



United States  
Department of  
Agriculture

Forest Service

Forest  
Products  
Laboratory

General  
Technical  
Report  
FPL-GTR-203



# Physical Deterioration of Preservative Treated Poles and Pilings Exposed to Salt Water

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## Abstract

This report details the results of laboratory analyses of wooden pilings sent to the USDA Forest Products Laboratory in March 2011. These samples were removed from coastal wooden posts, poles, piles, and deck boards. A total of 22 samples, consisting of either core borings or surface fiber samples, were removed from four installations along the South Carolina coast. Methods focusing on the physical, chemical, and biological properties of the wood determined that the 22 specimen samples consisting of core borings and surface fiber samples were physically deteriorated by salt accumulation and not biological deterioration. This report presents the findings of these analyses and discusses the cause of the documented damage.

Keywords: defibration, salt damage, salt kill, pilings, dock fungus, non-biological damage, tracheid separation.

## Acknowledgments

Thank you to Jim Healey of Cox Industries for the sampling and data collection in Charleston, South Carolina; Tom Kuster, FPL Forest Products Technologist, for conducting SEM/EDAX analyses; and Dan Foster, FPL Chemist, for conducting the IC analysis.

**Significance of Cover Photo:** Salt damage or “fuzzy wood” can be mistaken for biological deterioration, although it actually represents physical deterioration. This image of a deck piling has extensive salt damage from seawater exposure. The seawater is wicked through the piling by capillary forces, splashed up by wave action, and as the water evaporates, the residual salt is deposited in the fibers near

the top of the pole. This is commonly seen in wood exposed to saline conditions and is largely considered cosmetic damage. As illustrated in this picture, the pilings do not have to be submerged in saltwater for damage to occur; these pilings were located directly adjacent to a wharf in Charleston, South Carolina, and were frequently inundated with seawater. (Photo provided by Jim Healey, Cox Industries, Orangeburg, South Carolina).

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September 2011

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Kirker, Grant T.; Glaeser, Jessie; Lebow, Stan T.; Green III, Frederick; Clausen, Carol A. 2011. Physical Deterioration of Preservative Treated Poles and Pilings Exposed to Salt Water. General Technical Report FPL-GTR-203. Madison, WI: U.S. Department of Agriculture, Forest Service, Forest Products Laboratory. 5 p.

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# Physical Deterioration of Preservative Treated Poles and Pilings Exposed to Salt Water

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## Introduction

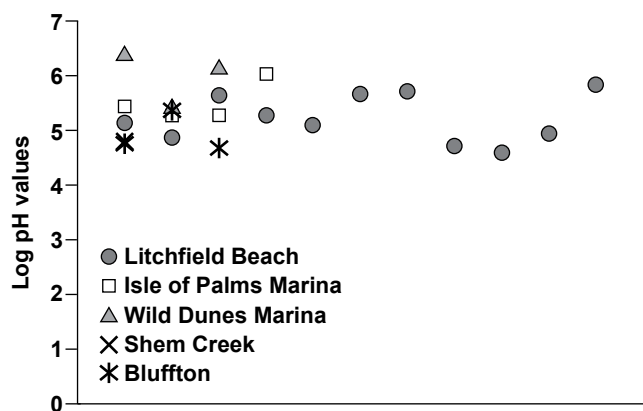
Wood has been used in marine settings for hundreds of years. Treated pilings offer protection from biological deterioration from marine organisms and extend the service life of the product. Wood in marine contact is also subject to uptake and accumulation of salt, primarily sodium and potassium chloride, from the seawater that is splashed onto the pilings by wave action and salt spray, and physically wicked up through the pole by capillary forces. The evaporation of the seawater from the surface of the submerged piling leaves residual salt crystals that are reported to precipitate and disrupt the middle lamella and separate the tracheid fibers (Johnson and others 1992). The result is an orange-brown, fuzzy appearance that is normally considered cosmetic and does not affect the structural integrity of the piling. Salt damage can be found in almost every instance in which wood comes in frequent contact with brine, including alkaline salt storage areas (Parameswaran 1981) and archeological sites (Blanchette 2002). Salt damage is sometimes confused with brown-rot decay, but the bright orange color of the affected area is the only similarity between the two. Brown-rot decay fungi are equipped with cellulytic enzymes that degrade the cellulose fibers in the wood, leaving the brown cubical remnants (lignin) behind (Kirk and Highley 1973). Whereas marine fungi exist (Leightley and Eaton 1979), brown-rot fungi are terrestrial and not equipped to survive in marine environments (Jones and others 2000). Comparatively, white-rot fungi are capable of degrading both lignin and cellulose in wood and cause a bleached white, spongy appearance because of the presence of residual cellulose fibers (Kirk and Highley 1973). White-rot fungi are also not compatible with or frequently encountered in marine environments. Additionally, soft-rot fungi occur in environments with high moisture and require an external nutrient source to degrade the wood (Worrall 1991). This type of decay is not as aggressive as white or brown rots and also is uncommon in marine areas. The images and data collected and compiled for this technical report are based on

