

## **Leachable and Dislodgeable Arsenic and Chromium from In-Service CCA-Treated Wood**

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### **ABSTRACT**

Leachable and dislodgeable arsenic and chromium from CCA (chromated copper arsenate)-treated wood were studied to evaluate the fate of these CCA-chemicals and possible human exposures when the chemicals have been released to the environment. To evaluate the leachable component, two full sized decks were constructed. One was made of CCA-treated wood, and the other was made of untreated wood. Rainfall, runoff water from the top surface of the deck, and infiltrated water through 70 cm of soil below the deck had been monitored for 408 days. Soil below the decks was collected 6 months and 13 months after deck installation. The results of the deck monitoring showed that a significant portion of arsenic could be leached to environment during the service life of the CCA-treated wood product when exposed to rainfall. During the monitoring period, the average concentration in the runoff water from the CCA-treated deck was 1,000 ug/L for arsenic and 99 ug/L for chromium. Release of these metals to the surface soil was also observed. The surface arsenic concentrations increased from 4.5 mg/kg for the 6 month soil sample to 11.5 mg/kg for the 13 month sample. The impacts of the releases were also observed in the infiltrated water samples collected

from below the experimental decks. The arsenic concentrations below the CCA-treated deck increased from a background level of 2 ug/L to 20 ug/L during the 408 day monitoring period; the chromium concentrations were more consistent at concentrations typically between 3 to 4 ug/L.

The dislodgeable components from CCA-treated wood were quantified through wipe tests, which were designed to evaluate the effects of different wood retention levels, sapwood versus heartwood, repetitive wipes, and long-term weathering. This part of the study demonstrated that significantly larger amount of dislodged arsenic and chromium could be removed from higher retention CCA-treated wood. The average mass of dislodged arsenic from the 40 kg/m<sup>3</sup> CCA-treated wood sample was 1200 ug/wipe, and 74 ug/wipe for the 4 kg/m<sup>3</sup> CCA-treated wood sample. The amount of dislodged arsenic and chromium from the sapwood side of CCA-treated wood was larger than from the heartwood side, and these differences were significant for the first repetition of wipe samples collected. Furthermore, the amount of dislodged arsenic and chromium significantly decreased as the number of consecutive sets of wipes increased on the same area. The average quantities of dislodged arsenic and chromium decreased from 6 months to the 12 month study period, however these averages were not statistically different.

Overall, this study confirmed that CCA-chemicals are released from the wood products through both leaching and dislodging. These releases result in environmental contamination, and may serve as a source of arsenic and chromium exposure for humans.

**Keywords;** leachable CCA, dislodgeable CCA, arsenic, chromium, and CCA-treated wood

## INTRODUCTION

CCA is a chemical mixture consisting of three metal/metalloid compounds (i.e. arsenic, chromium, and copper) registered for wood preservative uses. CCA is the most common wood preservative utilized in the US, representing over 75% of the wood preservation market since the 1970s (Micklewright 1998). During this time, CCA has been used to treat lumber used for decks, playgrounds, docks, and other outdoor uses. Arsenic, one of the element contained within CCA, is well known for its toxic nature and its toxicity depends upon its chemical form (WHO 1996).

Earlier studies have shown that a significant portion of the CCA chemicals could be leached into the environment during the service life of the treated wood products when exposed to rainfall and low pH solutions (Warner and Solomon 1990; Cooper, 1991). Other studies have shown that the surface soils below CCA-treated wood decks can become contaminated with arsenic. For example, an average of 76 mg/kg (3 ~ 305 mg/kg) of arsenic in soils was observed in Connecticut (Stilwell and Gorney 1997), and 28.5 mg/kg (1 ~ 217 mg/kg) in Florida (Townsend et al., 2001). Leachable arsenic from the CCA-treated wood increases arsenic soil concentrations under CCA-treated wood products, and may result in potential groundwater contamination. It has been noted that children are exposed to environmental chemicals, such as pesticides, and often in greater quantities than adults. In the case of many pesticides, a major route of exposure is non-dietary ingestion; significant correlations between the levels of pesticides on the hands of young children and in urine have been reported (Shalat 2001). A study reported that total urinary arsenic excretion was significantly increased in children living in a community with high levels of arsenic in soil compared with a community with low levels in soil (Binder et al. 1987). Studies have shown that arsenic can be dislodgeable by contacting or rubbing on the surface of CCA-treated wood (U.S. CPSC 1990). Therefore, these studies suggest that particularly young children could have potential exposure to leachable and dislodgeable arsenic through normal behavior on and around CCA-treated wood products.

Currently, the U.S.EPA is reassessing CCA as part of its ongoing re-registration program for older pesticides. On February 12, 2002, U.S.EPA Administrator Whitman announced a voluntary decision by the Industry to move away from consumer use of CCA-treated lumber by December 31,

2003, in favor of new alternative wood preservatives (U.S.EPA 2002). As of January 1, 2004, the U.S.EPA will not allow the new use of CCA to treat wood intended for most residential uses (U.S.EPA 2002). However, as of November 2003, the U.S. EPA had not yet recommended that consumers replace or remove existing structures made with CCA-treated wood or the soil surrounding those structures. Recommendations concerning existing playground equipment are pending an on-going study sponsored by the U.S. EPA and the U.S. Consumer Products Safety Commission.

