Laboratory scale VOC emissions testing of air-dried basswood lumber

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Abstract

Random width, 32-mm (5/4-in) nominal thickness air-dried basswood lumber was received from a supplier in the Lake States region. Two laboratory-scale charges were cut from the lumber and kiln-dried to determine volatile organic compound (VOC) emissions as per federal guidelines. The mean emission value from the two charges was 0.0222 kg VOC as carbon per cubic meter (0.115 pounds per MBF) of dried lumber.

Across the nation, environmental protection regulations require lumber kilns to report estimated air pollution emissions. When operations are changed or upgraded, revised permits must usually be obtained. In general, permitting is handled at the state level and varies from state to state. Limited data exist regarding emission factors from various hardwood species. As stated in the Federal Register (2006[1]), small-scale kilns can be used to "reasonably approximate" emissions from full scale commercial operations. Thus, a given mill can use published factors (if available), perform onsite testing, or arrange for pilot-scale testing. To the best of the author's knowledge, no emission factors for basswood lumber have been published to date. To address this void, two charges, as required by the Federal Register (2006), of random width, 100 to 300 mm (4 to 12 in) wide, 32-mm (5/4-in) nominal thickness, approximately 2.4-m long basswood lumber were dried and the results are reported herein.

Drying procedure

Basswood lumber was acquired from a commercial operation in the Lake States region. Request was made that lumber (width, thickness, MC) be representative of that which the mill commonly processes. At the mill, rough lumber was selected, wrapped in plastic to prevent moisture changes, palletized, and shipped to the Forest Products Department at Mississippi State University (MSU). Lumber was then received at MSU and placed immediately in cold storage at 2 °C (35 °F).

For the study, approximately 0.31 m^3 (130 BF) was procured. Lumber was unwrapped and the first randomized kiln charge was cut 1 day prior to drying. The interior chamber dimensions for the small scale kiln are: 0.61 by 0.71 by 0.76 m (32 by 35 by 28 in). To build a kiln charge, approximately 150-mm (6-in) of length was removed from each parent board to limit any residual end-effect present in the delivered lumber. Lengths of 585-mm (23-inches) were then cut to build the first kiln charge. Each kiln charge contained approximately 0.071 m^3 (30 BF) volume. Total kiln capacity is approximately 0.078 m^3 (33 BF). Also, 25-mm (1-in) long sections were cut to determine green MC. The residual boards were then rewrapped and replaced in cold storage. The kiln charge was also wrapped and placed in the cooler until the start of kiln-drying on the following day. Following drying of the first kiln charge, the second kiln charge was processed in the same manner as the first.

Green moisture sections from charge 1 were cut, weighed (W$_{green}$), dried in an oven at 103 °C (217 °F), and reweighed to determine initial MC. Initial MC of the sections was 25.3 percent, which suggests that the lumber was air dried prior to kiln-drying; consistent practice for the cooperating mill.

Lumber was dried in the pilot-scale kiln with a conventional temperature kiln schedule. Each charge contained eight lumber courses. Lumber courses were separated with aluminum kiln stickers. Heat was supplied via electrical resistance heaters. Initial dry and wet-bulb temperatures were 71° and 43 °C, respectively. Final dry and wet-bulb temperatures were 82° and 54 °C (180 and 129 °F), respectively. The entire schedule

[1] Federal Register. 2006. 71(32):8387. Appendix C to Subpart DDDD of Part 63-Considerations for a Small-Scale Kiln Emission Testing Program. Rules and Regulations, Thursday, February 16, 2006.

Table 1. — Kiln schedule.

MC	Dry bulb	Wet bulb
	--------------- (°C) ---------------	
30 to 25	71	43
25 to 20	77	49
20 to 15	82	54
15 to target	82	54
Equalize	82	58

Table 2. — Moisture and volume data.

