

DECAY RESISTANCE OF OUT-OF-SERVICE UTILITY POLES AS RELATED TO THE DISTRIBUTION OF RESIDUAL CREOSOTE CONTENT

HAN ROLIADI
CHUNG Y. HSE*
ELVIN T. CHOONG*
TODD F. SHUPE*

ABSTRACT

Decay resistance of out-of-service poles was investigated to evaluate their effectiveness against biodegradation for possible recycling of these poles for composite products. Decay resistance was related to creosote content and creosote distribution in poles with service durations of 5 and 25 years and also freshly treated poles. Weathering of the poles had caused reduction in creosote content such that the residual content of the outer and upper portions of the poles was lower than the inner and bottom portions. Overall residual creosote content in the 5-year poles was lower than in freshly treated poles, but still higher than in 25-year poles. Above a 14 percent level of residual creosote content, the decay resistance of weathered poles was still high. Below that level, the decay resistance decreased dramatically. Decay resistance of 5-year poles was mostly still comparable to freshly treated poles, while the decay resistance of 25-year poles, especially in the outer portions, was much lower and approaching that of untreated southern yellow pine. In reutilization of out-of-service poles for composite wood products, components with lesser creosote content should be placed in the interior, while those with higher creosote content are more suitable for the outer part.

There are about 150 million wood poles in service carrying electrical transmission and distribution lines. Each year, the ever-expanding basic electric and communication industries consume about 6 million treated poles. Approximately 75 percent of the annual consumption of the poles consist of southern yellow pine (SYP) (*Pinus* spp.) (13). Creosote was used in 17 percent of U.S. pole production (11 million ft.³) in 1993 and part of this volume was exported (4). About 1 to 2 million poles are being replaced each year, mostly due to mechanical wear and not because of biodegradation. As a result, utility companies are faced with a dilemma concerning the disposal of out-of-service poles that still contain residual creosote. Popular waste disposal options, such as combustion and landfilling, are

becoming more and more limited due to strict environmental regulations.

Reutilization of waste poles by conversion to useful products, such as wood composites, can be regarded as one way to solve disposal problems. Moreover, the remaining creosote content in the poles can still have the preserving capability against decay. Nearly 5 million metric tons of preservative-treated wood are disposed of annually into landfills

(11). About 2 million m³ per year of weathered utility poles treated with creosote are available for recycling (12). Standing poles in service are affected by long-term weathering, thereby causing changes in their creosote content and its distribution inside the poles. As a result, these changes may affect the effectiveness of the weathered poles, and also their converted wood products, against biodegradation.

The authors are, respectively, Former Graduate Research Assistant, School of Forestry, Wildlife, and Fisheries, Louisiana State Univ. Agri. Center, Baton Rouge, LA; Principal Wood Scientist, Southern Res. Sta., USDA Forest Serv., Pineville, LA; Professor and Assistant Professor, School of Forestry, Wildlife, and Fisheries, Louisiana State Univ. Agri. Center, Baton Rouge, LA. This paper (No. 99-22-0650) is published with the approval of the Director of the Louisiana Agri. Expt. Sta. This paper was received for publication in October 1999. Reprint No. 9037.

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Previous investigations have examined different aspects regarding the feasibility of recycling out-of-service utility poles into composite poles or any other wood product. Adams et al. (1) developed an innovative approach to produce a substitute for solid wood poles. The new poles (Compoles™) were manufactured from composite wood material consisting of chemically treated wood flakes bonded together using a synthetic adhesive. An economic analysis showed that the octagonal poles could compete effectively in the marketplace. Cooper (8) conducted a pilot study to evaluate the recovery and grade of lumber produced from typical poles and to assess the feasibility of handling the contaminated sawdust produced. The results showed that good grade and volume recovery could be obtained from used poles using a portable bandsaw. The study also indicated that special sawdust handling and disposal provisions must be made if this practice is to be adopted.

Falk (11) stated that at this time, the recycling potential for treated wood-waste is unknown. According to Falk (11), a major problem associated with recycling treated wood is that products made from recycled treated wood may not have the same resistance to decay and insects as the original treated wood product. Similarly, Cooper (9) stated that there is a need for extensive research into ways of reducing, reusing, recycling, and disposing of treated wood in environmentally acceptable ways. There-

fore, the objective of this study was to evaluate the extent of decay resistance of out-of-service utility poles and its relation to residual creosote content and internal distribution.

MATERIALS AND METHODS

The investigation was divided into two parts: 1) distribution of residual creosote content in weathered poles; and 2) decay resistance of the corresponding poles.