The primary objective of this study was to obtain essential information on leachable and dislodgeable arsenic and chromium from CCA-treated wood. The intent was to incorporate these data into a contaminant transport model and a risk analysis for evaluating possible human exposures associated with CCA releases to the environment.

## MATERIALS AND METHODS

This study consisted of two sampling efforts. One focused on leachable arsenic and chromium, and the other focused on dislodgeable arsenic and chromium.

### Sample Collection

**Leachable arsenic and chromium:** Two decks (with a 3 m<sup>2</sup> top surface area of deck sitting on a 6 m<sup>2</sup> surface area of sand base) were installed to monitor leachable arsenic and chromium during in-service use of wood (Figure 1). One deck was constructed of CCA-treated wood retention level of 4 kg/m<sup>3</sup> (= 0.25 pcf) as indicated upon purchase of the wood. The other served as a control, and was constructed of untreated wood. The sand was from local rock mining activities in south Florida which is formed during the excavation of the local limerock within the area. The total bulk volume of soil below each deck was 4.2 m<sup>3</sup> soil (sand: porosity of 35%, soil particle density of 2,690 kg/m<sup>3</sup>), resulting in a depth of 0.7 m of soil. Sawdust samples were collected from each deck by drilling approximately 1.5 cm depth from the top deck boards, sideboards, and legs in order to confirm treatment with the CCA-chemicals, and to determine the initial concentration and retention level of the CCA-chemicals in the wood boards if initially positive for CCA chemicals. The results of sawdust analysis confirmed that all boards used for the untreated deck were not treated wood. For the CCA-treated deck, only the top surface boards were CCA-treated wood. The sideboards and legs were confirmed as ACQ (Alkaline Copper Quat)-treated wood. The concentrations of arsenic, chromium, and copper in the CCA-treated deck top boards were 1,460, 1,586, and 729 mg/kg respectively, with a resulting 3.2 kg/m<sup>3</sup> CCA retention level.



Figure 1: Deck used to evaluate leachable arsenic and chromium



Figure 2: Outdoor wipe stations to evaluate dislodgeable arsenic and chromium

*Water Sample Collection:* The two decks had been monitored for a 13-month period since September 7, 2002 through October 20, 2003 for a total of 408 days. Three types of water samples were collected from each deck: rainwater, runoff water from the deck surface, and infiltrated water through sand below the deck. The water samples from each deck were collected in 100 ml plastic bottles everyday for the first month and then twice a week (Monday and Thursday) thereafter. pH and oxygen reduction potential (ORP) was measured (525A, Orion Research Inc., Beverly, MA, USA) immediately after sample collection for all water samples collected from the two decks. All water samples, after being measured for pH, were acidified by adding 1 ml of 1:1 nitric acid (HNO<sub>3</sub>) and stored in a refrigerator until sample analysis. Rainfall depth and rainwater sample collection was facilitated through the use of a set of standard rain gages located 1.2 m above each deck. A total of 84 rainfall measurements resulting in 1,850 mm of rainfall were measured at the gage located above the CCA-treated deck. The mean rainfall measured at the gage above the untreated deck was statistically equivalent to the mean rainfall measured above the CCA-treated deck (alpha 0.05, p = 0.996) thus all subsequent computations requiring rainfall depth were based upon data collected at the rain gage located above the CCA-treated deck. Rainwater samples from each of the gages were collected from the first rainfall event for each month resulting in a total of 26 rainwater samples with 13 collected per deck.

The runoff water collection system consisted of a gutter that drained the lowermost board from each deck. The gutter was covered with a polyethylene liner to prevent rainfall from entering the gutter. Water from the gutter was collected in a plastic reservoir located below each deck. A total of 51 runoff samples were collected from the CCA-treated deck and 49 samples were collected from the untreated deck. The mean runoff water volumes collected from each deck were statistically the same (alpha = 0.05, p = 0.983) and the amount of runoff water collected was strongly correlated with rainfall (r = 0.855). Every runoff water sample collected from each deck was analyzed for arsenic and chromium with the exception of the samples collected during the last 5 months from the untreated deck. During the last 5 months, only the first runoff sample was analyzed due to the consistently low concentrations observed in the runoff from the untreated deck.

The infiltrated water was collected from below a 0.7 m sand layer. The drainage system below the sand layer consisted of a felt liner underlaid by gravel and an impervious liner which facilitated the drainage of the water towards a graduated plastic reservoir. The volume of water collected was measured directly from the graduated reservoir and infiltrated water samples were collected from the reservoirs during the pre-determined sampling intervals, which were consistent with the sampling intervals used for runoff water collection. The mean volumes of infiltrated water collected from each deck were statistically the same (alpha 0.05, p = 0.519). The amount of infiltrated water was strongly correlated with rainfall (r = 0.883) and runoff water volume (r = 0.871). A total of 98 infiltrated water samples were collected from the CCA-treated deck and 82 samples were collected from the untreated deck. All samples collected from below the CCA-treated deck were analyzed for arsenic and chromium and all samples collected during the first 5 months of monitoring were analyzed from the untreated deck. After the first 5 months only the first sample during each month from the untreated deck was analyzed for arsenic and chromium.

