

VOC AND HAP EMISSIONS FROM WESTERN SPECIES

Michael Milota
Oregon State University
Corvallis, OR

VOC and HAP emissions from several species of lumber were measured in a lab kiln: southern pine, lodgepole pine, ponderosa pine, Douglas-fir, and white fir. The trends in the values with time as well as variability among tests are discussed.

Introduction

The emissions from lumber dry kilns are more difficult to measure than other dryers because most kilns do not have a single point of exhaust. Kilns vent intermittently throughout a drying cycle that may last less than a day for some softwoods to a month or more for some hardwoods. During this time the amount and composition of the emissions change. Replication of an emissions measurement on a kiln means that a whole different batch of lumber is dried and it is possible and likely that the new batch of wood will have different properties. To avoid some of these problems, a small-scale method was developed to measure the emissions from lumber kilns.

Procedures

A schematic of the small-scale kiln is shown in the Figure 1. The kiln box is approximately a 1.2 m cube. It is indirectly heated by steam. Four dry-bulb thermocouples and two wet-bulb thermocouples are located on the entering-air side of the load. The dry-bulb thermocouples are spaced in a grid. The two wet-bulb thermocouples are under a single sock at the center of the entering-air side of the load. The airflow can be adjusted up to 6 m/s.

A single 200 L/min MKS mass flow controller regulates and primarily measures the amount of air entering the kiln. Additional flow devices (MKS 0-50 L/min flow meter and Dwyer 0-200 SCFH flow meter) can be used when high rates of venting are desired. A minimum of 10 L/min enters the kiln at all times, more than removed by the analyzer and methanol/formaldehyde sampling train. Putting air into the kiln at a rate of 100 L/min (a typical vent rate) causes the pressure in the kiln be approximately 130 Pa above ambient on the high pressure side and 60 Pa on the low pressure side. Thus, any fugitive leakage should be out of the kiln. The steam spray line is disabled, so no water vapor is added to the kiln atmosphere.

Wood is sampled at the mill, then cut to 1.2-m lengths and wrapped for shipping. After sorting and rewrapping in the lab, the wood is typically frozen to preserve its freshness. Wood is removed from the freezer approximately 24 hours prior to drying and allowed to thaw while still wrapped. The kiln is made ready and 5 cm are trimmed from each end of each board to give 1.1 m samples. The samples are weighed, placed in the kiln, and dried according to a schedule that matches a commercial schedule. Sampling for hydrocarbon and methanol-formaldehyde is done as described below. At the end of drying, the wood is weighed, oven dried, and reweighed so initial and final moisture contents could be determined by ASTM D4442. Then board properties are measured

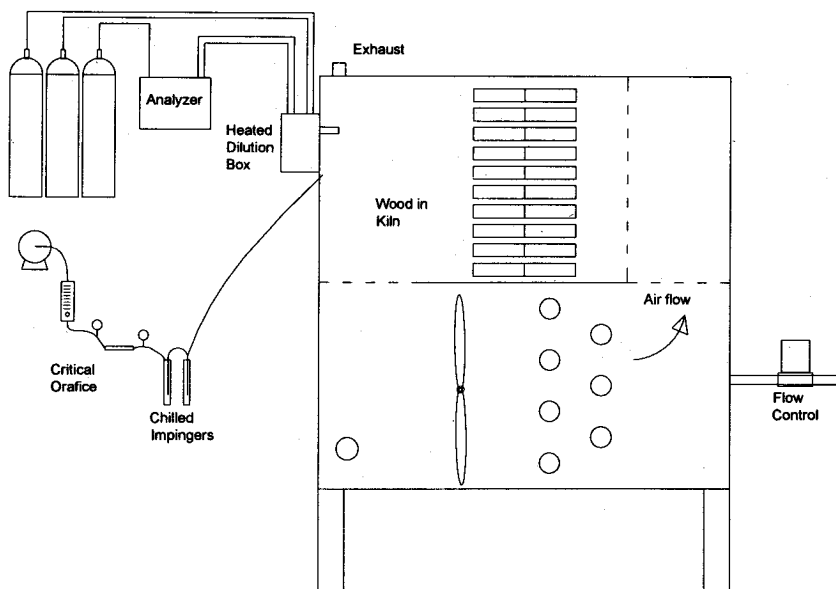


FIGURE 1. Schematic of kiln and sampling systems.

including heartwood by visually estimating the percent of heartwood at each end of the board, ring count by measuring the number of rings in a 1" radial distance, and knots by estimating the area of knots on one face.