samples and pile cores received at the Forest Products Laboratory (FPL) for analysis. Our results reinforce the conclusion that the discolored wood is due almost entirely to salt precipitation that results in physical disruption and damage to the wood fibers and not fungal decay. These results are consistent with the results reported by Johnson and others (1992).

## Materials and Methods

A total of 16 pile cores and six surface fiber samples were obtained by Cox Industries (Orangeburg, South Carolina) and submitted to FPL for analysis. Samples were collected from posts, poles, piles, and deck boards. The samples were collected in and around the port of Charleston in Charleston, South Carolina. Most of the samples were collected in the Litchfield Beach community, which is located approximately 500 yards from the ocean. Other sample locations included Isle of Palms Marina, Wild Dunes Marina, and a more southern location (Bluffton) located near Hilton Head, South Carolina. A single sample of wood fiber was also received from Shem Creek, located in Mount Pleasant, 50 yards from a tidal creek.

Samples were divided and subjected to five types of analyses: pH, light microscopy, scanning electron microscopy, EDAX (energy dispersive X-ray analysis, and ICP–AES (inductively coupled plasma spectroscopy—atomic emission spectroscopy). Visible examinations and pH determinations were conducted on all samples. Fifteen increment borings were sectioned and examined for the presence of fungi using light microscopy. A minimum of three sections was made of each specimen in order to examine the wood cells in radial and transverse (cross sectional) views. Each specimen was stained with lacto-phenol/cotton blue—a stain that preferentially dyes fungal hyphae bright blue—and examined at 450×, 600×, and 1000×. When fungal hyphae were observed in the wood or on the surface of the specimen under low magnification (100×), additional sections or surface tape mounts were made of the wood in that area. For



**Figure 1. Ranges of pH values found in submitted fuzzy wood and pile cores.**

scanning electron microscopy (SEM) of the marine pilings, fibers or 5- by 7-mm pieces of wood were placed on sticky silver tape on aluminum mounts and coated with gold using a Denton Desk-1 sputter coater (Denton Vacuum, LLC, Moorestown, New Jersey). Samples were examined and photographed with a LEO EVO 40 SEM (Carl Zeiss NTS, Peabody, Massachusetts) at 15 kV.

For EDAX analysis, piling fibers were pelletized in a Parr press (Parr Instrument Company, Moline, Illinois); or if samples were solid, 5- by 5-mm pieces of wood were mounted on carbon stubs with sticky carbon tape. Uncoated specimens were viewed in the LEO EVO 40 at a variable pressure of 40 Pascals at 1.0nA's and 20kV. EDAX analysis was performed using an IXRF 550i system with a 50-mm SSD detector (IXRF Systems, Inc. Houston, Texas). Spectra were collected for 100 seconds.

ICP–AES analysis was conducted on all samples to determine the preservative retention and sodium content. Sample preparation and instrument calibration was conducted in accordance with AWP standard A21 (AWPA 2010). This method details the procedure for digesting a wood sample and analyzing the resulting solution for preservative components. The AWP standard density value for southern pine (512 kg/m<sup>3</sup>) was used to calculate preservative concentration on a weight/volume basis (AWPA 2010).

## Results and Discussion

### Physical Properties of the Wood

Upon receipt of the wood samples, they were screened for basic properties. Visual observations were made and pH of the samples was obtained on extracts of each sample in deionized water using a Corning pH/ion meter and probe (Corning Incorporated, Corning, New York). PH values of the individual samples are presented in the sample summary (Fig. 1). Typically, brown-rot decay produces oxalic acid in order to facilitate the decay process, and production of

oxalic acid will decrease wood pH to around 2 (Green and others 1991). The pH of these samples was consistent with the normal pH range of wood (i.e., 4.5–6.5).

