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Metals content of recycled construction and demolition wood before and after implementation of best management practices☆

Nicole M. Robey [a], Helena M. Solo-Gabriele [b,*], Athena S. Jones [b], Juniper Marini [b], Timothy G. Townsend [a]

[a] Department of Environmental Engineering Sciences, University of Florida, P.O. Box 116450, Gainesville, FL, 32611 – 6450, USA
[b] Department of Civil, Architectural and Environmental Engineering, University of Miami, P.O. Box 248294, Coral Gables, FL, 33146 – 0630, USA

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ABSTRACT

A limitation to recycling wood from construction and demolition (C&D) waste is contamination of metals from the inadvertent inclusion of preservative treated wood, in particular wood treated with chromated copper arsenate (CCA) and newer copper-based formulations. To minimize contamination many regions have developed best management practices (BMPs) for separating treated from untreated wood. The objective of this study was to evaluate the fraction of preservative treated wood in recycled C&D wood after the implementation of BMPs, using Florida as a case study. Methods involved collecting recycled C&D wood samples from throughout the state, measuring metals concentrations (As, Cu, and Cr) in the samples to compute the fraction of recycled wood treated with waterborne wood preservatives, and comparing measurements with those taken prior to the formalization of BMPs. Metals concentrations were measured using two methods, one based on traditional laboratory digestion methods and another using a more rapid hand-held X-ray Fluorescence (XRF) device in the field. The proportion of waterborne preservative-treated wood in recycled wood products has reduced significantly in the intervening 20 years (from 6% to 2.9%), and the fraction of CCA-treated wood has been reduced even further, to 1.4%. The remaining fraction of waterborne preservative-treated wood is comprised of new formulations of copper-based preservatives. This suggests that restrictions from the wood preservation industry and best management practices implemented at recycling facilities have been effective in reducing heavy metal contamination from pressure treated lumber in recycled wood products.

1. Introduction

Construction and demolition (C&D) debris makes up a substantial portion of the municipal solid waste (MSW) stream globally (Rodríguez et al., 2007; Zheng et al., 2017). The US Environmental Protection Agency (US EPA) found that in 2014, 484 million metric tons of C&D debris were generated in the US (US EPA, 2016). After road materials (asphalt and Portland cement concrete), which are produced in vast quantities during roadway demolition and repaving, wood products make up the largest fraction of C&D debris materials, or approximately 7% by mass (38.7 million tons annually) and 26.4% by volume. Wood used in outdoor construction applications is commonly treated with preservatives to prevent or delay decay caused by fungi or termites. Wood preservation methods are typically categorized by the nature of the chemicals used for treatment – either oilborne or waterborne. Oilborne preservatives include creosote and pentachlorophenol, and wood treated with these preservatives is typically used in specific industrial applications (e.g., railroad ties and utility poles). Waterborne preservatives (of which there are dozens of formulations) are used to treat a wider variety of wood products, including dimensional lumber and plywood, for both commercial and residential applications.

Until recently (from the 1970's until 2004) the most common waterborne wood preservative was chromated copper arsenate (CCA). Arsenic's toxic properties (WHO, 2011; ATSDR, 2017) and propensity to leach from CCA-treated wood (Khan et al., 2004, 2006; Townsend et al., 2004a, 2005; Shibata et al., 2006, 2007; Hasan et al., 2010) are well documented. Several studies focused on

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* Corresponding author.
E-mail addresses: nicolemr@ufl.edu (N.M. Robey), hmsolo@miami.edu (H.M. Solo-Gabriele), a.jones18@umiami.edu (A.S. Jones), jmarini1@med.miami.edu (J. Marini), ttown@ufl.edu (T.G. Townsend).

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the impacts from leached wood (Townsend et al., 2003; Hemond and Solo-Gabriele, 2004) and potential exposure to children during play activities on CCA-treated structures (Kwon et al., 2004; Shalat et al., 2006; Barraj et al., 2009; Lew et al., 2010). In 1996, Tolaymat et al. (2000) endeavored to determine the proportion of CCA-treated wood in recycled C&D wood in Florida. Results from these studies collectively contributed to industry-wide changes in pressure-treated lumber production and sales. In December 2003, manufacturers of the preservative chemicals used in CCA-treatment of lumber voluntarily phased-out sales to residential customers by ceasing the production of CCA-treated wood intended for residential applications. The EPA has never pursued a complete ban on the products, so CCA-treated wood is still used for some commercial and industrial applications. Arsenic-free copper-based formulas of waterborne preservatives have replaced much of the market previously occupied by CCA products (Vlosky, 2009; Solo-Gabriele et al., 2016). These alternative formulations include micronized copper quat (MCQ) and micronized copper azole (MCA).

