Volatile Organic Compounds Emitted during the Kiln Drying of Southern Pine Utility Poles

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Abstract

Southern pine is the most common species used for utility poles in the United States. However, information regarding air emissions from pole drying is very limited. With respect to drying, poles have longer lengths, resulting in limited end-grain exposure, higher final moisture content, and lower ratios of surface area to volume, and typically southern pine poles have higher amounts of heartwood compared with southern pine lumber because of pole age. For this research, several green southern pine utility pole bolts were obtained and cut into matched kiln charges that contained sapwood only, mostly sapwood, mostly heartwood, and knotty material. Eight charges were dried at 230°F dry bulb with at least a 50°F wet bulb depression until the poles reached a moisture content of 30 percent at a depth 3 inches from the surface. Volatile organic emissions from the kiln charges were measured using federal guidelines. The mean emission values from the all sapwood, mostly sapwood, mostly heartwood, and knotty wood kiln charges were 3.59, 3.52, 2.64, and 3.65 pounds of volatile organic emissions per thousand board feet, respectively. The emissions of the sapwood, mostly sapwood, and knotty charges were similar to clear lumber emission values. The emissions from the knotty charges were less than emissions from knotty lumber. The results suggest that heartwood-rich utility poles release much less organic emissions than heartwood lumber, perhaps because of the band of sapwood that always surrounds the heartwood in poles as opposed to lumber where the heartwood is often exposed at the surface.

Southern pine (SP) is the species most commonly used in the production of utility poles (Micklewright 1992). In the absence of published data on drying poles, species-specific emission factors for lumber have been applied to pole kilns. SP lumber typically averages between 3 and 4 pounds of volatile organic compounds (VOCs) emitted per 1,000 board feet (lb VOC/MBF) during kiln drying (Milota 2000). However, with respect to drying, poles have numerous factors that differ from lumber. These include longer lengths that result in limited end-grain exposure and thus slower drying times, higher final moisture content, different schedules, and lower ratios of surface area to volume. SP poles also have higher amounts of heartwood compared with lumber because lumber is increasingly harvested from relatively young small-diameter SP trees that typically lack heartwood. Given the numerous differences between lumber and utility poles, the accuracy of using lumber emission factors for pole drying is somewhat questionable.

The objective of the study was to determine the VOC emissions from poles and to compare these results to previously published values of lumber to determine if applying emission factors to poles from lumber is reasonable. To address these issues, charges of SP pole sections, as required in the *Federal Register* (2006), were dried, and the results are reported herein.

Materials and Methods

Drying procedure

SP bolts were obtained from a local pole supplier. Sections were taken from the conveyor outfeed from the cutoff saw that followed the peeler. As such, the bolts were fresh. Each pole section was approximately 6 feet (1,829 mm) long and 6 to 12 inches (152 to 305 mm) in diameter at the small end. The pole sections were selected on the basis

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of pole quality such that some poles contained only sapwood, some poles contained mostly sapwood but some heartwood, some poles contained mostly heartwood, and some poles contained an abundance of knots. The knotty poles contained mostly sapwood material. Heartwood was detected visually. The mostly sapwood charges and knotty charges contained approximately 20 percent heartwood, while the mostly heartwood charges contained more than 50 percent heartwood. After transport to Mississippi State University, the pole sections were stored in a cooler at 35°F (2°C) until drying. Two drying runs of each matched kiln charge were dried for a total of eight runs.

To first prepare the kiln test material, approximately 12 inches (305 mm) of length was removed from each end of each 6-foot (1,829-mm)-long bolt to eliminate any end drying that occurred during storage and handling. Approximately two 1-inch (25-mm)-long discs were then crosscut to determine initial moisture content. One disc was weighed and oven dried to determine overall moisture content, while the second disc was cut into three bands: core, material 3 inches from the surface, and face material. Next, a single 23-inch (584-mm)-long piece was cut from each of the pole sections and classified as sapwood, mostly sapwood, mostly heartwood, or knotty. As such, each kiln charge contained two or three pieces, each 23 inches (584 mm) long. The poles from each kiln charge were measured prior to drying to determine green volume (cubic feet) and converted to board feet (1 cubic foot = 12 board feet) to facilitate comparison to VOC emissions from lumber values.

