used to evaluate paints, other architectural coatings and finishes, sealants, adhesives, wall coverings, floor coverings, acoustical ceilings, wood paneling, and wall and ceiling insulation used in public and commercial office buildings, schools, residences, and other building types. The method applies to newly manufactured products before they are installed in construction, finishing, and furnishing of buildings.

The scope of CDPH 01350 states that it "*does not* apply to structural building products, janitorial products, air fresheners, electronic air cleaners, and other electronic equipment".[10] Nonetheless, because the testing method within CDPH 01350 follows the basic testing principles for VOCs determination specified in the ASTM D5116 method,[11] the test method was determined to be suitable for engineered wood products for the purpose of this study. However, the application of other evaluation principles within CDPH 01350 may not be appropriate for engineered wood products.

H1 product sampling

Products listed in Table 1 were sampled by staff of APA–The Engineered Wood Association (APA) at manufacturing facilities. Sampling details included provisions to mitigate risk of contamination and involved wrapping test samples in aluminum foil and polyethylene sheeting prior to shipping them to the test laboratory. The samples were selected to be representative of a common grade and configuration of the product. The product sample size was larger than that required for testing; the samples were trimmed at the laboratory to the appropriate test specimen size prior to testing. Three pieces of each product type were sampled; the actual test specimen was sandwiched between two other samples of the same material.

All samples were shipped or hand–delivered to the Advanced Testing Services (ATS) Laboratory in Springfield, Oregon. The ATS Laboratory is accredited to ISO 17025, "General Requirements for the Competence of Testing and Calibration Laboratories," by the International Accreditation Services (IAS),[12] with the scope inclusive of the CDPH 01350 test method.

Table 1 Description of test samples[a]

Product ID	Standard[b]	Standard[b]
DF Ply	PS 1	15/32–in. 5–ply plywood with 5 plies of Doug–fir veneer using PF adhesive
SP Ply	PS 1	15/32–in. 4–ply plywood with 4 plies of Southern Pine veneer using PF adhesive
ASP OSB 1	PS 2	7/16–in. aspen OSB using PF adhesive on the outer layers and pMDI adhesive in the inner layers
ASP OSB 2	PS 2	7/16–in. aspen OSB using pMDI adhesive in all layers
SP OSB	PS 2	7/16–in. Southern Pine OSB using PF adhesive in the outer layers and pMDI adhesive in the inner layers
DF LVL 1	ASTM D5456	1–3/4–in. LVL using all DF veneers and PF adhesive
DF LVL 2	ASTM D5456	1–3/4–in. LVL using all DF veneers and PF adhesive and a water repellant sealer on the face and back
DF IJ 1	ASTM D5055	11–7/8–in. I–joist with DF LVL flanges and ASP OSB web; polymer isocyanate adhesive for web–web and web–flange joints
DF IJ 2	ASTM D5055	11–7/8–in. I–joist with DF lumber flanges and ASP OSB web; polymer isocyanate adhesive for web–web and web–flange joints and MF adhesive for flange FJs
DF GL	ANSI A190.1	3–1/8–x 12–in. DF glulam; PRF face adhesive and MF FJ adhesive
SP GL	ANSI A190.1	3–1/8–x 12–in. SP glulam; PRF face adhesive and MF FJ adhesive
SP LVL	ASTM D5456	1–3/4–in. SP LVL using PF adhesive
SP IJ	ASTM D5055	11–7/8–in. I–joist using SP LVL flanges and ASP OSB webs; polymer isocyanate adhesive for web–web and web–flange

[a]Ply, plywood; DF, Douglas fir; SP, Southern Pine; ASP, aspen; IJ, I–joists; GL, glued–laminated timber; LVL, laminated veneer lumber; PF, phenol formaldehyde; pMDI, polymeric diisocyanate; PRF, phenol resorcinol formaldehyde; OSB, oriented strandboard.

[b]ASTM D5055, "Standard Specification for Establishing and Monitoring Structural Capacities of Prefabricated Wood I–Joists"; ASTM D5456, "Standard Specification for Evaluation of Structural Composite Lumber Products"; ANSI A190.1–2017, "Standard for Wood Products—Structural Glued Laminated Timber"; U.S. Voluntary Product Standard PS 2–10, "Performance Standard for Wood–Based Structural–Use Panels"; U.S. Voluntary Product Standard PS 1–09, "Structural Plywood."

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H1 testing method

Prior to conditioning and testing, the wood product specimen of controlled size was mounted onto a stainless steel plate with edge taping. Edge taping with low–VOC aluminized tape overlapped the wood specimen by a controlled amount to provide the targeted exposed surface area and sealed the specimen to a stainless steel caul plate.

