

Environmental Impacts of CCA-Treated Wood Within Florida, USA

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Abstract

Studies in Florida, USA, focusing on the environmental impacts of wood treated with chromated copper arsenate (CCA) were initiated because of elevated levels of arsenic and chromium encountered in ash from wood cogeneration plants within the State. During 1996 it was determined that these elevated levels were due to contamination of wood fuel with discarded CCA-treated wood. Since this time, a research team from the University of Miami and the University of Florida have been evaluating: a) disposal pathways for CCA-treated wood within the State, b) new disposal management strategies for CCA-treated wood, and c) impacts of CCA-treated wood during its in-service use.

In-service leaching was evaluated through two focused efforts. These efforts included a study that characterized metal concentrations in soils below 9 pre-existing decks (8 CCA treated and 1 not CCA treated) and a controlled field-scale experiment where 2 decks (one CCA treated and one untreated) were constructed over a leachate collection system. Immediately below the pre-existing decks the average soil arsenic concentration was 28.5 mg/kg. This was contrasted by a value of 1.5 mg/kg for the background samples. Arsenic concentrations in runoff collected from a CCA-treated deck ranged from 0.1 to 8.4 mg/L with 0.7 mg/L, on average. Arsenic in the runoff was predominately in the +5 valence; however, some As(III) was measured. Detectable amounts of arsenic were also measured in the infiltrated water below the sand supporting the decks. A larger fraction of As(III) was observed in the infiltrated water as compared to the runoff water.

Disposal pathways for CCA-treated wood within Florida include construction and demolition (C&D) debris landfills (which are generally unlined in Florida) and inadvertent mixing with mulch and wood fuel that is produced from recycled C&D wood. Leaching test results demonstrate that CCA-treated wood leaches enough arsenic to cause the wood to be a toxicity characteristic (TC) hazardous waste (if it were not otherwise exempted) and to pose a potential risk for contaminating

groundwater at unlined landfills. Samples collected from C&D debris facilities located in Florida indicate that CCA-treated wood represents 6% of the recycled wood on average with values as high as 30%, by weight, for some facilities. Contamination from CCA has been detected within some mulch samples purchased at retail stores within Florida, and these mulches exceed the State's guidelines for land application of recycled waste. When CCA-treated wood represents 5% or more of a recycled wood mixture, the ash from its combustion will typically be characterized as a TC hazardous waste. Results from chemical speciation analysis indicate that unburned wood leaches arsenic primarily in the +5 valence and chromium in the +3 valence. Chemical speciation of the ash however was much more variable with some samples showing significant amounts of As(III) and Cr(VI).

Ways to minimize the impacts of CCA-treated wood during disposal include options for waste minimization and disposal-end management. Waste minimization focuses on the use of alternative wood treatment preservatives that do not contain arsenic. Non-arsenic chemicals evaluated include ACQ, CBA, CC, and CDDC. These alternatives were shown to leach less arsenic but more copper than CCA-treated wood. Options for disposal-end management described in this study include sorting technologies to separate CCA-treated wood from other wood types. Sorting technologies evaluated included the use of a chemical stain and two systems based upon the use of lasers or x-rays. Chemical stains were found to be effective for sorting small quantities of CCA-treated wood. Both the laser and x-ray systems were shown to be very promising technologies for sorting large quantities of wood in a more automated fashion.

Keywords: CCA, arsenic, chromium, disposal, in-service use

BACKGROUND

The most common U.S. formulation for CCA is the "type C" formulation which is composed of 47.5% CrO₃, 18.5% CuO, and 34% As₂O₅ (AWPA 2001). The amount of CCA chemical added to wood depends upon the intended use of the treated wood product. Wood used for above ground applications is treated in the U.S. using a minimum of 4 kg of chemical per cubic meter of wood product (kg/m³). Utility poles are treated at 6.4 kg/m³ and wood used for pilings within marine environments is treated at 40 kg/m³. The CCA chemical typically imparts a green color to the wood. At low retention levels (4 kg/m³) the color is a very faint green whereas at high retention levels (40 kg/m³) the color is a strong olive green.

Chromated copper arsenate (CCA) was the most common wood treatment preservative utilized in the U.S. during the 1980s, 1990s, and early 2000's. A proposed phase-down for residential uses of CCA is scheduled to take effect at the end of 2003 (U.S. EPA 2002). This phase-down will result in an estimated 60 to 80% decrease in CCA-treated wood production. Due to the predominance of CCA-treated wood until recent times, the majority of outdoor wood structures currently in-service in the U.S. are treated with CCA and these structures will ultimately require disposal long into the future. Thus the impacts from CCA-treated wood will likely be experienced during in-service use and during disposal for many years to come.

IN-SERVICE LEACHING

In-service leaching of CCA-treated wood was evaluated by measuring soil metal concentrations below 9 pre-existing decks (8 CCA treated and 1 not CCA treated) and 2 decks (one CCA treated and one untreated) constructed over a leachate collection system. Only the results for arsenic are discussed below for brevity.