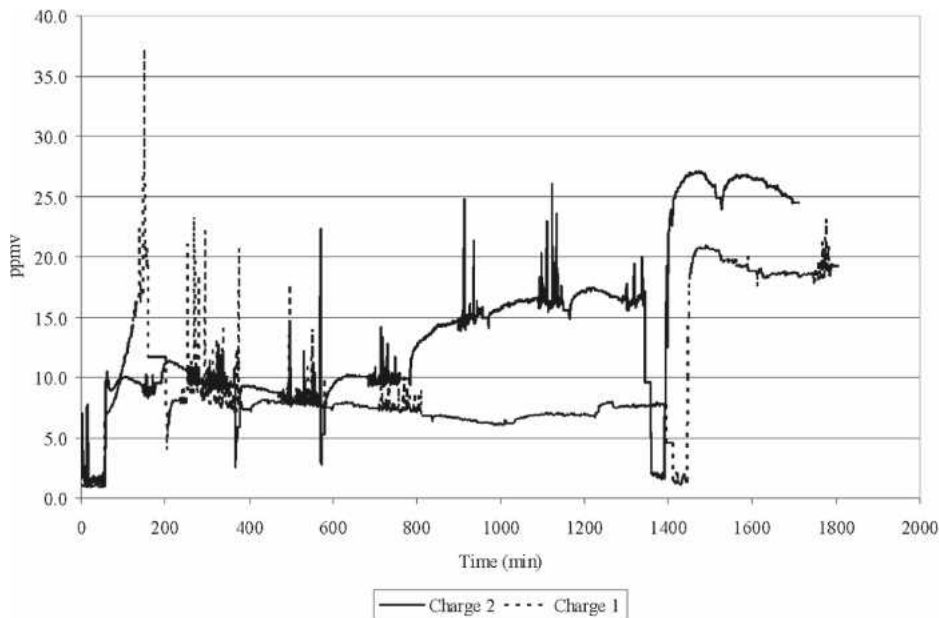|	Charge 1	Charge 2	Mean
Volume, m^3	0.065	0.066	0.066
Initial weight, kg	30.0	30.3	30.2
Final weight (kiln-dry), kg	25.4	26.0	25.7
MC green, %	27.1	26.6	26.9
MC final, %	8.1	8.4	8.3

Figure 1. — Emission profile, TVOC as ppmv vs. time, for the basswood lumber in charges 1 and 2. Intermittent spikes are the result of periodic calibration.

is shown (**Table 1**). Temperature changes were based on lumber MC. The wet-bulb temperature was regulated via a mass flow controller thus the quantity of air entering the kiln at all times is known. This volume is required for total volatile organic compound (VOC) emission calculation. Approximate drying time was 30 hours for each charge, including approximately 6 hours of moisture equalization. Moisture and volume statistics for each charge are shown in **Table 2**. Air velocity through the stack was approximately 3.2 m s^{-1} (630 feet min^{-1}) as generated and maintained with a variable speed drive fan.

Air sampling for total VOC

Emissions sampling was performed in adherence to 40 CFR 60 Appendix A Method 25 A[2] through the use of a direct read flame ionization detection (FID) analyzer and the NCASI Standard Protocol for VOC Concentration Measurement Method for Use at Small-Scale Kilns.[3] Because the maximum exhaust air MC as called for by the kiln schedule was 19 percent, no dilution gas was used (dilution gas is called for when moisture in the air stream exceeds 20%).

Air sampling occurred continuously throughout the drying cycle. Calibration of the FID was performed at approximately 3-hour intervals. Each 3-hour time block was termed a sample run. In no case did machine drift exceed the tolerances and cause data loss. As the FID results were downloaded to a datalogger in "real-time," data gaps, for instance during calibration or charge weighing, were encountered. Effort was made to minimize these gaps and assure that they did not exceed 45 percent of the total drying cycle time as per USEPA[2] criteria. At the end of the total drying time, the individual sample runs were assembled chronologically. A short description of the sampling protocol follows:

1) Warm up total hydrocarbon analyzer (THC); 2) Vacuum leak check; 3) Calibrate (zero and span); 4) Calibration check; 5) Sample flow check; 6) Sample run; 7) Drift check (span, mid, zero); 8) Final leak check