While much of the wood portion of C&D debris is disposed of in a landfill (either a designated C&D debris landfill or a Resource Conservation and Recovery Act (RCRA) subtitle D MSW landfill), a significant portion may be ground and recycled either as landscaping mulch or fuel (Solo-Gabriele and Townsend, 1999; Jacobi et al., 2007a; Ormondroyd et al., 2016). Because of their prevalence and wide-ranging applications, wood products treated with waterborne preservatives are oftentimes more difficult to identify than oilborne preservative-treated wood products, and are therefore more likely to contaminate recycled C&D wood products (Blassino et al., 2002; Rasem Hasan et al., 2011). The EPA has ruled that pressure-treated lumber (specifically arsenated wood) is exempt from hazardous waste classification (US EPA, 1980), but clarified in 2004 that this exemption does not apply to wood recycled as mulch or burned as fuel (US EPA, 2004). The State of Florida highly encourages wood recyclers to implement BMPs through memorandums in 2002 (FDEP 2002) and ultimately through inclusion within its regulatory statutes in 2010 (HCSHWM, 2006; FDEP, 2010; Solo-Gabriele et al., 2017). Because of these federal and state regulations, recycling and biomass energy industries would benefit from knowledge about the proportion of recycled wood that is treated. They would also benefit from strategies that can be used to identify and remove treated wood.

C&D debris wood recycling facilities rely on source restriction (e.g., only accepting wood from pallet manufacturers), manual sorting using visual methods, and, possibly, X-ray fluorescence spectroscopy (XRF) technology to eliminate pressure-treated wood from their products (Jacobi et al., 2007b). The objective of the research described herein was to compare the fraction of waterborne preservative-treated wood within recycled C&D wood before and after the implementation of C&D debris recycling BMPs in Florida, over a time period of approximately 20 years. Measurements were made in the current study using both traditional laboratory methods and newer methods based upon XRF. The treated wood fractions were compared to previous work (Tolaymat et al., 2000) and the total concentrations of heavy metals of concern (i.e., arsenic and copper) were compared to Florida risk-based soil-screening thresholds for direct human contact. Comparisons were also made between analytical results obtained between XRF and traditional laboratory methods.

2. Methods

2.1. Approach

C&D debris wood was collected from seven C&D materials recycling facilities throughout the state of Florida. These samples were analyzed for total heavy metals concentration (specifically copper, chromium and arsenic) both in the field using XRF technology, and in the laboratory using a traditional digestion method followed by elemental analysis of the digestate. Total concentrations, coupled with retention rates in pressure treated wood products, were used to calculate the fraction of each sample comprised of CCA- or copper alternative-treated wood. These fractions were compared to previous findings (i.e., Tolaymat et al.'s field sample collection in 1996 and published in 2000) and a statistical analysis was performed to investigate resulting trends.

2.2. Sampling

At participating facilities, wood mulch was removed from a stockpile. Using clean shovels, ground C&D wood was placed onto a clean tarp (in order to reduce contamination from other sources) in 20 subsamples. Subsamples were then mixed thoroughly on the tarp and placed in a clean container covered, labeled, and sealed for transportation to the laboratory. Tolaymat et al. (2000) collected 18 samples from 12 facilities operating in Florida at the time. Since that time, and possibly due to previously described regulations and BMPs, there has been a reduction in the C&D wood recycling market, meaning substantially fewer facilities were in operation during the current study making it impossible to exactly replicate the sampling procedure of the previous study. For this study, 15 samples were collected from seven facilities. Details regarding the facilities, input materials, final products (either mulch, boiler fuel, or a combination of the two) and collection dates are included in Table 1. Notably, some facilities were visited more than once at time intervals of several months apart (Facilities II, IV, V).

2.3. Heavy metal analysis

Samples were processed according to Tolaymat et al. (2000). Ground C&D wood was size-reduced as necessary using pruning shears, then three representative subsamples of approximately 1200 g were removed from each sample container. These subsamples were dried in an oven at 100 °C for 24 h to determine the dry weight. The analytical method to determine metal concentration calls for 1-g samples; because of the heterogeneous nature of the wood mulch, and the relatively small proportion of pressure-treated wood, the samples were reduced to ash (removing volatile solids but conserving heavy metals) by muffle furnace ignition at 550 °C in order to analyze larger quantities of wood. Percent volatile solids were calculated using the mass of material before and after ignition. The wood ash samples were transferred to sterile glass jars with HDPE lids, and stored at 0 °C until they were digested using a combination of nitric acid, hydrogen peroxide and hydrochloric acid according to EPA Method 3050b (US EPA, 1996). Any residual solids in the digested samples were removed with 80-micron nominal pore-size paper filters, and the digestate was then analyzed by inductively coupled plasma atomic emission spectroscopy (ICP-AES) (Thermo Scientific iCAP 6200). The concentration of metals (mg of element per kg-dry wood) in the samples were calculated from the mass and proportions of moisture content and volatile solids. Detection limits of the ICP-AES instrument for the metals of interest were 0.004 mg kg^{-1} for arsenic and 0.002 mg kg^{-1} for chromium and copper.

2.4. XRF analysis

XRF uses X-ray radiation to extract electrons from atoms in a targeted sample, and then reads the wavelength and intensity of a secondary X-ray emitted by the target atoms to identify and