### Microscopic Examination

No decay fungi were observed in any of the specimens. Certain specimens contained brown-pigmented fungi within the tracheids or ray cells of the wood. These fungi are most likely *Aureobasidium pullulans*, the “black yeast fungus,” or common mold fungi (technically “dematiaceous hyphomycetes”) that cause dark stains in wood when exposed to moisture. The common mold fungus *Cladosporium cladosporioides* was found on the surface of many of the increment borings. This fungus is probably present in the wood and then grew on the surface of the increment boring while it was confined within the high humidity of the plastic collection tube. One sample, Litch P6, contained non-pigmented fungal hyphae within the wood cells that did not contain clamp connections typically present in decay fungi. For example, the brown-rot decay fungus *Fibroporia radiculosa* (= *Antrodia radiculosa*) is characterized by large, frequent clamp connections; there was no indication that this fungus was present in any of the samples. In fact, there was no microscopic evidence of brown-rot wood decay at the cellular level.

### SEM

SEM micrographs were generated for a subset of the samples. The advantages of SEM are that high-resolution images can be obtained at micrometer scale and this method allows us to observe changes to the wood structure as well as the presence of fungal hyphae. No indication of brown-, white-, or soft-rot fungi were found in any of the samples. Tracheid separation was apparent in marina samples (Fig. 2), and SEM micrographs did show cubical salt crystals throughout the marina sample (Fig. 3). Oxalic acid crystals are typically needle-like or tetrahedral (Green and others 1996).

### ICP–AES Results

As expected when sampling a range of commodities treated for different use categories, the samples collected in this study exhibited a wide range of preservative retentions (Fig. 4). The observed retentions generally appear to be in accordance with expected values, although differences in assay zones and sample composition makes comparisons difficult. The relative proportions of chromium, copper, and arsenic within the samples in this study did not indicate any systematic depletion of either copper or arsenic. The proportions of chromium, copper, and arsenic in exposed CCA-treated wood can provide some indication of the extent of leaching because chromium is more leach-resistant than copper or arsenic (Lebow 1996). Sodium concentrations in all but one sample were over 1,000 ppm, and many samples contained over 10,000-ppm sodium. In contrast, naturally





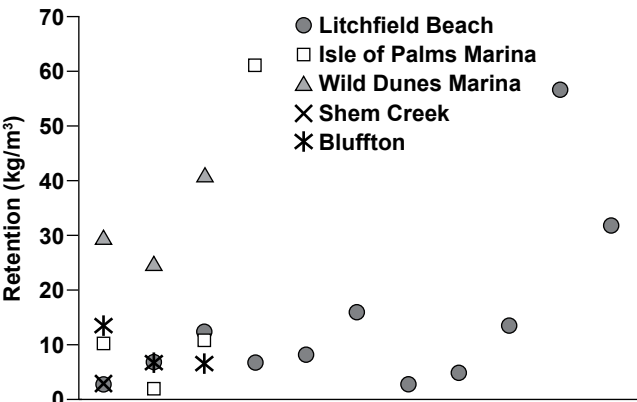
**Figure 2.** Image of salt-damaged pilings and corresponding sample showing tracheid separations and no fungal presence using SEM (175× magnification).

occurring sodium concentrations in Southern Pine wood have been reported to vary from 28 to 130 ppm (Choong and others 1974; Cutter and others 1980). The single sample with lower sodium levels (130 ppm) was removed from a pole approximately 135 meters from the water. It is noteworthy that this pole did not show any evidence of surface deterioration. It is also noteworthy that the five greatest sodium concentrations were associated with surface fiber samples (Fig. 5). These results confirmed the presence of sodium in the affected wood and corroborate the EDAX data implicating salt as the causative agent of the fuzzy wood.

The poles and piles that were sampled were not of a uniform use class, but ICP–AES indicated retentions of CCA and ACQ were within the acceptable retention range based on their service age. Also, ICP–AES analysis found on average 4× as much sodium (Na) in the fuzzy wood samples than was found in the core samples. These results confirmed the presence of sodium chloride (NaCl) and corroborate the EDAX data implicating salt as the causative agent of the fuzzy wood (Fig. 6). A full summary of all samples received and the results of the individual analyses is presented in the Appendix.



**Figure 3.** Image of salt damaged deckboards at Isle of Palms Marina (a) and salt crystals (white arrows) located in corresponding sample using Scanning Electron Microscopy (b, 450× magnification).



**Figure 4.** Retention of preservative in samples removed from poles, piles, posts, or decking.

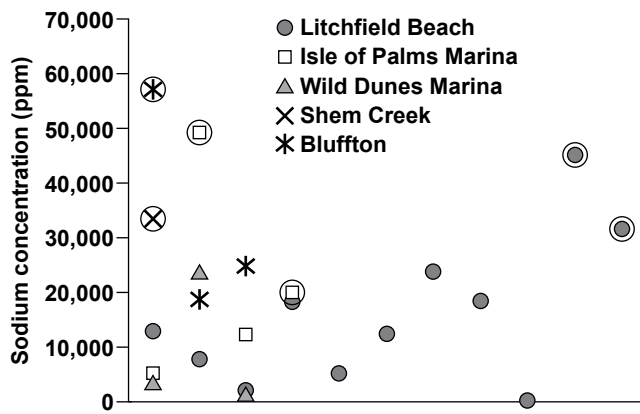


Figure 5. Sodium concentration in samples removed from poles, piles, posts, or decking. Ovals around symbols denote surface fiber samples.