Steps 1 and 2 were performed only at the start of the drying cycle. Steps 3 through 7 were performed as part of each drying run (3-hour block). Step 8 was performed only at the end of the total drying cycle. Mid and span calibration gases were 50 and 100 ppmv respectively. Max ppmv values during charges 1 and 2 were 37.1 and 22.4, respectively. Charts illustrating the emission profiles for the lumber are shown in **Figure 1.** In these figures it is noted that emission levels drop precipitously at approximately 1400 minutes, remain low for approximately 20 minutes, and then recover to a higher level than was noted before the drop. This pattern is associated with opening the kiln door at approximately 24 hours to weigh the wood. The charge was reweighed as quickly as possible and in conjunction with a calibration event such that only a minimum amount of data would be missed. The period of approximately 20 minutes at the lower emission level occurred after the wood was reloaded in the kiln and the kiln restarted. At that point, the air and wood were reheating and the air venting rate was automatically retarded such that the wet-bulb temperature could recover to the set point. THC analyzer drift checks following each 3-hour sample run showed that the analyzer maintained calibration throughout. **Table 3** contains air pollution sampling time summary statistics.

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[2] United States Environmental Protection Agency (USEPA). 2006. Method 25A – Determination of total gaseous organic concentration using a flame ionization analyzer. USEPA, Washington, DC.

[3] National Council for Air Stream Improvement (NCASI). 1998 (estimated). Standard protocol for VOC concentration measurement method for use at small-scale kilns. NCASI, Gainesville, Florida.

Table 3. — Summary of total sampling and calibration times.

	Charge 1	Charge 2
Total drying time (minutes)	1805	1711
Total down time (drift checks, calibrations, reweighs, etc.)(minutes)	183	122
Total sampling time (minutes)	1622	1589
Percent sampling time (55 percent minimum requirement)	89.9	92.9
Percent interpolation (45 percent maximum allowable)	10.1	7.1

Table 4. — Summary of VOC emissions.

	Charge 1	Charge 2	Mean
Mean ppmv	9.9	14.1	12.15
Total time (minutes)	1805	1711	1758
Total ppmv	17958	24180	21069
Total kg VOC	1.29 by 10^{-3}	1.62 by 10^{-3}	1.45 by 10^{-3}
Emission factor: kg VOC as carbon per m^3 (pounds per MBF)	0.0198 (0.103)	0.0245 (0.127)	0.0222 (0.115)

Total VOC emissions

Following drying, emissions data along with wood, moisture, and kiln information were assembled in order to calculate total VOC emissions on a "kg m^{-3}" basis. To this end, first total VOC emissions as carbon per minute were calculated as per NCASI[4] method, which includes: instrument response, total flow rate, sample flow rate, atmospheric pressure, and MC of exhaust stack air. By calculation, total kg of VOC as carbon for every 1-minute sample event was determined. Then, the individual values from each 1-minute sample event are summed to produce total VOC emissions. **Table 4** lists the total VOC emissions as carbon for the two kiln charges.

These results show that a small amount of VOC emissions are produced during basswood lumber drying. It is difficult to compare these values to other hardwood species because "there is still a gap in our knowledge of VOCs produced during drying of hardwoods."[5] As compared to information from Milota,[6] the average level determined herein, 0.115 pound MBF^{-1} is approximately 8 percent of that observed from Douglas-fir and about 3 percent of that from southern pine.

[4] National Council for Air Stream Improvement (NCASI). 1998. (estimated). Standard protocol for VOC concentration measurement method for use at small-scale kilns. NCASI, Gainesville, Florida. Appendix I:9.

[5] Solliday, D.S., J.P. Armstrong, and B.E. Dawson-Andoh. 1999. Dehumidification drying of red oak. Part I, chemical characterization of volatile organic compounds. Forest Prod. J. 48(7/8):21-23.

[6] Milota, M. 2000. Emissions from wood drying, the science and the issues. Forest Prod. J. 50(6):10-20.