Poles are longer and have limited end-grain exposure compared with lumber. While lumber is commonly 8 to 16 feet in length, poles are commonly between 30 and 40 feet in length (Taylor 1996). To prevent end drying in the kiln, urethane adhesive with aluminum foil was used as an end-coating treatment on the transverse faces of the 23-inch (584-mm) sections (Fig. 1). Urethane adhesive was selected because it adheres to green wood and aluminum foil and should not interfere with the analysis of the VOCs. To ensure that the urethane adhesive was not adding to the emissions profile or deteriorating under the high temperature in the kiln, the urethane adhesive was tested separately after curing approximately 2 ounces of adhesive on a metal plate. The adhesive was heated to 230°F (110°C) in the pilot-scale kiln and tested for VOC emissions; no emissions were detected, and the adhesive remained functional. A previous study on emissions on SP lumber determined that end effect did not significantly affect VOC emissions (Shmulsky 2000). Thus, the end coating should allow the pole section in the pilot-scale kiln to more closely follow the drying of a commercial pole operation. Once the ends of the pole pieces were sealed, the pieces were allowed to stand outside the kiln for approximately 24 hours in order to bring their temperatures to ambient and to allow for the resin to fully cure.

Figure 1.—Pole samples with urethane adhesive and aluminum foil.

The kiln schedule followed that of a commercial pole manufacturing facility. In general, this kiln schedule required 4 hours of ramping to a dry bulb temperature of 230°F (110°C). The wet bulb depression was at least 50°F, as required by pole drying standards when using a 230°F high temperature schedule (American National Standards Institute 1987). The wet bulb depression was controlled with a mass flow controller via venting action with the quantity of air entering and thus leaving the kiln. Air velocity across the poles was approximately 700 ft/min. The target drying time was 54 hours, as per the mill's schedule. Because the pilot-scale kiln often dries slightly faster than a commercial kiln, total drying time was dependent on the individual charge necessary to arrive at the target final moisture content. Poles are typically dried to 25 to 35 percent moisture content at a depth of 3 inches (76 mm) from the surface, depending on the subsequent preservative treatment used (Boone 1994). For this study, the poles were dried to at least 30 percent moisture content 3 inches from the surface. For each pole section, the final target weight was estimated on the basis of the two 1-inch sections cut from each pole. Following drying, the moisture content of the poles was checked by cutting a 1-inch disc from the center of the pole and subsequently cutting three bands—core, material 3 inches from surface, and face material—to verify proper drying.

Air sampling for total VOC

Emissions sampling was performed according to 40 CFR 60 Appendix A Method 25A, through the use of a direct-read flame ionization detection analyzer (Environmental Protection Agency 2006), and the NCASI ''Standard Protocol for VOC Concentration Measurement Method for Use at Small-Scale Kilns'' (National Council for Air and Stream Improvement [NCASI] 1998). A J.U.M. VE-7 instrument was used to determine the total hydrocarbons in the air exhaust of the kiln. Based on a dry bulb temperature of 230°F and a wet bulb depression of 50°F, the maximum gas moisture content in the kiln was calculated as 50 percent. Because this is higher than the 20 percent gas moisture content recommended for the VE-7, the sample air was diluted with clean, dry, compressed air. The compressed air was heated to approximately 250°F (121°C) prior to dilution.

Air sampling occurred continuously throughout the drying cycle. Calibration of the J.U.M. VE-7 was performed at approximately 3-hour intervals. Leak checks were performed at the beginning and ending of each kiln charge.

Mid and span calibration gases were approximately 1,000 and 3,000 parts per million volume (ppmv) of propane in air, respectively. Each 3-hour time block was termed a sample run. At the end of the total drying time, the individual sample runs were assembled chronologically. Emissions data along with wood, moisture, and kiln information were assembled in order to calculate total VOC emissions. To this end, total VOC emissions as carbon per every 30 seconds were first calculated as per the NCASI method, which includes instrument response, dry bulb temperature, wet bulb temperature, total flow rate, sample flow rate, atmospheric pressure, and moisture content of exhaust stack air. Then the individual values from each 30-second sampling event were summed to produce the total VOC emissions. Detailed instructions are found in NCASI (1998).

