# REMOVAL OF CREOSOTE FROM WOOD PARTICLES AT DIFFERENT HORIZONTAL AND VERTICAL LOCATIONS OF DECOMMISSIONED POLES USING STEAM TREATMENT[1]

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## ABSTRACT

This study used steam treatment to evaluate the potential of this method to remove residual creosote content of sawdust from weathered, out-of-service poles. Steaming was successful in reducing the creosote content to a level of 1.31%, regardless of creosote content at the start of the steaming treatment. Poles with higher initial creosote contents required longer steaming durations. At any given initial preservative content, creosote removal from weathered poles was more difficult than from freshly treated poles. Moreover, creosote from samples taken near the inner core of the poles was also more difficult to remove than creosote in the outer portions of the poles. Steaming proved an efficient mechanism to remove creosote. Some other technology must be applied to remove creosote content below 1.31%.

*Keywords:* Creosote, wood poles, sawdust, steam.

## INTRODUCTION

A major development in wood preservation history was the use of coal-tar creosote, which was patented in 1836 by Moll, in a pressure impregnation process patented by John Bethell in 1838. Known as the Bethell, or full-cell, process, it was the first major use of pressure for wood treating and remains the basis of most modern wood treating operations (Hunt and Garratt 1967; Freeman et al. 2003). Since the early days of its inception, creosote has grown in market share to be one of the most industrially important wood preservatives.

Creosote, a high boiling fraction of coal or petroleum distillate, is widely used as a preservative for wood in utility structures, marine pilings, and other applications. Most of the volume

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of material treated with creosote is for the railway industry. Approximately 78% of the volume of creosote used is to treat crossties and an additional 6% of the used creosote goes into switch and bridge ties (Micklewright 1998). In 1997, for example, some $2.76 \times 10^6$ $m^3$ ($97.4 \times 10^6$ $ft^3$) of wood was treated with $2.92 \times 10^8$ L ($77.2 \times 10^6$ gals.) of creosote along with $1.78 \times 10^7$ L ($4.7 \times 10^6$ gals.) of petroleum solvent, which represented approximately 13% of all industrially preservative-treated wood (Micklewright 1998).

Preservative-treated wood that goes into service almost always will be decommissioned and removed from service for various reasons such as mechanical damage, poor treatment or in-service maintenance, or obsolescence. It has been estimated that approximately $2 \times 10^6$ $m^3$ ($7.06 \times 10^7$ $ft.^3$) of creosote-treated wood is taken out of service each year in the U.S. and that total will grow to approximately $16 \times 10^6$ $m^3$ ($5.65 \times 10^8$ $ft.^3$) in 2020 (Cooper 1994). Furthermore, it has been estimated that a total volume of $2.8 \times 10^6$ $m^3$ ($1.00 \times 10^8$ $ft.^3$) of creosote-preserved wood is annually decommissioned (AWPI 1997).

Historically, the most common treatment options for this material were either incineration or landfilling. Neither option is particularly economically viable nor without potential adverse environmental consequences. Thus, recycling options, both removal of the toxic preservatives from the preservative-treated wood and recycling of the detoxified preserved wood, are of great importance to those concerned with the life-cycle management of treated wood.

Previous research has examined the technical feasibility of recycling creosote-treated wood for particleboard (Zhao and Gardner 2001a,b) and timber production from reclaimed creosote-treated wood pilings (Shi et al. 2001). A study by Roliadi et al. (2000a) found that decommissioned creosote-treated utility poles have adequate gluability and decay resistance for many value-added applications.

Although many value-added products can be produced with recycled creosote-treated wood, it is acknowledged that residual creosote content can have an adverse effect on the marketability of these products. Removing creosote from decommissioned creosote-treated wood products has largely been done by two methods: (1) bioremediation and (2) solvent extraction. Both methods can be effective to bring the creosote content to near zero percent; however, bioremediation can be time-consuming (Esslyn 1976), and solvent extraction is costly (Portier et al. 1994). Catallo and Shupe (2003) used supercritical water to transform creosote-treated wood. During treatment, the creosote-derived hydrocarbon residues in the wood were nearly completely (>99%) recovered, and the wood itself was transformed into a mixture of hydrocarbons including substituted benzenes, phenolics, and light PAHs. The industrial application of this technology is highly dependent on the yet determined economics of the process.