DISTRIBUTION OF RESIDUAL CREOSOTE

Weathered out-of-service SYP poles of two service duration groups (5 and 25 years of service duration) were selected. In addition, freshly treated poles of the same species were used for comparison purposes. Five different poles from each group were taken as replicates. These poles were obtained from Entergy Gulf States Utility Company and brought to Lee Memorial Forest near Bogalusa, La., for processing. All the poles were passed through a metal detector to remove metal objects. After metal removal, the poles were cut into 8- to 10-foot-long bolts. Three bolts (top, middle, and bottom) were selected from each pole. Each bolt was sawn into experimental specimens using a portable Wood-Mizer band sawmill at horizontal distances of 0.5, 1.5, 2.5, and 3.5 inches from the pole surface, respectively. Samples were taken and appropriately labeled from these sampling distances (Fig. 1). During sawing, sawdust samples obtained from various vertical and horizontal locations in the poles were

collected for creosote content determination, while the lumber portions were used for the decay test.

Creosote content (C) (% of dry, extracted wood) was determined using toluene extraction in accordance with AWWA Standard A6-83 (2), as follows:

$$C = [(W_1 - W_2 - W_3)/W_2] \times 100 \quad [1]$$

where W_1 is the weight of the wood sample before extraction, W_2 is the weight of the oven-dry extracted sample, and W_3 is the weight of water in the sample.

Creosote content (C) (pcf) was also determined as follows:

$$C = [A/100 \times 32] \quad [2]$$

where A is the creosote content (% of dry, extracted wood) and 32 is the assumed density of the wood.

DECAY RESISTANCE

As described in the procedure for residual creosote distribution, visually defect-free samples were obtained from lumber at several vertical and horizontal locations in the poles. The samples were further sawn into blocks measuring 0.75 in.³ They were stored in an environmental chamber at 80°F and 70 percent relative humidity (RH) for 24 hours until they reached equilibrium moisture content. Decay resistance was performed by the soil-block method, using a sandy loam soil with a water-holding capacity of 22 to 25 percent, in accordance with AWWA Standard M10-77 (3). Block samples were subjected to decay with the fungus *Neolentinus lepideus* Fr., which was obtained from the American Type Cultural Collection with specification No. 12653 (Madison 535). *Neolentinus lepideus* was used because it is creosote tolerant (7). For comparison purposes, 20 blocks of reference untreated SYP were also prepared. After air-drying and weighing, they were conditioned and subjected to decay in the same manner as treated test samples. SYP strips measuring 0.125 by 0.125 by 1.275 inches with the grain parallel to the long dimensions were used for each block. The bottles and feeder strips were sterilized using steam from an autoclave. Each of the strips was placed inside a bottle, containing the sandy loam soil, and then inoculated with fungus. The inoculated bottles were incubated in a conditioned room at 80°F and 70 percent RH for 3 weeks until the feeder strips were covered with mycelium. Test

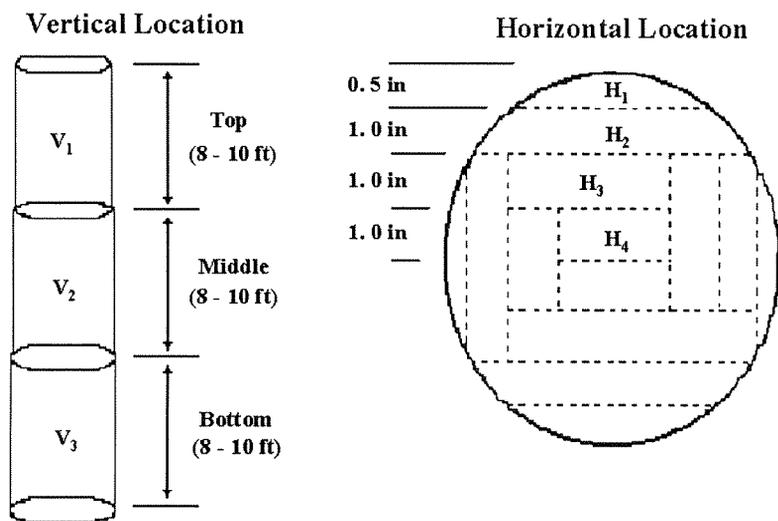


Figure 1. — Pattern of sawing procedures used for treated poles.

blocks from either treated or untreated SYP were then inserted into the bottles, which were then placed in the incubation room.

At the end of the 12-week incubation period, the blocks were removed from the bottle, and the mycelium was carefully brushed off. The blocks were re-conditioned again and then weighed at equilibrium. The following formula was used to determine the weight loss (WL) in percent, as follows:

$$WL = [(W_i - W_f)/W_i] \times 100 \quad [3]$$

where W_i and W_f are the initial and final weight of the block samples, respectively.