A sample for total hydrocarbon is drawn from the kiln directly into a dilution/filter box mounted on the side of the kiln. It is assumed that the gas in the kiln is well-mixed and that the composition in the kiln near the exhaust is the same as the composition of the exhaust. The kiln gas is diluted to less than 20 percent moisture prior to reaching the analyzer. The dilution ratio obtained by flow measurement is checked by diluting span gas and observing the analyzer reading. Calibration of the analyzer is done using propane in air at the beginning of a run. The calibration is checked at the end of each run with no adjustments made to the zero or span during the run. The method is very similar to EPA Method 25a. For methanol/formaldehyde collection, the NCASI chilled impinger is used. Methanol is analyzed by GC and formaldehyde is analyzed by the acetyl-acetone reagent method.

We have reported emissions in production units of lbs per 1000 board feet (lb/mbf). Two pounds per 1000 board feet is approximately one gram per kilogram of oven-dry wood for the species tested. The exact value of this conversion varies with the density of the wood, and target size of the lumber.

Measurements made in past studies have shown the lab kiln to be a reasonable surrogate for a mill dry kiln (Tables 1 and 2). Note that we expressed lab measurements as a percentage of mill measurements; however, the mill measurement is not necessarily more correct than the lab measurement. The values obtained at the ponderosa pine mill, for example, are very high and we suspect an error in measurement at the mill. The lab measurements tend to be more reproducible and certainly the variables can be more

TABLE 1. Comparison of mill and lab VOC measurements for steam-heated kilns (lbs/mbf).

Species	Charge	Mill	Lab	Lab/Mill, %
Douglas-fir (1)	1	1.8	1.5	83
Douglas-fir (1)	2	1.5	1.4	93
ponderosa pine (2)	1	3.7	2.4	66
ponderosa pine (2)	2	4.1	2.8	65
southern pine(4)	1 ¹	3.0 ²	4.4	146
southern pine(4)	2 ¹	3.9	3.9	100
southern pine(4)	3 ¹	4.7	4.6	98
southern pine(4)	4 ¹	3.1	3.8	122
southern pine(4)	5 ¹	3.0	4.4	146
southern pine(4)	6 ¹	3.5	4.4	126

¹ values pending approval by EPA

²noticeable fugitive emissions at mill kiln

TABLE 2. HAP measurements at mill and lab.

Species	Charge	Methanol			Formaldehyde		
		Mill	Lab	Diff, %	Mill	Lab	Diff, %
southern pine(4)	1 ¹	0.14	0.17	121	0.01	0.01	158
southern pine(4)	3 ¹	0.26	0.27	103	0.01	0.02	121

¹ values pending approval by EPA

closely controlled and measured. Similarly, Table 2 shows that HAPs emissions can be reproduced in the small-scale kiln, but conclusions are difficult with only two charges.

Results

VOC and HAP emissions from a lab kiln for several western species are shown in Table 3.

Difference from Other Data Sets

It can be seen that there is considerable difference between the values in Tables 1 and 3, 1.5 versus 0.5 lb/mbf for Douglas-fir and 2.6 versus 1.38 lb/mbf for ponderosa pine VOC emissions. We have no immediate explanation for this except that Inland Douglas-fir was used in the second study whereas the wood for reference (2) came from the west slopes of the Cascade mountains (known as Coastal Douglas-fir). The average value for a third data set in which Coastal range wood was measured was also close to 1.5 lb/mbf (Wu and Milota, 1999). This seems to explain the Douglas-fir discrepancy, and the differences in the ponderosa pine data could also be explained based on mill of origin.