One method that has been used to remove residual preservatives from wood is steam explosion. Clausen and Smith (1998a,b) and Shiau et al. (2000) examined the potential of steam explosion alone and following acid extraction and bacterial fermentation to remove metals from chromated copper arsenate (CCA)-treated wood. The results suggest that steam explosion does not increase the extractability of the metals.

Steaming has been used to increase wood permeability (Hickin 1971; Eaton and Hale 1993) and separate volatile compounds in wood extractives (Browning 1967). However, the application of steam treatment to creosote-treated wood has not been widely studied. The objective of this study is to determine the potential of using steam and hot water washing to remove creosote from sawdust produced from out-of-service poles. In this paper, this process will be referred to as steam treatment. The successful development of this technology will allow for decommissioned creosote-treated wood to be used for numerous products in which residual creosote content is not only technically adverse to the remanufacturing process but may also be not permissible according to current U.S. Environmental Protection Agency (EPA) regulations.

## MATERIALS AND METHODS

Weathered out-of-service southern yellow pine (SYP) poles of two service duration groups (5- and 25- years' service duration) were selected. In addition, freshly treated poles of the same species were used for comparative purposes. Five poles from each group were taken as replicates. These poles were obtained from Energy Gulf States Utility Company and brought to the LSU Agricultural Center's 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 2.4–3.0-m (8–10 ft.) 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 1.3, 3.8, 6.4, and 8.9 cm (0.5, 1.5, 2.5, and 3.5 in.) from the bolt surface as measured from the butt end of each bolt. During sawing, sawdust samples obtained from various vertical and horizontal locations in the poles were collected for creosote content determination (Fig. 1). A plastic bag was fit around the sawdust outlet for each cut of the bolts to collect the sawdust. The sawdust was thoroughly mixed, and the bags were coded according to horizontal and vertical position within the pole. The sawmill was thoroughly cleaned with an air hose between each cut to avoid cross contamination.

Creosote content (C) (% of dry, extracted wood) was determined using toluene extraction in accordance with AWPA (1984) Standard A6-83, as follows:

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

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

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

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

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

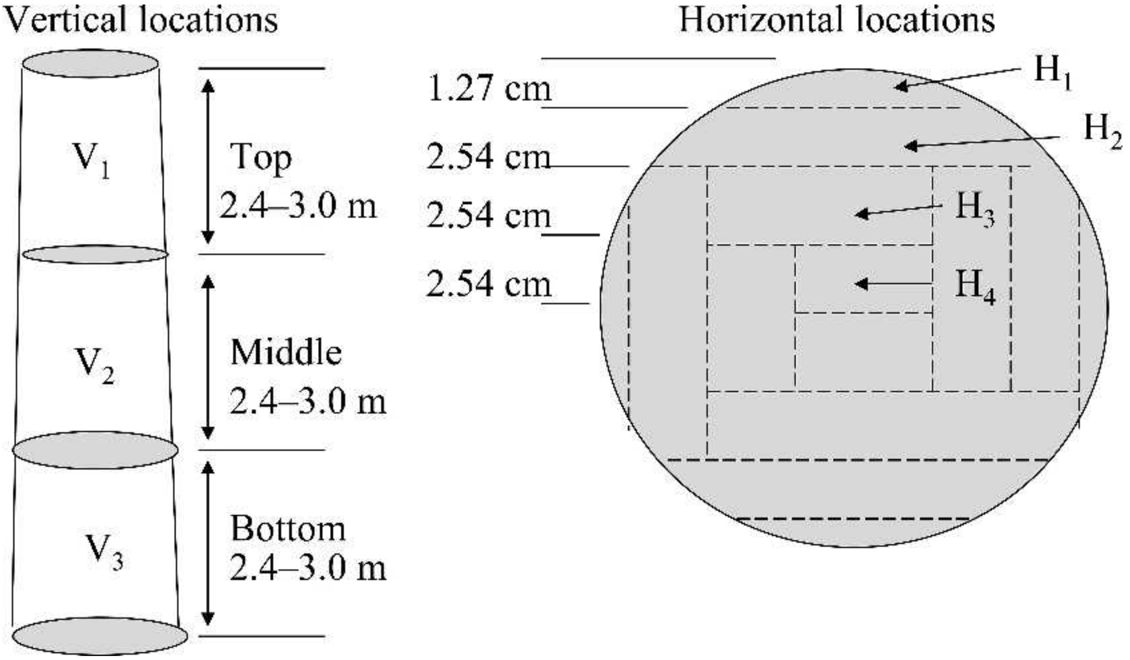

FIG. 1. Sawing pattern of the experimental poles.

Sawdust samples weighing 5 grams, with predetermined creosote contents using toluene extraction in accordance with AWPA Standard A6-83 (AWPA 1984), were placed in a fritted glass crucible and then steam-treated in a retort at atmospheric pressure of 100°C (212°F) for up to 3 h. At intervals of 15 min, the samples were removed from the retort and washed with boiling water to facilitate the removal of as much creosote as possible. The remaining creosote contents in the samples were determined again. Steam treatment was terminated when the residual creosote content became stable and values at this point were considered as the final creosote content. Criteria used to evaluate the effectiveness of steam treatment were final creosote content and steaming duration.

## RESULTS AND DISCUSSION

Figure 2 shows the effect of steaming duration on creosote content. The freshly treated, 5 years of service, and 25 years of service poles contained initial creosote contents, creosote content prior to steam treatment, of 34.18, 9.12, and 2.84%, respectively. It is interesting to note that regardless of the initial creosote content, steaming was successful in reducing the final creosote content to approximately 1.2–1.5% (Fig. 2).

The high degree of success of the steam treatment can be largely attributed to the basic physics of the steam-treatment. The heat from the steam would have resulted in the volatilization of some of the lower molecular weight volatile organic compounds in the creosote and lowered the creosote's viscosity. Consequently, the movement of creosote, which is not chemically bound or fixed in the wood, would have been greatly enhanced by the steam treatment. However, the capability of the steam treatment was limited in its ability to remove creosote. The steam treatment was unable to reduce the final creosote content to less than approximately 1.5%, which is less than the final creosote content attainable through solvent extraction or bioremediation (Portier et al. 1994) due to the fact that creosote is oil-soluble and therefore immiscible in a polar substance such as steam. It is likely that the remaining creosote after steam treatment will contain a greater fraction of high-boiling compounds, which are difficult to evaporate by steam (Andrew 1952; Wells and Bordenca 1955).

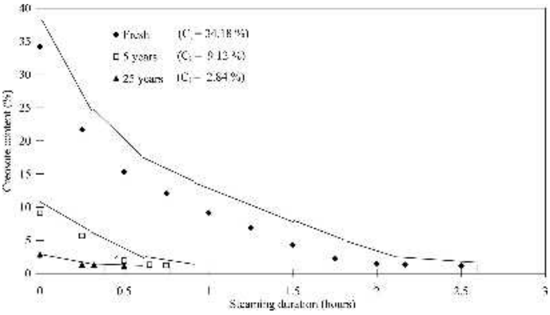

FIG. 2. Effect of steaming duration on creosote content of freshly treated, 5 years of service, and 25 years of service creosote-treated utility poles.

The analysis of variance (ANOVA) (Table 1) shows that the final creosote contents are not significantly different among all the variables tested; hence, the final content values can be averaged or pooled, which yields a value of 1.31%. The approximate steaming duration for various initial contents could be determined, by interpolating it to the overall mean of 1.31%, which was regarded as the effective final creosote content. As a result, when the experimental data of initial creosote content were plotted against steaming duration (Fig. 3), the plot reveals, as expected, that higher initial content required longer steaming duration.