Results and Conclusions

Average moisture content of the charges for the sapwood, mostly sapwood, mostly heartwood, and knotty charges was 83, 80, 41, and 82 percent, respectively. Average volume of the charges for the sapwood, mostly sapwood, mostly heartwood, and knotty charges was 0.041, 0.043, 0.071, and 0.065 m^3, respectively.

The maximum ppmv values during all the charges did not exceed the span calibration gas, and the VE-7 drift did not exceed the allowable tolerances and did not cause data loss. All leak checks were passed. A graph of the total hydrocarbon release from a sapwood charge is shown Figure 2.

Table 1 lists the average VOC emissions as carbon for the different kiln charges and VOC emission data from previous studies on SP lumber dried to below 19 percent moisture content. The sapwood, mostly sapwood, and knotty charges had similar emissions to previous results for clear SP lumber. The knotty charges emitted less volatile organics than a previous study from knotty lumber. Perhaps seasonal influence contributed to this difference, as seasonal influence has been shown to influence VOC emissions (Conners et al. 2001), or perhaps a combination of factors, including season influence, knot size and quantity, heartwood amount, and the lower moisture content that poles were dried to, influenced this.

The major difference found between emissions from poles and previous studies was with regard to heartwood emissions, 2.64 pounds per thousand versus 11.16 pounds in heartwood lumber (Ingram et al. 2000). Perhaps the difference is due to the band of sapwood that always surrounds the heartwood in poles. This sapwood band potentially prevented organic material in the heartwood from migrating to the surface of the lumber and being released into the air. In comparison, heartwood in lumber is often exposed at the surface, and the organic compounds are easily volatilized.

With regard to volatile emissions and based on the results obtained in this study, it is reasonable to permit SP pole drying kilns using values obtained from clear SP lumber regardless of the mixture of sapwood, heartwood, and knots in poles. Many questions remain following this study, such as how accurately pole emissions from pilot-scale kilns emulate actual kilns as well as what amounts of hazardous air pollutants are released from poles. These questions will be investigated in subsequent research.

Table 1.—VOCs emitted during pole drying.[a]

Charge	lb VOC/MBF	kg VOC/m^3 wood
Sapwood poles	3.59	0.79
Mostly sapwood poles	3.52	0.68
Heartwood poles	2.64	0.52
Knotty mostly sapwood poles	3.65	0.68
SP (Milota 2006)	3–4	0.72–0.96[b]
SP sapwood (Ingram et al. 2000)	3.83	0.92[b]
SP heartwood (Ingram et al. 2000)	11.16	2.68[b]
SP knotty (Ingram et al. 2000)	5.46	1.31[b]

[a] VOC = volatile organic compound; MBF = thousand board feet; SP = southern pine.
[b] kg VOC/m^3 wood calculated on the basis of lb VOC/MBF × 0.24 (Milota 2006).

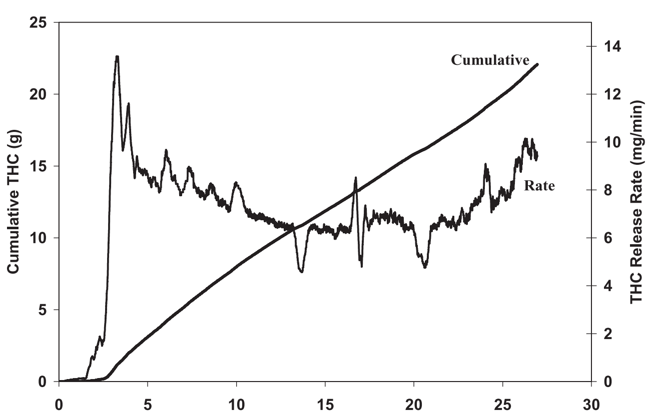

Figure 2.—Emissions release for sapwood run 1.

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