RESULTS AND DISCUSSION

DISTRIBUTION OF CREOSOTE CONTENT

The analysis of variance reveals that the effects of main sources of variances (service duration, vertical locations, and horizontal locations) and the interaction of these three variables were significant (Table 1). The significant interaction shows that at a given pole service duration and vertical location, the creosote content had specific patterns of changes with respect to horizontal location (Figs. 2 and 3). Creosote content in freshly treated poles was much higher than in weathered poles. In weathered poles with 5-year service duration, the residual creosote content tended to increase horizontally from the surface to the pith, and vertically from the upper to the bottom portions. To the contrary, the horizontal trend in freshly treated poles was the inverse of weathered poles; the creosote content was highest in the outer portion and lowest in the interior. The vertical trend, however, showed no significant changes.

The decreasing trend in residual creosote from the pith to the surface of 5- and 25-year poles is mainly due to the effect of bleeding and leaching of creosote during service (6,9,14,15,17). In long-term weathering, the surface of poles was more exposed to high temperature than the interior, causing the evaporation mostly of low-molecular-weight (more volatile) fractions of the creosote. As a result, outward movement of creosote occurred due to the pressure gradient between the surface and the interior of the poles. Higher residual creosote content inside the weathered poles beyond 2.5 inches distance from the surface could

TABLE 1. — Analysis of variance of creosote content and percent weight loss in treated poles.

Source of variation	DF	F-values	
		Creosote content	Weight loss
Service duration (S)	2	24.57***	24.92**
Vertical location (V)	2	6.79**	19.43**
Horizontal location (H)	3	16.96**	8.74**
Interaction (S × V × H)	12	2.98**	3.94**

*** denotes significance at alpha = 0.05.

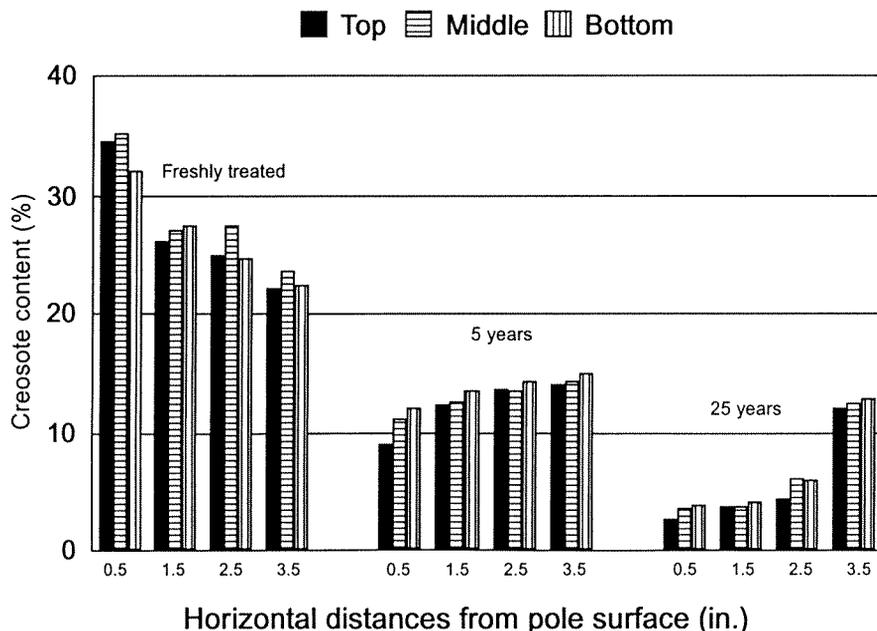


Figure 2. — Distribution of creosote content (%) in treated poles.