Results from Sampling Soils Below 9 Pre-Existing Decks

The soils below eight CCA-treated decks and one non-CCA-treated deck were sampled throughout Florida to evaluate the degree to which the decks impact the surrounding environment (Townsend et al. 2001a; Townsend et al. 2003a). Two sets of samples were collected: one set corresponded to core samples (roughly 8 inches deep below the center of each deck) and the second set corresponded to surface samples (upper 1 inch of soil) collected in a grid-like fashion below each deck. Between 8 to 9 surface soil samples were collected from below each deck, and between 8 to 9 control samples were collected at a short distance (3 to 10 meters) from each deck. Samples were analyzed for arsenic, copper, and chromium using standardized laboratory methods.

Results indicate that arsenic was detected in all surface soil samples collected from below the decks (figure 1). The arsenic concentrations for surface soils collected from underneath the CCA-treated decks ranged from 1.2 mg/kg to 217 mg/kg with an average of 28.5 mg/kg. The average arsenic concentration of the control samples was 1.5 mg/kg. The average arsenic concentrations for surface soils collected below all the CCA-treated decks were higher than the corresponding control samples at 95% confidence limits.

Results from the soil cores indicate that the maximum concentrations of arsenic were found within the first two inches of the soil within all cores collected. On average, elevated arsenic concentrations were observed within the cores down to a depth of roughly 8 inches.

Results from 2 Decks Constructed Over a Leachate Collection System

Two decks, one made of CCA-treated wood and the other made of untreated wood, were constructed over two separate leachate collection systems. The decks were 2 meters by 2 meters in surface area and were housed inside a 2.4 meter by 2.4 meter untreated wooden enclosure containing 0.7 m depth of sand. The leachate collection system for each deck consisted of two parts: the first was a gutter system designed to collect direct runoff from the decks. The second was designed to collect infiltrated water from below 0.7 m depth of sand (figure 2). Samples have been collected from the leachate collection system since September 2002. Results to date indicate that the concentration of arsenic in the runoff from the CCA-treated deck was 0.73 mg/L, on average (0.1 to 8.4 mg/L range, n = 43), whereas for the untreated deck the concentrations consistently measured near 0.002 mg/L. The primary arsenic species observed in the runoff was As(V), although low levels of As(III) were detected in particular during times when total arsenic concentrations were elevated (Figure 3) (Khan 2003). The arsenic concentrations of the infiltrated water collected below the CCA-treated deck generally increased from 2 to 3 ug/L at the beginning of the monitoring period to 18 ug/L after 1 year of monitoring (Figure 5). The initial arsenic concentrations are consistent with the concentrations observed from the untreated deck. For the untreated deck, infiltrated water arsenic concentrations were roughly constant between 2 to 3 ug/L. Both As(V) and As(III) were observed in the infiltrated water collected from below the CCA-treated deck, with As(V) predominating. The proportion of As(III) to As(V) was larger for the infiltrated water relative to the runoff water. Possible reasons for the higher proportion of As(III) in the infiltrated water may be due to preferential infiltration of As(III) or due to the conversion of As(V) to As(III) within the sand.

DISPOSAL PATHWAYS (A Florida Case Study)

The primary disposal pathway for CCA-treated wood in Florida is through the construction and demolition waste stream. The wood processed at these facilities is ultimately disposed through one of three methods: within construction and demolition (C&D) landfills, recycled as wood fuel, or

recycled as mulch. Testing of recycled wood piles throughout Florida has found that the fraction of CCA-treated wood within these piles appears to be increasing in more recent years. In 1996, C&D wood waste was found to have 6% CCA-treated wood, on average, for 12 facilities evaluated (Tolaymat et al. 2000). In 1996, an evaluation of wood waste at three C&D facilities found that the wood waste piles were composed of 9 to 30% CCA-treated wood (Blassino et al. 2002). Of interest, is the fact that 2 of the 3 C&D facilities visited in 1999 practiced visual sorting of treated wood from the remainder of the wood waste stream. Visual sorting was accomplished at these facilities by noting the green hue of the wood. The fact that these two facilities used visual sorting methods indicates that this method although helpful in removing some CCA, is not capable of removing enough of the CCA-treated wood for recycling purposes.

Disposal within C&D landfills

In Florida, C&D landfills are generally unlined, and research has shown that CCA-treated wood does exceed Florida Department of Environmental Protection (FDEP) guidelines for leaching (Townsend et al. 2001a). These guidelines are based upon two tests, the Synthetic Precipitation Leaching Procedure (SPLP) and the Toxicity Characteristics Leaching Procedure (TCLP). These tests involve the addition of a waste material to a leaching fluid and contacting the waste with the fluid for a period of 18 hours. The metal concentrations in the leachates are then measured at the end of the test. If the concentration of a given metal exceeds a set level, then the waste fails that particular test. In general, SPLP is used to evaluate whether a waste can be land applied or disposed in an unlined landfill. The TCLP test is used to evaluate whether the waste can be disposed in a lined landfill. Results have shown that CCA-treated wood consistently fails guidelines based on the SPLP test (Figure 5) and will on occasion fail guidelines based on the TCLP results. Failures were more frequent when the samples were ground to finer particle sizes. The primary arsenic species observed in the leachates were inorganic As(V) and As(III). More As(III) was observed in leachates from weathered CCA-treated than from unweathered wood (Khan 2003).

Results from a series of paired lysimeters (each pair containing one lysimeter that contained CCA-treated wood and another that contained only untreated wood), suggest that arsenic concentrations in leachates from a CCA-treated wood monofill would result in arsenic concentrations on the order of 50 mg/L, requiring disposal of that leachate as a hazardous waste (Jambeck et al. 2003). Concentrations from the C&D and Municipal Solid Waste (MSW) lysimeters were on the order of a few mg/L.