However, three years earlier we measured lumber from the same mill as that in Table 3 and got values closer to Table 1 (unpublished data). Harvest location may vary well be a major factor in the emissions measured, we don't have any way of knowing. All of these VOC measurements were made in the same kiln with the same techniques and each is an average of four to eight replicate charges.

Differences Among Species

Lower VOC emissions would be expected from white fir because it is a nonresinous species. It might also be implied from the data that VOC emissions are not a surrogate for HAP emissions because the white fir has the highest combined HAP emissions and was very high in methanol.

Variability among Charges of the Same Species

In general, the small-scale method is fairly repeatable for VOCs with the standard deviation 8 to 16% of the mean value. Repeatability is not as good for the methanol and formaldehyde. Although the wood properties are shown in Table 3, in approximately six similar studies we have never been able to make a clear association between emissions and a specific wood property. However, none of the studies were specifically designed to for this purpose.

When Emissions Are Released

There is an initial peak of VOC release early in drying. This probably corresponds to chemicals in the wood moving with the free water and chemicals that are near the surface of the wood evaporating. Sometimes (although it doesn't show in Figure 2) there is a second peak later; however, the VOC release rate most often decreases with time (Figure 2a). The second peak is probably due to the wood temperature rising. We have always observed an increase in the HAP release rate with time (Figure 2b). In the example figure, this increase in rate is slight; however, it can be more dramatic.

Conclusions

The laboratory kiln functions like a scaled down version of the mill dry kiln with respect to venting characteristics, temperature, and humidity. Wood does tend to dry faster in the lab kiln, probably because the load is narrow. While perfect agreement is never seen between the measurements on lab and commercial kilns, the agreement was good for two out of the three species.

Acknowledgments

The author wishes to acknowledge assistance from the Intermountain Forest Association and the National Council for Air and Stream Improvement for their contributions to this work.

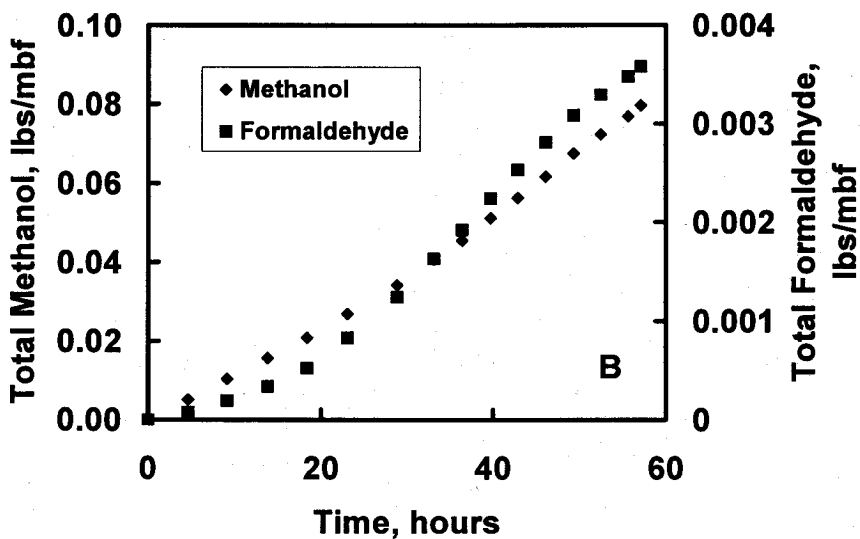
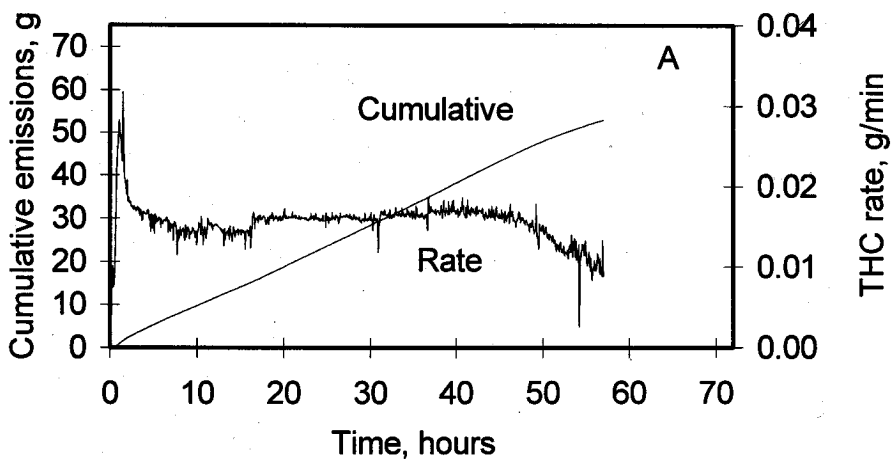


