Reusing Remediated CCA-Treated Wood

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Abstract: Options for recycling and reusing chromated-copper-arsenate-(CCA) treated material include dimensional lumber and round wood size reduction, composites, and remediation. Size reduction by remilling, shaving, or resawing CCA-treated wood reduces the volume of landfilled waste material and provides many options for reusing used treated wood. Manufacturing composite products from CCA-treated wood combined with untreated wood, plastic, or cement has been explored. Remediation strategies are numerous; chemical extraction, bioleaching, chelation, and liquefaction or a combination of these techniques has been successful at removing metals from treated wood to varying degrees. Bioremediation is a novel approach to recycling CCA-treated waste wood and provides an opportunity to reuse this abundant fiber source in value-added composite products. In this method, oxalic acid extraction and bioleaching with a metal-tolerant bacterium have successfully removed 70% copper, 81% arsenic, and 100% chromium from chipped CCA-treated Southern Pine. The two-step sequence of acid extraction followed by bioleaching removed more metals than either acid extraction or bioleaching alone. Reversing the sequence and bioleaching prior to acid extraction was also not as effective at metal removal. Metals that are released from CCA-treated wood during biomediation are recoverable from a liquid medium and available for reuse or disposal. The "cleaned" wood particles were reassembled into medium-density particleboard prepared with urea-formaldehyde resin and evaluated for physical properties, such as internal bond strength, modulus of elasticity, modulus of rupture, thickness swell, and water absorption. Bioremediation removes 80% to 100% of the heavy metals from spent CCA-treated wood enabling the wood fiber to be reused in composite products. However, as long as CCA-treated wood can be disposed in landfills, economics will remain unfavorable for wide acceptance of alternative reuse and remediation options.
Keywords: Remediation, bioleaching, recycling, chromated copper arsenate, treated wood

Introduction

Options for managing used CCA-treated wood are needed. The increase in demand for CCA-treated wood products since the preservative gained popularity in the early 1970s has resulted in an annual production of approximately 5×10^8 ft^3 (1.4×10^7 m^3) of this product (Micklewright 1994), with the primary use in residential decks. Figure 1 shows the volume of CCA-treated wood consumed annually in the United States from 1984 through 1997 (Micklewright 1998) and a projected consumption for 2001. Despite an impending ban on residential use of CCA in 2004, commercial applications of CCA-treated wood will continue. Large volumes of this material will be coming out of service for decades to come. Reusing used CCA-treated wood is one way to divert this sizable source of fiber and heavy metals from landfills. A number of options for reusing CCA-treated wood have been developed since the mid 1990s, but few have gained wide acceptance. Because chromium and arsenic are fixed to the lignin component of wood, CCA-treated wood is not classified as hazardous waste at the Federal level and is primarily disposed in landfills. Reuse options involving handling, transporting, or chemically processing treated material are not economically feasible compared with landfill disposal. Options that are suitable for remediating or reusing the next generation of copper-based wood preservatives will have an advantage over processes that are specific to one preservative, because new preservatives may face similar scrutiny when they begin to come out of service.