Groundwater samples were collected from the vicinity of C&D landfills within Florida. Both inorganic As(III), As(V), and the organic methylated forms of arsenic were observed (Khan 2003). It was not clear whether or not the arsenic concentrations detected in the groundwater samples was due to the waste within the C&D landfills (Solo-Gabriele et al. 2003a).

Recycling as Wood Fuel

CCA-treated wood within wood fuel is of concern due to potential air emissions, in particular arsenic, during the incineration process and due to the accumulation of metals within the ash. During 1996, CCA-treated wood was identified as the cause of elevated arsenic and chromium concentrations in the ash from wood cogeneration facilities located in Florida (Solo-Gabriele and Townsend 1999). Subsequent studies to characterize CCA-treated wood ash indicate that all ash samples made entirely from CCA-treated wood failed TCLP regulatory levels and would thus be considered a hazardous waste. It was also found that a mixture of 95% untreated wood with 5% CCA-treated wood (0.25 pcf) would cause the ash to fail on some occasions. Therefore, if the goal is to generate an ash that is considered non-hazardous, the proportion of CCA-treated wood within the wood fuel mix should be less than 5% (Solo-Gabriele et al. 2001b).

Metals speciation of the ash from CCA-treated wood showed that chromium in the CCA-treated wood is converted from Cr(III) to the more mobile and toxic Cr(VI) form during the incineration process. This conversion is strongly a function of pH with samples characterized by more alkaline pH values showing a greater conversion of chromium towards the hexavalent form. Such results question whether or not CCA-treated wood should be incinerated during disposal.

Recycling as Mulch

Given that the cause of elevated levels of metals within wood ash from cogeneration facilities was caused by the presence of CCA-treated wood, these facilities have, in general since 1996, developed more stringent guidelines for the types of wood waste accepted and have thus limited their use of recycled C&D wood waste. As a consequence there has been a recent increase in the use of C&D wood waste within the mulch industry, primarily for the production of colored mulch. Given the high probability of such wood to be contaminated with CCA, the production of mulch from recycled C&D wood waste serves as a mechanism by which CCA-treated wood is being land applied throughout the State of Florida, thereby increasing the potential for contaminating the environment with arsenic, chromium, and copper. A preliminary study conducted by Townsend et al., 2003b, found that among 3 samples of colored mulch purchased at retail establishments, 2 failed regulatory guidelines for arsenic, whereas the 3 controls made of vegetative wood were all negative for arsenic leaching. A follow-up study that is currently on-going has focused on the analysis of over 90 mulch samples purchased from retail stores. To date, the analysis of 20 samples has been completed. Of the 20 samples, 13 were red colored mulch samples and 7 were not colored (Table 1). Among the non-colored samples, one contained elevated concentrations for arsenic, chromium, and copper. Among the red colored samples, 6 or almost half of the samples contained elevated concentrations of the CCA chemicals.

POSSIBLE SOLUTIONS

Disposal alternatives should be developed and implemented, given that the current disposal methods for CCA-treated wood are undesirable due to their potential for dispersing the CCA chemical into the environment. Alternatives can take the form of waste minimization and/or new disposal-end management strategies.

Waste Minimization Through the Use of Wood Treated with Alternative Chemicals

Waste minimization is a process by which the amount of CCA-treated wood ultimately disposed is reduced. One waste minimization strategy is to encourage consumers to buy alternatives to CCA-treated wood. Wood has many positive structural qualities including a high strength to weight ratio and ease of machining. Wood is also a relatively inexpensive building material. However, it does degrade when subject to insect and fungal attack and it is thus necessary to treat the wood when used in the outdoor environment.

Several alternative wood preservatives have been used commercially and standardized by the American Wood Preservers' Association, the standards writing agency for the wood treatment industry. The preservatives that have been found to be the most promising for residential home use are: alkaline copper quat (ACQ), copper boron azole (CBA), copper citrate (CC), and copper diethyldithiocarbamate (CDDC) (Solo-Gabriele et al. 2000). These alternative chemicals have been standardized for above ground and ground contact applications. They are considered to be just as effective as CCA for these applications. These alternatives have the advantage from an environmental perspective in that they do not contain arsenic. As such, these alternatives do not leach arsenic into the environment. Data (Townsend et al. 2001b) indicate that these alternatives do leach

more copper than CCA (Figure 6). From a regulatory perspective, alternative-chemical treated wood poses a lower risk than CCA-treated wood within the disposal sector and within terrestrial environments. Slightly higher risks are associated with alternative-chemical treated wood products used in aquatic environments due to the toxicity of copper to aquatic organisms. The use of the alternatives is not recommended within highly sensitive aquatic environments in areas characterized by limited flushing.