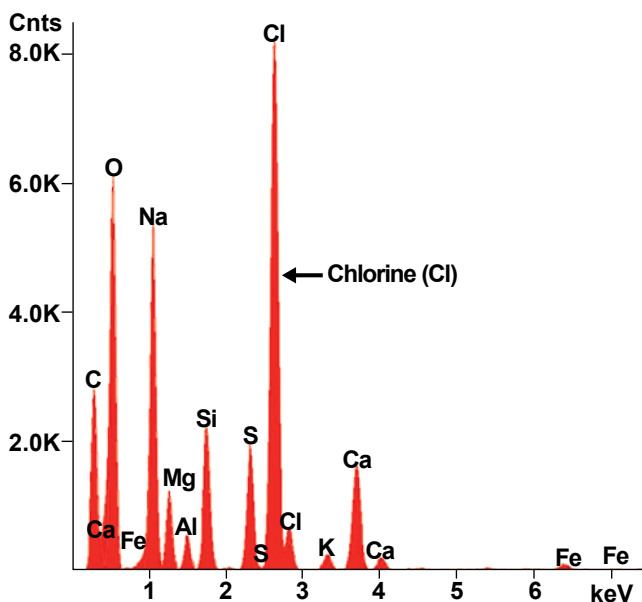


Figure 6. Analysis using EDAX found an abundant amount of sodium and chlorine relative to the other elements (including carbon and oxygen) as evidence of NaCl.

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Appendix—Summary Information for 22 Samples<sup>a</sup>