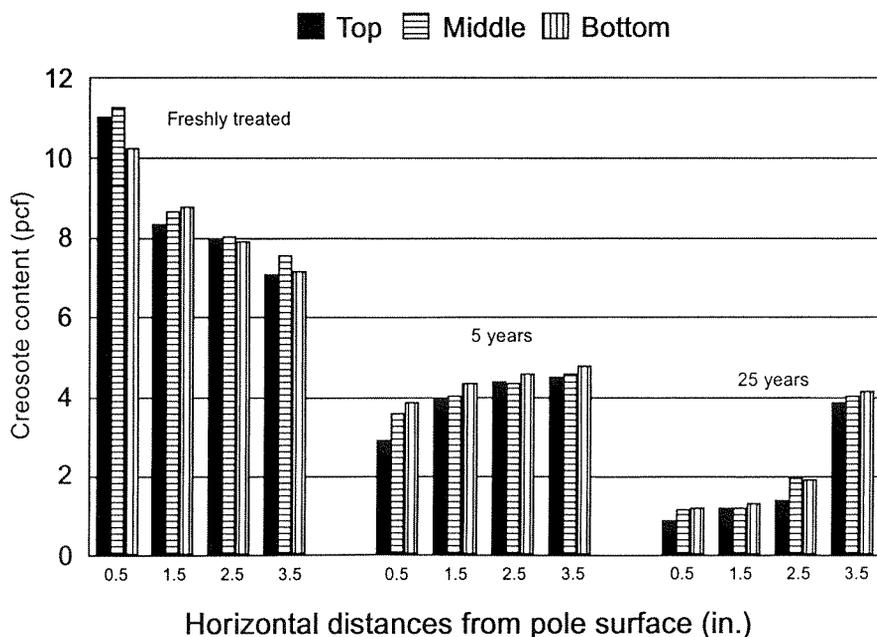


Figure 3. — Distribution of creosote content (pcf) in poles.

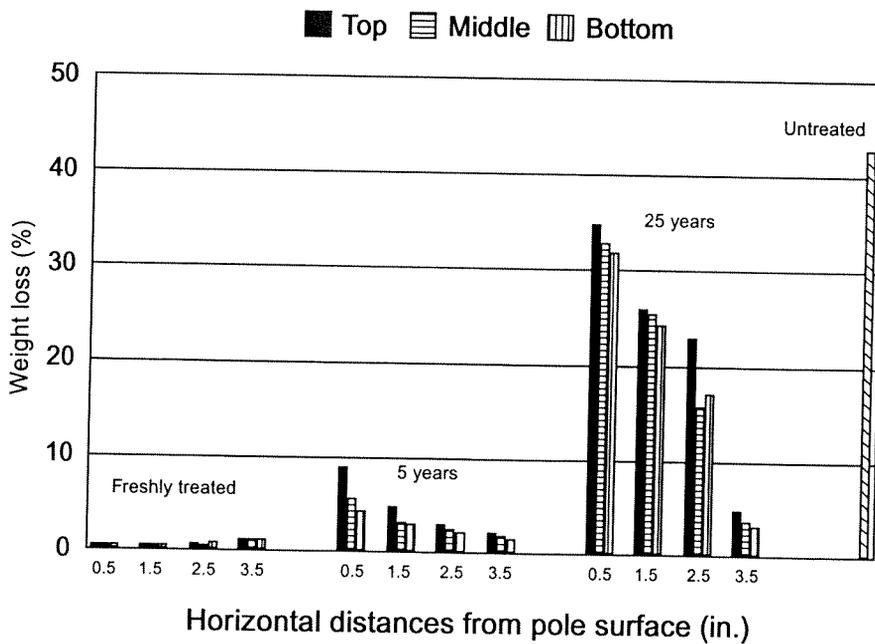


Figure 4. — Weight loss with respect to vertical and horizontal locations in treated poles.

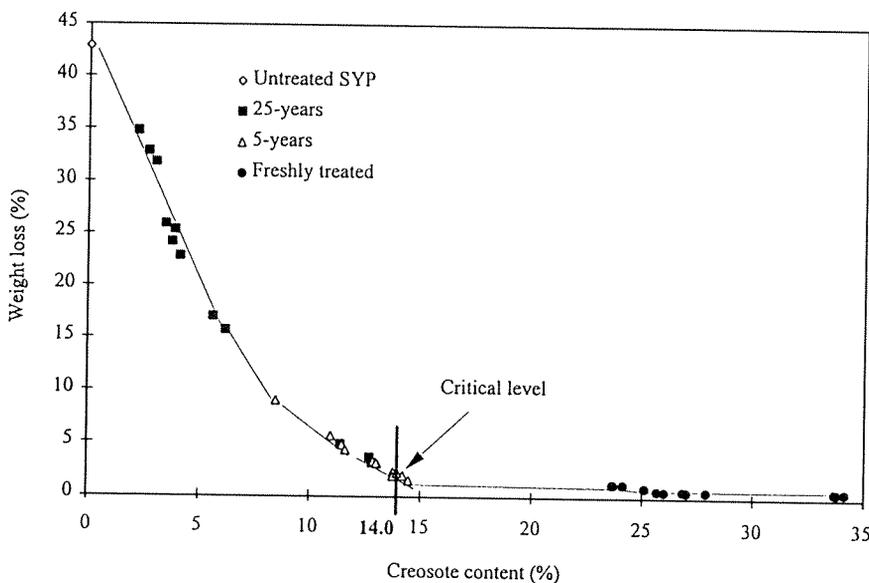


Figure 5. — Relationship between creosote content and weight loss.