Alternative Disposal-End Management Options

Given that problems associated with the disposal of CCA-treated wood emerged as an ash contamination problem, early research through our research team focused on evaluating methods to extract chromium, copper, and arsenic from CCA-treated wood ash for remediation purposes. The thought was that as long as air emissions could be controlled, incinerating the wood would serve to greatly reduce the volume of the CCA waste and would concentrate the metals. These metals are considered valuable, and in an ideal scenario it would be beneficial to recycle these metals back into the wood treatment process. A series of solvent extraction experiments were conducted (Solo-Gabriele et al. 2001b), which found that nitric acid was capable of removing between 70 and 100% of the copper, between 20 and 60% of the chromium, and 60 to 100% of the arsenic for samples characterized by low retention levels. It was also found that citric acid was particularly effective at removing arsenic (between 40 to 100%) for ash samples produced from wood containing low CCA retention levels. Recycling the extracted metals into a form that can be used for CCA treatment, however, requires a considerable amount of additional research due to the fact that the metals extracted must be converted to their proper valence before reuse. Such additional processing adds to the cost of recycling which are not considered economically feasible at this time, in particular in comparison with the costs for landfilling the discarded wood.

In the absence of a good ash treatment technology, it would thus be important to assure that wood fuel (and also mulch) is free from CCA if recycling of wood waste is to continue. One option to assure clean wood waste is to develop sorting technologies for CCA-treated wood. Sorting technologies are necessary, in particular for lumber and timbers, given that CCA treatment within these products is difficult to identify through visual examination. Three different sorting technologies were evaluated and included: a chemical stain, a detection system based upon the use of lasers, and a detection system based upon the use of x-rays. The chemical stains are based upon the reaction of PAN indicator solution with the CCA. When sprayed on untreated wood, the PAN indicator produces an orange color on wood. In the presence of CCA, PAN indicator produces a magenta color. Experimentation with these stains in the field (Blassino et al. 2002) has shown that the stains are effective for sorting small quantities of wood (less than a few tons) and are good for spot-checking wood waste quality. However, when much larger quantities of wood are to be sorted, the use of chemical stains was found to not be cost effective due to excessive labor costs. For such situations more automated methods, such as the laser and x-ray detection systems, should be employed. Results of testing the laser and x-ray (XRF, x-ray fluorescence) systems indicate that both technologies can easily detect the presence of CCA within treated wood (Solo-Gabriele et al. 2003b). Of special note is that the x-ray system evaluated was capable of identifying the presence of CCA, even when the wood was wet or painted (Figure 7). The technologies are considered cost effective for facilities that process more than 8,000 tons of wood per year (Solo-Gabriele et al. 2001a).

CONCLUSIONS AND RECOMMENDATIONS

CCA-treated structures leach arsenic into the environment. In Florida, the arsenic concentration observed in soils located below pre-existing decks was 28.5 mg/kg, which is over an order-of-magnitude greater than background concentrations. The below-deck concentrations are elevated to the point that they exceed Florida's risk-based soil guidelines (a.k.a. soil cleanup target levels), which suggest that the soils may pose a risk to human health and the environment. Such risks should be evaluated further.

Results from the 2 decks constructed over leachate collection systems indicate that the arsenic concentrations in direct runoff from CCA-treated wood are on the order of mg/L. These are considered high relative to background concentrations in Florida's waters (e.g. background concentration of arsenic in Florida's groundwater is approximately 0.002 mg/L, Focazio et al. 1999). The data further indicate that metals do migrate through soil once released by runoff. Much of these metals can be sorbed by the soil matrix but over time it is possible that the sorption capacity of these soils is exceeded so that impacts to groundwater can occur. This is a particular concern due to the shallow depth to groundwater drinking water supplies within some parts of the State. Work should focus on evaluating the sorption capacity of different soil types and possible risks to Florida's groundwater resources.

The potential use of alternative wood preservatives should be promoted as a potential substitute for CCA, as a means of minimizing the CCA waste. Prior to the adoption of these alternatives, reasonable assurances should be provided that these alternatives are less harmful to humans and the environment than the chemicals found in CCA. Given that the alternatives do not contain arsenic, a highly toxic metal, it appears that these alternatives will likely represent a lower human health threat than CCA. It would be useful to further evaluate the human health risks associated with the organic co-biocides associated with the alternatives.

The effects of waste minimization efforts will be observed in the disposal stream in the long term, after the typical service life of CCA-treated wood products, which varies between 10 to 40 years. Regardless of waste minimization efforts, improved disposal-end management practices will play a key role in minimizing the impacts of CCA-treated wood upon disposal within the short term (10 to 40 years) due to the large inventory of CCA-treated wood that is currently in service in the U.S. Promising new disposal strategies have been identified to automate the process of sorting CCA-treated wood from untreated wood within the disposal stream. Such technologies should be explored further and potentially implemented at full-scale operation to validate and fine-tune the sorting process.

Once CCA-treated wood is sorted out from untreated wood, the untreated wood can then be marketed for wood fuel and mulch, as long as reasonable assurances are provided that the material is free of CCA. The CCA treated portion of the wood waste must ultimately be disposed. Currently, the most economical disposal strategy for CCA in the U.S. is disposal within lined landfills. Nevertheless, efforts should focus on finding other means for the ultimate disposal of CCA. One promising alternative identified earlier was the use of CCA-treated wood within wood cement composites (Moslemi 1988, Schmidt et al. 1994, Felton and Degroot 1996). CCA-treated wood has the advantage over untreated wood in that it provides for a stronger bond between the wood and cement due to the presence of chromium, which increases the strength of the wood cement composite. Originally it was believed that the CCA chemical could encapsulate the CCA chemical. However recent work by Cooper et al. (2003) has shown that the alkaline nature of concrete results in the

conversion of some of the chromium from the +3 valence to the +6 valence, a more mobile and toxic form. The conversion to hexavalent chromium thereby represents a major disadvantage to recycling CCA-treated wood into wood-cement composite materials.