FIGURE 2. VOC (A) and HAP (B) release from ponderosa pine.

TABLE 3. Summary of wood properties, drying times, total hydrocarbon, methanol, and formaldehyde released from four western species. Values are adjusted to 12% final moisture content for ponderosa pine and 15% for the other species.

	Charge	Time (hrs:min)	VOC (lb/mbf)	Formaldehyde (lb/mbf)	Methanol (lb/mbf)	Heartwood (%)	Rings (#/in.)	Knots (in ²)	green (%)
ponderosa	2	58:28	1.40			23	10	8.0	114.
	3	57:07	1.30			23	9	2.5	93.0
	4	55:02	1.29	0.0022	0.050	14	7	3.7	107.
	5	57:04	1.54	0.0036	0.080	17	9	2.0	124.
	ave.	56:54	1.38	0.0029	0.065	19	9	4.1	109.
white fir	1	36:19	0.26				12	2.0	106.
	2	43:19	0.27				11	1.7	113.
	3	42:36	0.22	0.0022	0.096		12	1.7	122.
	4	46:54	0.25	0.0034	0.148		13	1.3	133.
	ave.	42:17	0.26	0.0028	0.122		12	1.7	118.
lodgepole	2	16:34		0.0041	0.062	42	10	1.7	59.7
	3	16:49	1.19			34	10	1.3	64.9
	4	16:01	1.17	0.0041	0.063	47	9	2.6	59.1
	5	16:01	0.87	0.0039	0.056	39	9	1.8	56.9
	ave.	16:13	1.08	0.0040	0.060	41	10	1.9	60.2
Douglas-fir	1	23:31	0.51	0.00084	0.025	85	12	2.3	37.3
	2	28:28	0.55	0.00079	0.023	77	13	4.4	44.9
	3	27:04	0.45	0.00166	0.026	73	12	1.8	40.3
	4	25:13	0.46	0.00109	0.018	82	11	3.7	31.9
	ave.	26:04	0.49	0.0010	0.023	79	12	3.1	38.6

References

1. Lavery, Mark, R. and Michael R. Milota. 2000 VOC emissions from Douglas-fir: Comparing a commercial and a laboratory kiln. *Forest Products Journal*. 50(7/8):39-47.
2. Lavery, Mark R. and Michael R. Milota. 2000 Measurement of VOC emissions from ponderosa pine lumber using commercial and laboratory kilns. Submitted to *Drying Technology* for publication.
3. National Council for Air and Stream Improvement. 2000. Lumber kiln emissions data supplemental environmental project. Submitted to EPA in April 2000. Approval pending.
4. Word, David. 2000. Study of VOC and HAP emissions from small- and full-scale lumber kilns. In proceedings of National Council for Air and Stream Improvement West Coast Regional Meeting. September 27, 2000.
5. Wu, Jing and Michael R. Milota. 1999. Effect of temperature and humidity on total hydrocarbon emissions from Douglas-fir lumber. *Forest Products Journal* 49(6):52-60.