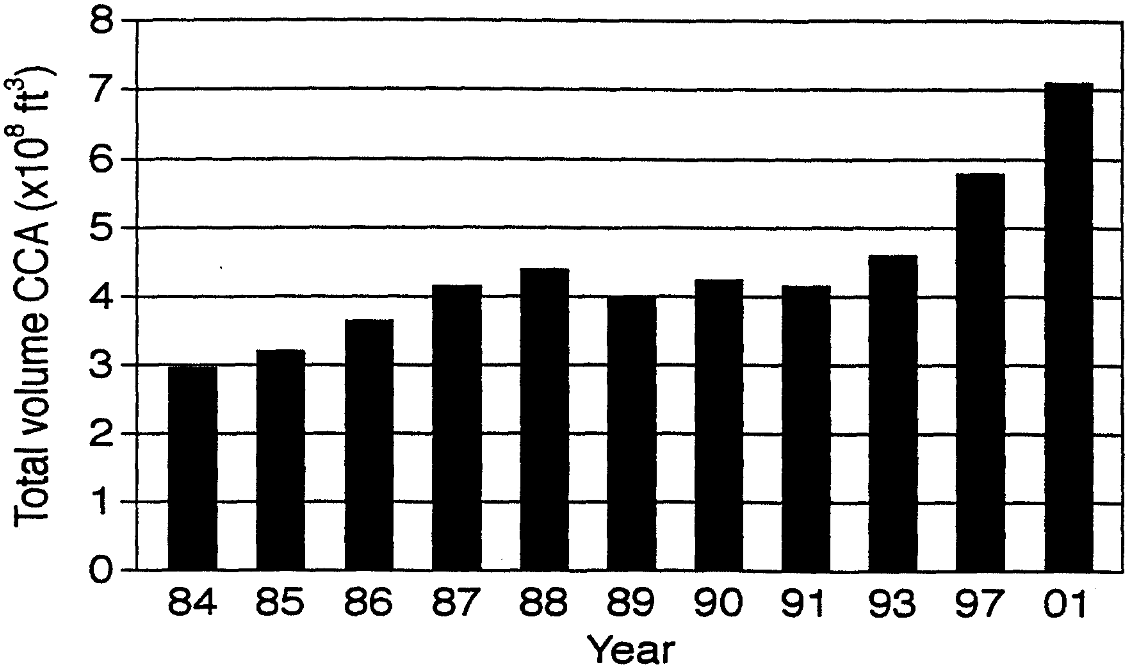

Figure 1. North American CCA consumption from 1984 to 1997 (Micklewright 1998) and projected consumption for 2001 (1 ft^3 = 0.03 m^3).

Regulatory questions, economics, and the perception that the material was once toxic have inhibited the development of a recycling industry for postconsumer CCA-treated wood (Clausen 2002; Felton and DeGroot 1996; Smith and Shiau 1998). Additionally, there are a number of mechanical, analytical, and logistical concerns associated with recycling or reusing CCA-treated wood. It is difficult to distinguish weathered CCA-treated wood from other types of treated and untreated weathered wood. This makes sorting and identifying CCA-treated wood difficult at best. However, two things are certain. First, most treated lumber acquired after 1980 would have been treated with inorganic arsenicals. Second, nearly all used CCA-treated wood consists of Southern Pine lumber or poles (DeGroot and Felton 1995). Solo-Gabriele and Townsend (2002) led an extensive program in the State of Florida on disposal pathways and techniques to sort, accurately identify, and differentiate CCA from other wood treatments in wood waste. Sorting techniques using chemical stains are effective in sorting CCA-treated wood on a small scale (a few tons or less). Laser and x-ray detection systems are cost-effective for facilities processing more than 8,000 tons of wood per year (Solo-Gabriele *et al.* 2001).

The Florida case study showed that CCA-treated waste wood was either landfilled, incinerated, or recycled as mulch, primarily colored mulch. A study conducted by Townsend and Solo-Gabriele (2001) revealed that two of three retail samples of colored mulch failed to meet regulatory guidelines for arsenic. Just as the impending ban on residential use of CCA was unexpected, reclassification of CCA-treated wood as a hazardous material could also become a reality for North America. European countries have already faced landfill restrictions and high tipping fees. Site-related environmental concerns already exist for landfilled CCA-treated material. Recycling this material would further raise concerns about air, water, and soil contamination at and surrounding recycling facilities, as well as concerns about exposure of workers to fine dust from any process involving size reduction of the material. Techniques currently used to reduce wood for composite production must meet air quality standards and control human exposure to untreated wood dust. Exposure to dust containing compounds in CCA-treated wood is regulated by the American Conference of Governmental Industrial Hygenists (ACGIH 1991) and Occupational Safety and Health Administration standards (OSHA 1989) (Table 1).

Table 1. Air health standards for human exposure to wood dust and compounds in CCA-treated wood (Felton and DeGroot 1996).