Other ultimate disposal options for CCA-treated wood include possibly incineration or disposal within dedicated wood monofill landfills. Disposal through incineration has a major disadvantage due to the conversion of chromium from Cr(III) to Cr(VI) during the incineration process. The production of a more toxic form of chromium, in addition to limited recycling options for extracted metals in the ash, represents a major disadvantage to this form of recycling. The high concentrations of metals anticipated in leachates from wood monofills would result in high costs for CCA-treated wood disposal within dedicated monofills due to the production of a hazardous leachate.

Given the higher costs associated with alternative disposal options (Clausen 2003), the primary option for the ultimate disposal of CCA-treated wood remains through Municipal Solid Waste (MSW) landfills. The cost for disposal within MSW landfills in Florida is approximately \$50/ton. As long as disposal within MSW landfills is allowed, it would be difficult for other innovative disposal and recycling technologies to compete with this relatively low-cost disposal option. Furthermore, the availability of MSW landfills throughout the State make this form of disposal practical from a transportation point-of-view. Concerns have been raised nevertheless about the impacts of CCA-treated wood on leachate quality within MSW landfills. Due to these concerns, some MSW landfills in Florida charge surcharge fees or will not accept loads known to contain CCA-treated wood. These landfills are in the minority in Florida, and it appears that for the current time, the disposal of CCA-treated wood within MSW landfills is the most economical and practical option for the State. However, it is believed that the MSW landfills within the State may not have enough dilution capacity to absorb all of the CCA-treated wood that will be discarded. There may be a time in the future where the quantities disposed will adversely impact leachate quality to the point that this form of disposal may no longer be feasible. As a result, more research is needed to identify disposal pathways for CCA-treated wood within communities throughout Florida and the rest of the U.S., especially since the disposal problems found in Florida are likely occurring in other parts of the country.

ACKNOWLEDGMENTS

Funding for the research presented in this manuscript was received from several different agencies including the Florida Center for Solid and Hazardous Waste Management, Sarasota County through the Florida Department of Environmental Protection Innovative Recycling Grants Program and through the National Institutes of Environmental Health Sciences (Grant No. S11 ES11181). The authors gratefully acknowledge the contributions of the numerous students from the University of Miami, University of Florida, and Florida International University.

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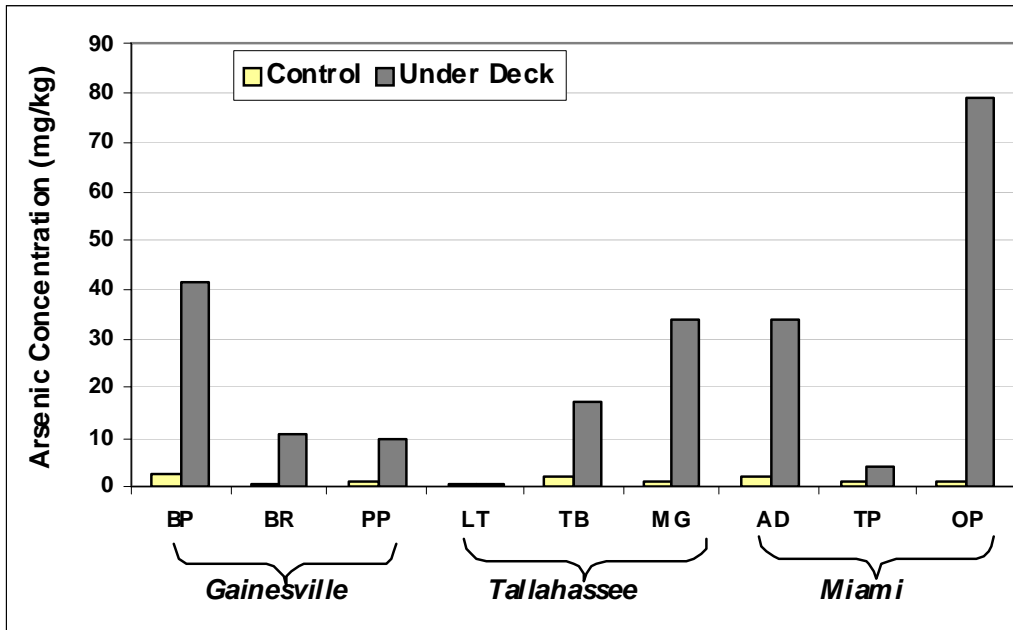


Figure 1: Comparison of Mean Arsenic Soil Concentration Below Wooden Decks Versus Background Soil Concentrations. Deck LT was the only deck that was not CCA treated.