TABLE 1. *Analysis of variance of final creosote content and steaming duration.*

| | Final creosote content | | Steaming duration | |
|---|---|---|---|---|
| Source of variation | DF | F-values | DF | F-values |
| Service duration (S) | 2 | 2.13 | 2 | 14.98* |
| Error (a) | — | | 12 | |
| Vertical location (V) | 2 | 2.08 | 2 | 2.47 |
| Horizontal location (H) | 1 | 2.55 | 1 | 9.22** |
| Interaction: | | | | |
| S*V | 4 | 1.98 | 4 | 1.78 |
| S*H | 2 | 1.77 | 2 | 3.67* |
| V*H | 2 | 1.13 | 2 | 1.34 |
| S*V*H | 4 | 0.97 | 4 | 0.91 |
| Initial creosote content | — | | 1 | 22.31** |

** and * denote significant at alpha = 0.01 and 0.05 levels, respectively.

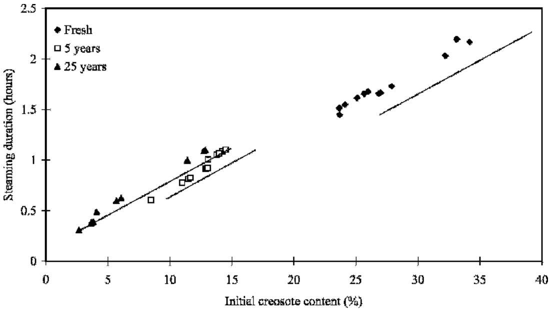

FIG. 3. Relationship between initial creosote content and steaming duration to reach 1.31% final creosote content, which is the mean value of final creosote content for all age classes of poles.

The effects of the horizontal and vertical sampling locations and different service durations were also analyzed by the ANOVA. Longer steaming durations were required for samples from poles of older service ages and from samples taken from inner portions of poles as compared to samples from freshly treated poles and outer portions (Fig. 4). The longer steam periods needed for the older poles again inferred that the residual creosote in 5- and 25-year weathered poles had greater high-boiling fractions, due to more evaporation of low-boiling compounds, as compared to the freshly treated poles.

It is noted that the reason that the creosote is more difficult to remove in the inner portions of the poles could also be due to the greater occurrence of aspirated pits in the cell walls in this portion of the pole. Pit aspiration was found to be less common on the outer surfaces of the poles due to the presence of sapwood. Moreover, the steam in the pre-treatment prior to the introduction of creosote in the treating process tends to relieve pit aspiration on the pole surface (Roliadi 1997).

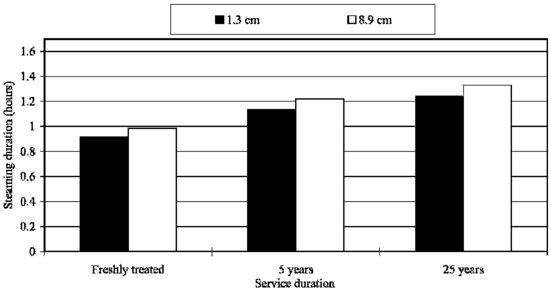

FIG. 4. Steam duration for sawdust from three pole age classes at two horizontal distances from the surface of the poles.

This work is part of a larger on-going project that is examining the technical feasibility of recycling decommissioned preservative-treated wood into value-added products. Although previous research (Roliadi 1997; Roliadi et al. 2000a) has examined the gluability of creosote-treated lumber, this work clearly has not. Additional research is needed to examine the feasibility of using steam treatment on large-size, creosote-treated wood and assess the subsequent gluability properties.

## CONCLUSIONS

The objective of this study was to determine the potential of using steam to remove creosote from out-of-service poles. This research has shown that the initial creosote content in sawdust samples from poles greatly determined the necessary steaming duration to remove as much creosote as possible. Regardless of initial creosote content, steaming reduced the creosote to 1.31%. Beyond this level, steaming caused no significant reduction in creosote content.

At a given initial creosote content, removal of creosote by steam was more difficult for poles with longer service duration and for materials from the inner pole regions. Steaming, however, does appear to be an efficient and relatively inexpensive method of reducing the creosote content in weathered poles. Additional treatment using a different technology will be necessary to remove all of the residual creosote from decommissioned or discarded creosote-treated wood.

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