Component	8-hr. average (mg/m)
Wood dust	
Non-western redcedar	5.00
Western redcedar	2.50
CCA	
Copper	1.00
Chromium III	0.50
Chromium VI (soluble)	0.05
Chromium VI (insoluble)	0.05
Arsenic (soluble)	0.20
Arsenic (organic)	0.50
Arsenic (gas)	0.16

[a]Lowest time-weighted concentrations from ACGIH (1991) and OSHA (1989).

Figure 2 shows some options for disposing of or reusing CCA-treated wood. Options are divided into recycling options or nonrecycling options.

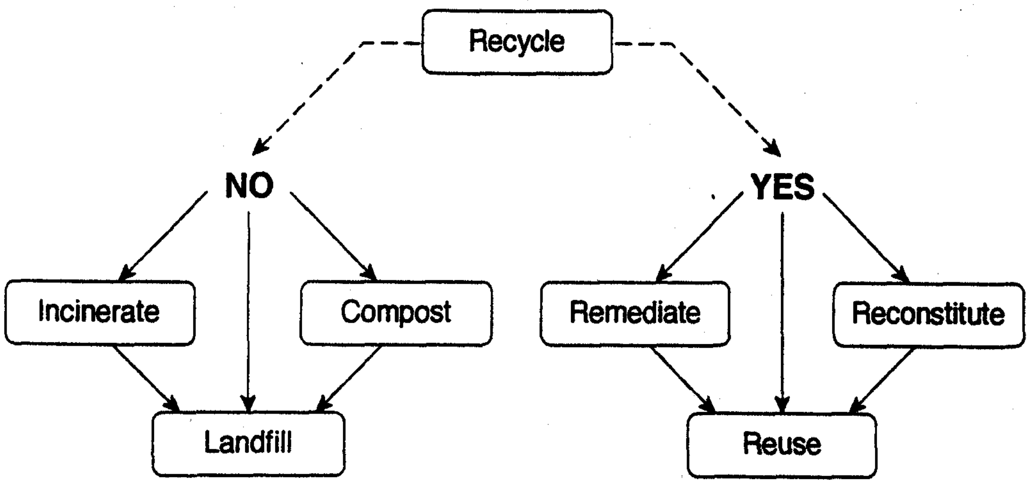

Figure 2. Options for disposing of or reusing CCA-treated wood.

Size Reduction

Treated poles and large timbers lend themselves to resawing or shaving because the heartwood of most species, including Southern Pine, is not penetrated by CCA during treatment. The untreated wood cores can be remilled into a variety of commodities, such as decking or value-added specialty products (Felton and DeGroot 1996).

Reconstituted Composites

The manufacture of reconstituted composites is an economically attractive recycling option for CCA-treated waste wood. However, preservative interference with adhesive bonding is a problem (Mengeloglu and Gardner 2000; Munson and Kamdem 1998; Vick *et al.* 1996). Vick (1995) and Vick *et al.* (1996) developed a hydroxymethylated resorcinol coupling agent to improve bondability of flakes from recycled Southern Pine lumber in flakeboard for siding, sheathing, and flooring for high decay-hazard applications, while Shupe and Hse (2001) evaluated the properties of flakeboard from recycled CCA-treated wood. Mengeloglu and Gardner (2000) also evaluated adhesives and CCA-treated Southern Pine flake types. They showed that the type and concentration of adhesive affected the physical properties (MOR and MOE) and internal bond strength. In both studies, the preservative treatment lowered physical properties below those of comparable flakeboard prepared from untreated flakes. Kamdem and Munson (1996) and Munson and Kamdem (1998) had greater success preparing reconstituted particleboard using CCA-treated red pine utility poles. In their first study, reconstituted particleboard made with either phenol-formaldehyde or urea-formaldehyde satisfied the American National Standards Institute (ANSI) (1993) for M-2 grade particleboard. In their second study, they showed that 50% CCA-treated red pine could be used to manufacture particleboard without significantly affecting particleboard properties.