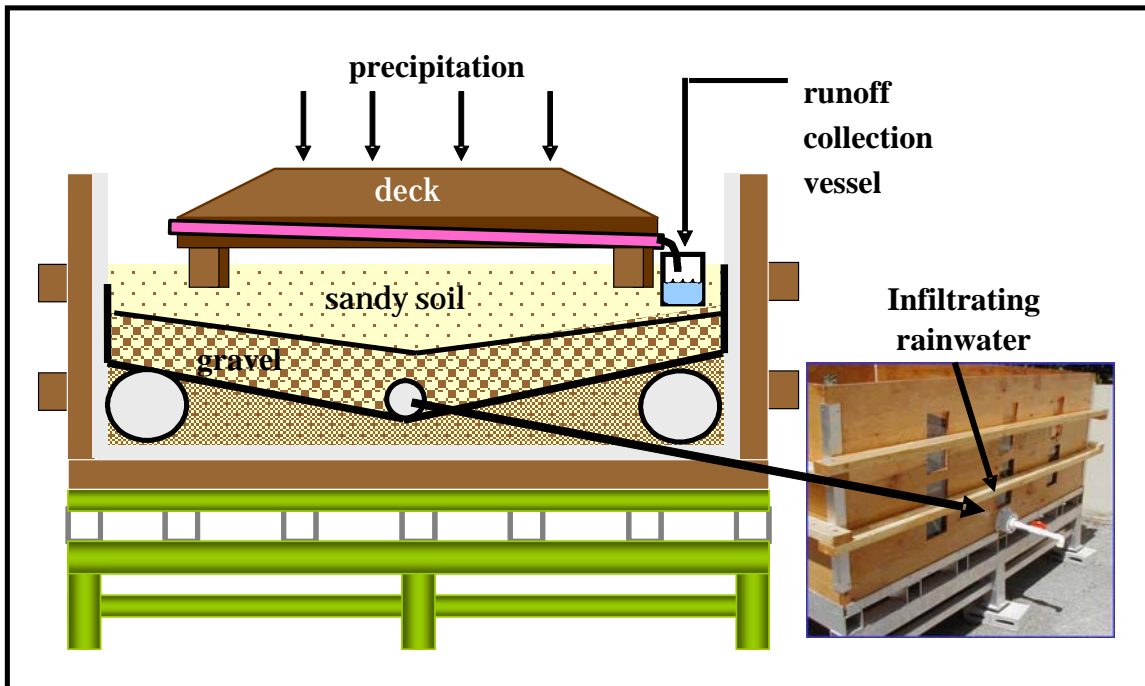


Figure 2: Configuration of Decks Designed to Capture Runoff and Infiltrated Water