Following the methods of CDPH 01350, each individual test specimen was pre–conditioned in clean air at 23°C and 50% relative humidity at an air exchange rate of 1.0 air exchange per hour for 10 days.

Immediately following pre–conditioning, testing was conducted in a small–scale environmental chamber measuring $0.067m^3$. Chamber conditions were maintained at 23°C and 50% relative humidity with a clear airflow rate of 1.0 air exchange per hour. The air in the chamber was considered to be fully mixed such that VOC concentration measured at the chamber exhaust was representative of air concentration in the chamber. Air samples from the test chamber were taken at 24, 48, and 96 h using the CDPH 01350 chamber test following the guidance of ASTM D5116 Standard.[11]

Each test used a controlled product loading factor (that is, exposed surface area per chamber volume), so an area–specific emission rate was calculated. The exposed area of the specimen was controlled to provide emissions that optimized the measuring precision of the measurement methods, without overloading the air sampling measurement devices.

Air samples taken at 24 and 48 h were analyzed for total VOC (TVOC) and formaldehyde concentrations. The air sample taken at 96 h was collected using Tenax–TA tubes (TENAX Corp., Baltimore, Maryland) and analyzed for the full characterization of VOC emissions using the dinitrophenylhydrazine (DNPH) or gas chromatograph (GC) methods described in ASTM D5197.[13]

Test results and conclusion

Test results (Table 2) from this study provide preliminary information on type and amounts of VOCs emitted from North American engineered wood products. All wood products tested emitted some level of formaldehyde and acetaldehyde. The wood products that contained a pine species emitted some level of alpha and/or beta pinenes. The VOC emission rates seem to indicate a relationship to the amount of heat and processing that the wood was exposed to during the production process.[3] This may indicate that many of the VOCs emitted by the wood products were VOCs naturally occurring in the wood rather than VOCs originating from adhesives, waxes, or sealers used in the manufacturing process. Further testing is needed to understand VOC emission rates from finished products and the raw wood used in their manufacture to assess the relative VOC emissions from the wood compared to the finished product that contains adhesives, waxes, and sealers that are used in engineered wood product production.

Table 2 VOC emission results at 96–h sampling time[a]

		Product ID[c]												
CAS[b]	**VOC**	**DF Ply**	**SP Ply**	**ASP OSB1**	**SP OSB**	**ASP OSB2**	**DF LVL1**	**DF LVL2**	**DF IJ–LVL**	**DF IJ–lbr**	**DF GL**	**SP GL**	**SP LVL**	**SP IJ**
50–00–0	Formaldehyde	0.33	11.38	10.42	25.96	7.74	6.14	5.46	30.67	123.86	24.9	534.39	19.32	13.48
75–07–0	Acetaldehyde	10.75	43.52	72.58	98.42	46.93	49.46	23.54	50.9	184.07	160.13	22.03	67.32	63.1
110–62–3	Pentanal			120.24	249.82	104.1			35.27	36.81		228.4	96.43	157.21
71–41–0	1–Pentanol		97.54	69.54	190				51.43	33.95		48.89		154.96
66–25–1	Hexanal		565.03	1,098.48	721.01	1,153.11	41.47		54.86	95.61		891.26	1,014.48	765.18
80–56–8	α–Pinene	14.85	274.71	32.03			125.64	573.98	48.77	114.11	387.92	127.43	1,371.13	304.68
79–92–5	Camphene									5.87				
108–95–2	Phenol								72.09	40.64				
127–91–3	β–Pinene		135.17				9.83	26.74	15.55	22.4		133.95	463.43	179.52
99–87–6	p–Cymene						6.93		12.55	22.44				
138–86–3	Limonene	4.32	27.39				11.21	41.21	14.56	20.57	32.54	62.52	88.43	45.16
128–37–0	BHT[d]								16.24	10.74				
108–65–6	PGMEA[e]				162.32									
109–52–4	Pentanoic acid				99.66				27.04					
111–71–7	Heptanal				72.2									
111–70–6	1–Heptanol				46.52									
124–13–0	Octanol				111.37									
90–02–8	Benzaldehyde, 2–hydroxy				67.32									
124–19–6	Nonanal				35.47									
	TVOC (toluene eqiv)	23.79	795.72	642.46	921.57	588.76	196.77	699.43	248.67	338.91	461.78	893.05	2,717.62	1084.18

[a]VOC emission results from 96–h test, in ug/m^2–h. Blank cells indicate the VOC was not detectable.
[b]CAS, Chemical Abstract Service.
[c]See product description in Table 1.
[d]BHT, butylated hydroxytoluene.
[e]PGMEA, propylene glycol methyl ether acetate.

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Conflict of interest

Author declares there is no conflict of interest.

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