Reconstituting CCA-treated fiber into cement-bonded Particleboard is a viable option for reusing CCA-treated wood. Schmidt et al. (1994) studied compatibility of CCA with cement mixtures. Their results suggested that CCA improves wood-cement composites compared with similar composites made from untreated wood. Wood-cement composites exhibit good resistance to rot, fire, and weather. This composite product also has the advantage of not needing drying or hot-pressing, and blender speed is low, reducing wood dust. Because of their good insulation and mechanical properties, cement-bonded composites are used widely in interior and exterior commercial and industrial building applications (Cooper et al. 1998; DeGroot and Felton 1995; Felton and DeGroot 1996; Goldstein 1997; Huang and Cooper 1999; Moslemi 1993; Qi and Cooper 2000).

Remediation

Economically removing CCA from waste treated wood could alleviate the possibility of environmental contamination, and the resulting “cleaned” wood fiber could be reused. The efficiency of any remediation process (i.e., metals remaining in wood following remediation) is measured by inductively coupled plasma emission spectroscopy according to the American Wood-Preservers’ Association standard method A21-00 (AWPA 1995) and compared with a matched sample of CCA-treated wood prior to the remediation process.

Chemical extraction

Chemical extraction with acids and oxides essentially reverses the CCA fixation process by increasing the solubility of the metals and seems to be a way to enable the removal of treatment chemicals. Kazi and Cooper (1999) showed that hydrogen peroxide at 122°F (50°C) for 6 hours oxidized 94% or more of the copper, chromium, and arsenic from CCA-treated sawdust. Previous studies on the chemical extraction of CCA have evaluated oxalic, citric, formic, nitric, sulfuric, and acetic acids (Clausen and Smith 1998; Cooper 1991, 1993; Kazi and Cooper 1998; Kim and Kim 1993; Pasek 1994; Pasek and McIntyre 1993; Stephan *et al.* 1993, 1996). Warner and Solomon (1990) reported that 100% of the copper was leached from CCA-treated wood with NaOH/citric acid buffer at pH 3.5 after 40 days of continual leaching.

Certain copper-tolerant wood decay fungi can readily decay wood that has been treated with CCA at levels intended to inhibit decay fungi (Illman and Highley 1996). These fungi are also known to produce large amounts of oxalic acid that convert chrome and arsenic salts into water-soluble oxalates and precipitate copper as insoluble copper oxalate (Clausen et al. 2000; Leithoff and Peek 1997). Stephan et al. (1996) examined the leachability of chromium and copper from chromium-copper-treated wood with oxalic acid at various concentrations. They showed that 98% of the chromium could be extracted at very low pH levels (0.69) but leachability declined quickly with an increase in pH. Minimal exposure of wood fiber to acids is desirable if fiber recovery is desired, because prolonged exposure to strong acid damages the fiber integrity by hydrolyzing carbohydrates. Clausen and Smith (1998) and Clausen (2000a) optimized chemical extraction of CCA-treated wood with oxalic acid to minimize the concentration of oxalic acid (0.8%, pH ~2.0) and the time of exposure to 18 hr to avoid damage to the fiber. This process served to augment bioleaching with a metal-tolerant bacterium (Clausen 2000a; Cole and Clausen 1997).