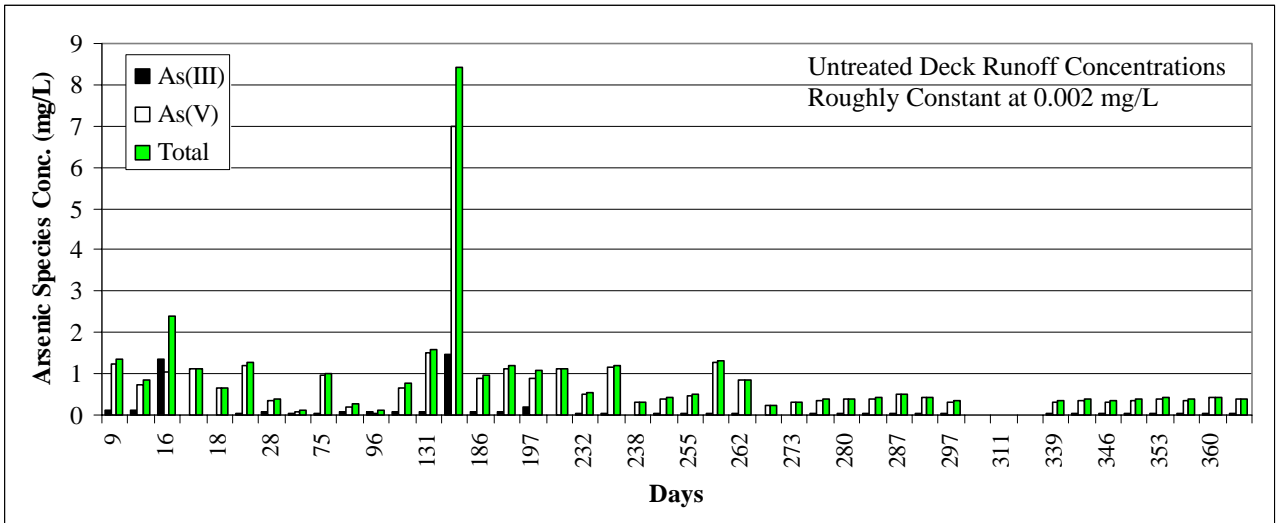


Figure 3: Arsenic Concentrations in Runoff Water from the CCA-Treated Deck

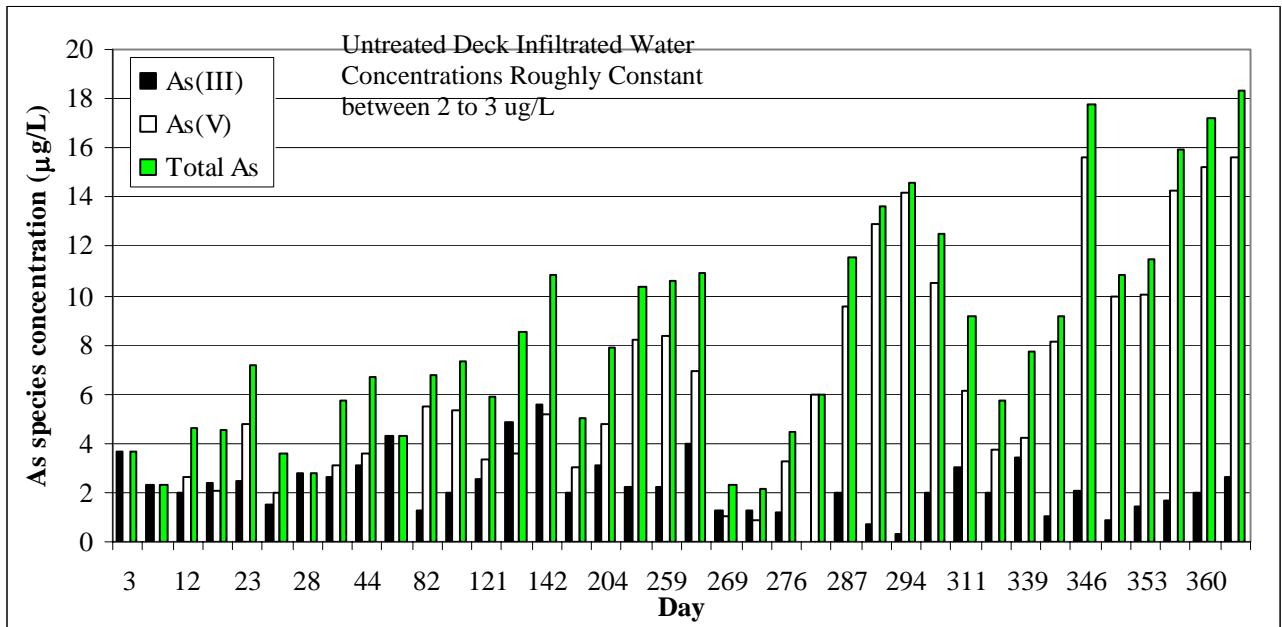


Figure 4: Arsenic Concentrations in Infiltrated Water Collected Below 0.7 m Sand from the CCA-Treated Wood Deck

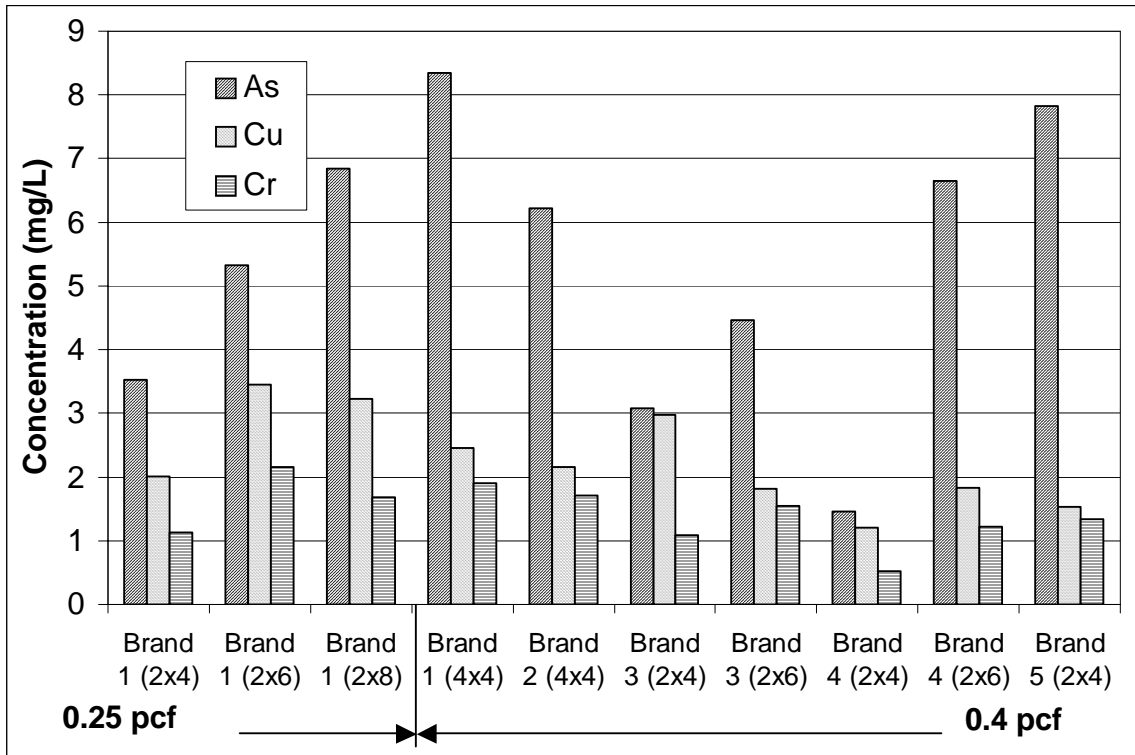


Figure 5: SPLP Extraction Results for As, Cu, and Cr from Sawdust (SPLP Regulatory Guideline for Arsenic is 0.05 mg/L)