| Sample name       | Location             | Treatment | DFW <sup>b</sup> (yards <sup>c</sup> ) | Type       | Treat date | Use class    | Target retention | Weight (g) | NA <sup>d</sup> | As <sub>2</sub> O <sub>5</sub> | CrO <sub>3</sub> | CuO  | Total pre-servative retention | pH <sup>e</sup> | SEM <sup>f</sup> | Microscopic <sup>g</sup> | Additional analyses |
|-------------------|----------------------|-----------|----------------------------------------|------------|------------|--------------|------------------|------------|-----------------|--------------------------------|------------------|------|-------------------------------|-----------------|------------------|--------------------------|---------------------|
|                   |                      |           |                                        |            |            |              |                  |            |                 |                                |                  |      |                               |                 |                  |                          |                     |
| IOP 1             | Isle of Palms Marina | CCA       | 3                                      | Core       | 1990       | Land pile    | 0.8              | 0.5065     | 53.284          | 0.21                           | 0.31             | 0.13 | 0.64                          | 5.45            | —                | X                        |                     |
| IOP 3 deck board  | Isle of Palms Marina | ACQ-C     | 3                                      | Fuzzy wood | Unknown    | Above ground | 0.8              | 0.4671     | 461.63          | 0.03                           | 0.06             | 0.02 | 0.12                          | 5.28            | X                | —                        |                     |
| IOP 4             | Isle of Palms Marina | CCA       | 3                                      | Core       | 1990       | Land pile    | 0.8              | 0.4999     | 119.62          | 0.23                           | 0.33             | 0.12 | 0.67                          | 6.03            | —                | X                        |                     |
| IOP 2 Jet Ski     | Isle of Palms Marina | CCA       | 0                                      | Fuzzy wood | Unknown    | Marine pile  | 2.5              | 0.4559     | 180.02          | 1.14                           | 1.44             | 1.25 | 3.83                          | 5.3             | X                | —                        |                     |
| Litch P1          | Litchfield Beach     | CCA       | 50                                     | Core       | 1978       | Land pile    | 0.8              | 0.4799     | 123.3           | 0.07                           | 0.09             | 0.02 | 0.18                          | 5.15            | —                | X                        |                     |
| Litch P2          | Litchfield Beach     | CCA       | 20                                     | Core       | 1978       | Land pile    | 0.8              | 0.5778     | 88.89           | 0.15                           | 0.2              | 0.08 | 0.43                          | 4.89            | —                | X                        |                     |
| Litch P3          | Litchfield Beach     | CCA       | 75                                     | Core       | 1978       | Land pile    | 0.8              | 0.5137     | 19.376          | 0.25                           | 0.38             | 0.15 | 0.78                          | 5.66            | —                | X                        |                     |
| Litch P4          | Litchfield Beach     | CCA       | 50                                     | Core       | 1978       | Land pile    | 0.8              | 0.4768     | 178             | 0.14                           | 0.22             | 0.05 | 0.42                          | 5.29            | —                | X                        |                     |
| Litch P5          | Litchfield Beach     | CCA       | 20                                     | Core       | 1978       | Land pile    | 0.8              | 0.5504     | 55.408          | 0.16                           | 0.26             | 0.09 | 0.51                          | 5.12            | —                | X                        |                     |
| Litch P6          | Litchfield Beach     | CCA       | 100                                    | Core       | 1978       | Land pile    | 0.8              | 0.4653     | 115.74          | 0.36                           | 0.54             | 0.09 | 0.99                          | 5.68            | —                | X                        |                     |
| Litch P8          | Litchfield Beach     | CCA       | 150                                    | Core       | 1978       | Land pile    | 0.8              | 0.4935     | 235.23          | 0.06                           | 0.09             | 0.02 | 0.17                          | 4.68            | —                | X                        |                     |
| Litch P8 back     | Litchfield Beach     | CCA       | 150                                    | Core       | 1978       | Land pile    | 0.8              | 0.4819     | 177.6           | 0.11                           | 0.13             | 0.06 | 0.3                           | 4.96            | —                | X                        |                     |
| Litch P9          | Litchfield Beach     | CCA       | 150                                    | Core       | 1978       | Land pile    | 0.8              | 0.4747     | 1.234           | 0.27                           | 0.41             | 0.17 | 0.84                          | 5.83            | —                | X                        |                     |
| Litchfield pile 6 | Litchfield Beach     | CCA       | 100                                    | Fuzzy wood | 1978       | Land pile    | 0.8              | 0.5838     | 526.23          | 1.54                           | 0.89             | 1.12 | 3.54                          | 5.73            | —                | —                        |                     |
| Litchfield pile 7 | Litchfield Beach     | CCA       | 100                                    | Fuzzy wood | 1978       | Land pile    | 0.8              | 0.5365     | 341.46          | 0.54                           | 0.75             | 0.7  | 1.99                          | 4.72            | X                | —                        |                     |
| SCEG #1 bag       | Bluffton             | CCA       | 3                                      | Fuzzy wood | 2002       | Land pile    | 0.6              | 0.4715     | 540.36          | 0.28                           | 0.43             | 0.12 | 0.84                          | 4.69            | X                | —                        |                     |
| SCEG 1            | Bluffton             | CCA       | 3                                      | Core       | 2002       | Land pile    | 0.6              | 0.4862     | 179.5           | 0.14                           | 0.2              | 0.07 | 0.41                          | 4.75            | —                | X                        |                     |
| SCEG 2            | Bluffton             | CCA       | 3                                      | Core       | 2002       | Land pile    | 0.6              | 0.4795     | 237.17          | 0.14                           | 0.2              | 0.06 | 0.41                          | 5.36            | —                | X                        |                     |
| Shem Creek        | Shem Creek           | ACQ-C     | 3                                      | Fuzzy wood | Unknown    | Post (6 × 6) | 0.6              | 0.4981     | 334.45          | 0                              | 0                | 0.15 | 0.15                          | 4.81            | X                | —                        |                     |
| WD 1              | Wild Dunes Marina    | CCA       | 0                                      | Core       | 2001       | Marine pile  | 2.5              | 0.5164     | 36.456          | 0.58                           | 0.94             | 0.32 | 1.84                          | 6.44            | —                | X                        |                     |
| WD 2              | Wild Dunes Marina    | CCA       | 0                                      | Core       | 2001       | Marine pile  | 2.5              | 0.4768     | 226.04          | 0.57                           | 0.76             | 0.24 | 1.56                          | 5.48            | —                | X                        |                     |
| WD 3              | Wild Dunes Marina    | CCA       | 0                                      | Core       | 2001       | Marine pile  | 2.5              | 0.1101     | 3.689           | 0.62                           | 1.6              | 0.34 | 2.56                          | 6.18            | X                | X                        |                     |

<sup>a</sup>Samples were received at USDA FS FPL located in Madison, Wisconsin.<sup>b</sup>Distance from water.<sup>c</sup>1 yard = 0.9144 meters<sup>d</sup>Not applicable.<sup>e</sup>pH analyzed by Carol Clausen, Supervisory Research Microbiologist at FPL.<sup>f</sup>SEM analyzed by Tom Kuster, Microscopist at FPL.<sup>g</sup>Analyzed by Jessie Glaeser, Research Plant Pathologist at NRS.