Bioleaching

The term bioremediation refers to using microorganisms to degrade or remove hazardous components of a waste from the environment (Dua *et al.* 2002; Glazer and Nikaido 1995). Bioleaching refers to the solubilization or dissolution of components from a material through the action of microorganisms. Together, these terms describe the process of microbial metal removal from CCA-treated wood without degradation of the wood fiber. This can be accomplished with the metal-tolerant bacterium, *Bacillus licheniformis* CC01. Several bacteria have been isolated with the ability to remove one or more components of CCA-treated wood (Clausen 2000b). Exposure of CCA-treated wood chips to *Bacillus lichenformis* CC01 removes 93% Cu and 45% As, but this organism is ineffective on chromium. A two-step remediation process, involving a combination of oxalic acid extraction and bioleaching with the metal-tolerant bacterium *Bacillus licheniformis* CC01, substantially reduces the amount of copper (90%), chromium (80%), and arsenic (100%) in CCA-treated wood (Clausen 2000a; Clausen and Smith 1998). The two-step bioremediation process was shown to be more effect than either oxalic acid extraction or bioleaching alone. Reversing the steps (i.e., bioleaching before oxalic acid extraction) was also not as effective at removing copper, chromium, and arsenic from CCA-treated wood. Bioremediated CCA-treated wood has been reassembled into medium-density particleboard (Clausen *et al.* 2001) and tested for physical properties. These tests showed an average 28% reduction in internal bond strength (IB), a 13% reduction in MOR and an 8% increase in MOE compared with particleboard samples prepared from virgin Southern Pine. Individual IB values for all specimens tested were above the ANSI standard for medium-density particleboard (ANSI 1993). It has also been shown that *Bacillus licheniformis* CC01 effectively removes copper from a number of copper-based wood preservatives, and bioleaching with this organism can be used to remediate wood treated with copper-based organic preservatives (Crawford and Clausen 1999).

Chelation

Kamdem et al. (1998) combined citric acid extraction with the metal chelating agent, ethylenediaminetetraacetic acid (EDTA) under controlled pH to remove 95% to 100% copper, chromium, and arsenic from red pine nominal 2 by 4 (standard 38- by 89-mm) dimensional lumber and sections of utility poles without substantial modification of sample size. EDTA has many applications as a chelating agent because it forms strong, stable water-soluble complexes with many metals. EDTA has been used to remediate CCA-treated wood chips and 40-mesh (0.420-mm openings) sawdust (Kartal 2002). Kartal found that 1% EDTA was able to remove greater amounts of copper, chromium, and arsenic from sawdust than from chipped wood, presumably because of increased surface area. The pH of EDTA solutions ranged from 2.2 to 3.2, which were acidic conditions and favored greater release of copper (93%) than the other metal components of CCA. Chelation may play an important role in remediating formulations of organometallic copper compounds and other waterborne wood preservatives containing copper.

Liquefaction

In this multistep remediation method, CCA-treated wood is liquefied with sulfuric acid in the presence of polyethylene glycol, glycerin, and heat. Unliquefied residue is sludged with acetone, complexing agents, and a precipitating agent with more than 85% efficiency (Lin and Hse 2002; Shiraishi and Hse 2000). The resulting liquefied wood can be used in the production of polyurethane products.

Conclusions

Table 2 summarizes the potential products from reused CCA-treated wood without regard to economic viability. As long as CCA-treated wood is not considered a hazardous material by the Environmental Protection Agency, disposal in landfills will take precedent over reuse of this sizable fiber source. Currently, landfill tipping fees for CCA-treated wood in the midwestern United States are approximately \$30/ton (\$33 per 1,000 kg). If increased restrictions on landfilling CCA-treated wood were imposed in the United States as they are in some foreign countries, landfilling costs could become prohibitive. Most of the recycling or reuse options described in this paper would be economically competitive only if landfill restrictions such as those seen in Europe were imposed domestically. Disposal fees for CCA-treated wood in special European landfills can cost \$300/ton (\$333 per 1,000 kg) due to these restrictions. A number of novel methods already developed for converting CCA-treated wood waste into tangible products would become economically attractive if landfill restrictions or front-end disposal fees are imposed on CCA-treated wood.

Table 2. Tangible products from reused CCA-treated wood arranged by method.

Method	Products
Size reduction	
Shaving, resawing, remilling	Decking, poles, posts
Reconstituted composites	
Wood–wood composites	Flakeboard, OSB[a], particleboard, MDF[a], glulam
Wood-cement composites	Sound barriers, structural forms
Thermoplastic composites	Specialty products
Remediation	
Chemical extraction, bioleaching, chelation	Composite products, paper products
Liquefaction	Polyurethane products

[a]OSB, oriented strandboard; MDF, medium-density fiberboard.

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