Sample #	Color	Plywood	Cu (mg/kg)	Cr (mg/kg)	As (mg/kg)
17	None	No	1	0	0
18	None	No	1	0	0
19	None	No	3	0	0
20	None	No	3	1	0
26	None	No	14	24	19
32	None	No	1	1	0
34	None	No	1	0	0
1	Red	Yes	2	1	0
2	Red	No	2	2	0
3	Red	No	3	5	0
4	Red	Yes	106	129	118
5	Red	No	2	3	0
6	Red	Yes	71	111	69
7	Red	Yes	106	123	68
10	Red	Yes	212	458	196
13	Red	Yes	144	358	150
14	Red	Yes	93	182	112
15	Red	No	2	2	0
24	Red	No	2	1	0
33	Red	No	3	2	0

Table 1: Results to Date for Commercial Mulch Study

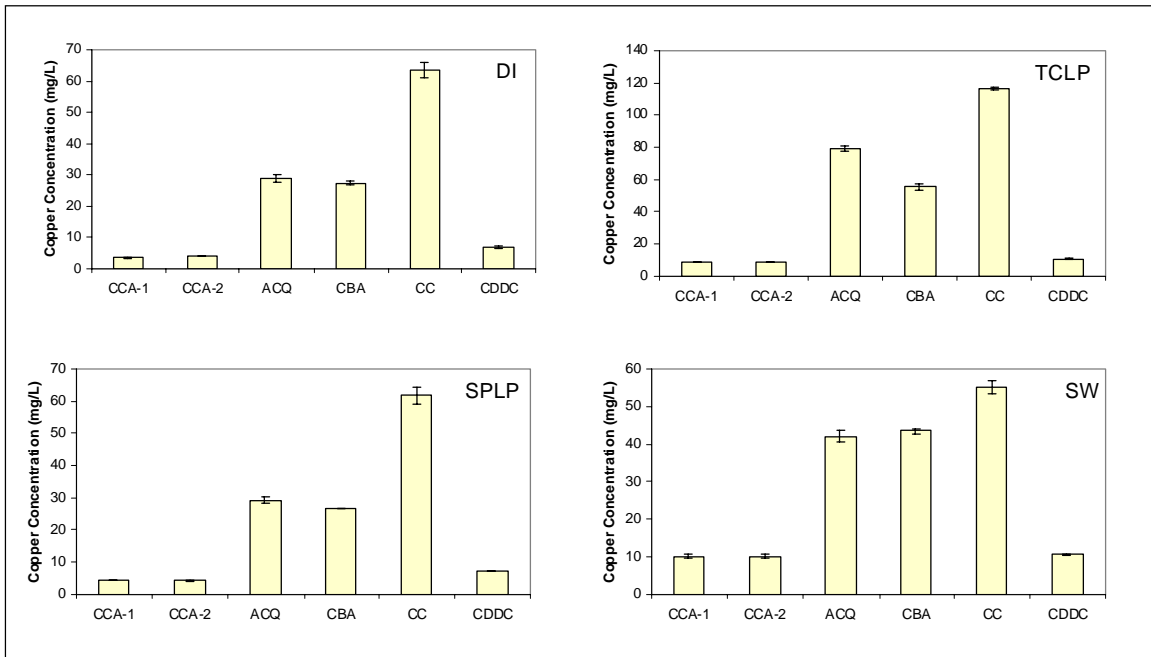


Figure 6: Copper Concentrations found in De-ionized water (DI), TCLP, SPLP and Saltwater (SW) Leaching Fluids

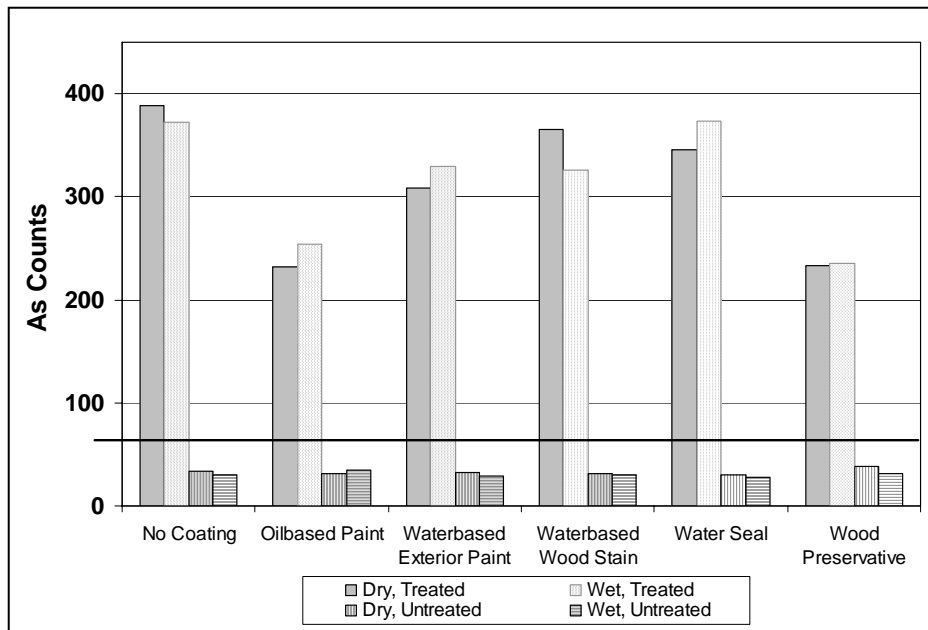


Figure 7: Arsenic Counts using the XRF System for CCA-Treated and Untreated Wood (Wet and Dry Conditions, and wood with various surface coatings)