be attributed to the presence of pit aspiration and bulking effect of extractives and shielding from surface effects, inhibiting the passage of creosote outward from the interior. Pit aspiration is one of many factors that are known to affect preservative penetration (5). However, pit aspiration is less common near the pole surface, since it consists mainly of sapwood. Also, steaming of the speci-

mens in the autoclave may relieve pit aspiration in the sapwood. These phenomena also explain the decreasing trend of creosote content from the outer to the inner portions of freshly treated poles. The higher creosote content in the bottom of 5- and 25-year poles was mainly due to gravity, which caused the downward movement of the creosote in standing poles during service.

DECAY RESISTANCE

The analysis of variance of weight loss of treated poles (Table 1) shows that the effects of all sources of variation (i.e., service duration and vertical and horizontal locations) were significant. Poles with longer service duration had higher weight loss, indicating more intensive decay (Fig. 4). Weathering, which caused a reduction in creosote content (Figs. 2 and 3), made the exposed part of the wood poles less protected, and therefore, more vulnerable to biodegradation by fungi. In untreated SYP, the weight loss was much higher than in all the treated poles.

In freshly treated poles, weight loss in the outer portion was negligible (Fig. 4) since the creosote content near the surface was high (Figs. 2 and 3). The weight loss increased slightly toward the pith due to the inward gradual decrease in creosote content. With respect to vertical location, the weight loss in freshly treated poles showed no significant changes. In 5- and 25-year poles, the weight loss was greater in the upper and outer portions than in the bottom and interior, while the residual creosote content in the same locations decreased horizontally outward and upward. This indicates that the loss of creosote in the outer and upper portions of weathered poles rendered the poles less effective in inhibiting the decaying activities of the fungus.

It is interesting to note that the fungus-induced weight loss was negligible at creosote contents above the 14 percent level (Fig. 5). Weight loss increased dramatically with the reduction in creosote content starting from this critical level, indicating that at low creosote contents there was much greater activity by the fungus. For example, the weight loss in the outer portions of 25-year poles ranged from 31.9 to 34.8 percent (Fig. 4), while the creosote content in the corresponding portions ranged from 2.7 to 2.8 percent. Conversely, weight loss in the inner portions of these poles was much lower (3.2% to 5.0%) since the creosote content was still close to the 14 percent critical level (11.4% to 12.9%). This might be linked to the reduction of creosote content in the outer portion, which was accompanied by some loss of its more volatile (i.e., low-molecular-weight) fractions, as described in the distribution of residual creosote inside the weathered poles.

Stasse (16) stated that creosote of low-molecular-weight fractions tended to have greater partial solubility in water than high-molecular-weight fractions. The toxicity threshold of *Neolentinus lepideus* Fr. is 4.8 pcf of coal-tar creosote in wood (10).

When pole averages are considered, the weight loss in freshly treated poles at 0.5 and 3.5 inches from the pole surface was 0.6 and 1.3 percent, respectively. For weathered poles, the weight loss at the corresponding horizontal distances was 6.4 and 1.9 percent in 5-year poles and 32.1 and 4.2 percent in 25-year poles, respectively. For untreated SYP, the weight loss was the greatest (42.9%). It is apparent that the decay resistance of 5-year poles was still high and closer to freshly treated poles; while low decay resistance in the outer portions of 25-year poles was approaching that of untreated SYP.

The results of this study suggest that when out-of-service poles are reutilized for composite-wood products, pieces from the low-decay-resistance wood poles with 25 years of service duration should be located in the inner part of the corresponding products. Pieces from the high-decay-resistance 5-year poles are more suitable for the outer part, which is more likely to be exposed to ground contact and other decay-inducing environmental factors.

CONCLUSIONS

Weathering affected the distribution of residual creosote content in out-of-service, previously used poles, such that longer service duration of the corresponding poles caused reduction in creosote content. The content in the upper and outer portions of the corresponding poles was lower than the bottom and the inner portions.

The variation in decay resistance of weathered poles was related to their residual creosote content. Reduction in decay resistance in 25-year poles, which approached that of untreated SYP in the outer zone, was greater than in 5-year poles. Decay resistance of most portions in 5-year poles was still high and similar to freshly treated poles.

In weathered poles, the residual creosote content at 14 percent was regarded as the critical level. Below this level, the decay resistance decreased considerably.

The significant relationship between decay resistance and residual creosote content in out-of-service poles should be considered when these poles are reutilized for other useful products such as wood composites.

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