*Soil Sample Collection:* Sand samples from below each deck were collected using a 28.6 mm diameter unslotted stainless probe fitted with a pre-acid washed plastic liner (Forestry Supplier, Inc., Jackson, MS, USA). Samples were collected after six months and one year from the installation date of the decks. The collected sand samples were divided into 2.5 cm depth intervals, and kept in a Ziploc bags until analysis.

*Dislodgeable Arsenic and Chromium:* In order to study dislodgeable arsenic and chromium, wipe samples were collected from CCA-treated wood boards. The wiping device was 8 cm in diameter and weighed 1.1 kg, consistent with the device used by the U.S. Consumer Products Safety Commission (U.S. CPSC. 2003). Between samples, the device was covered with a new piece of parafilm and

polyester cloth (static reutilizing cloth, VWR International, West Chester, PA, USA). The wipe cloth and parafilm were fixed to the sampling device with a rubber band. In advance of wiping action, a surface area of 400 cm<sup>2</sup> (50 x 8 cm) on the wood sample was measured, and the area was marked using tape. The sampling device was moved by pulling the attached strings five times forward and backward (forward and backward counted as one stroke). The sampling device was rotated 90 degrees, and then another five strokes were applied. The wiped cloth was carefully removed from the sampling device and stored in a Ziploc bag until analysis.

Wipe samples were collected from three different sets of wood boards. These sets included a set that was kept inside the laboratory (4 kg/m<sup>3</sup> as indicated upon purchase of the wood), one that was placed outside (untreated, 4 kg/m<sup>3</sup> and 40 kg/m<sup>3</sup> as indicated upon purchase) (Figure 2), and another set consisting of preselected boards from the constructed decks as described above (i.e. untreated and the 3.2 kg/m<sup>3</sup> confirmed CCA-treated deck).

The wood boards were used to evaluate 4 different factors: the effects of wood retention level, sapwood versus heartwood, repetitive wipes, and long term weathering. The effect of retention level was evaluated on: a set of 3 unweathered wood boards, 1 untreated board, 1 CCA treated at 4 kg/m<sup>3</sup>, and 1 CCA treated at 40 kg/m<sup>3</sup>. Each board was separated into 6 sections, and 1 wipe sample was collected from each section for a total of 6 wipes per board. Only the sapwood portions of the boards were wiped (with the exception of the untreated board where 3 wipes were collected from the sapwood side and 3 wipes collected from the heartwood side of the board).

Efforts also focused on comparing the wipe data collected from the heartwood side of CCA-treated wood versus the sapwood side since CCA-retention, in general, is small within the heartwood side due to the higher density of the wood within this region (Figure 3). A total of 36 wipes were collected for comparison between the sapwood and heartwood portions of CCA-treated wood. Eighteen wipes were collected from an unweathered 4 kg/m<sup>3</sup> wood board which was separated into 6 wiping sections. Three sections corresponded to the sapwood side of the board and three corresponded to the heartwood side. Three wipes were collected from each section for a total of 18 wipes collected from the unweathered board (9 from the sapwood side and 9 from the heartwood side). The remaining 18 wipe samples were collected from 3 preselected boards from the CCA-treated decks described above. Two of these deck boards were heartwood and one deck board was sapwood. After a 6-month period of weathering, each of the deck boards was wiped 3 times for a total of 6 heartwood wipes and 3 sapwood wipes. The same procedure was followed after a 12-month period of weathering with another 9 wipes collected (6 heartwood wipes and 3 sapwood wipes). Untreated wood controls from an unweathered board and from the untreated wood deck were also carried through the analysis. Wipes collected from the unweathered wood boards were processed in duplicate by splitting the wipes into quarters, with 2 of the quarters per wipe analyzed separately.

The effects of repetitive wipes were evaluated on the same set of samples as used to evaluate the possible differences between heartwood and sapwood. Thus a total of 36 wipes were used for this analysis. Eighteen wipes were collected from 6 sections on the unweathered 4 kg/m<sup>3</sup> wood board and 18 were collected from 3 weathered deck boards (after 6 months and 12 months of weathering).



Given that each section was wiped consecutively 3 times, the effects of the first wipe could be compared to the second wipe and to the third wipe.

The effects of long-term weathering were evaluated by comparing the results from the deck samples described above, with the results corresponding to 6 months of weathering compared to the results after 12 months of weathering. A total of 9 wipes were available for the 6 month period and 9 wipes were available for the 12 month period. Wipes were also collected from untreated wood as controls.

Figure 3: Photograph of CCA-treated wood

## Metals Analysis

Sample matrices analyzed in this project included sawdust, water, soil, and wipes. Each sawdust and soil sample was split into 4 sub-samples. All subsamples were digested in hydrogen peroxide and hot acid according to U.S. EPA Method 3050B (U.S. EPA 1996). Two sub-samples were digested in nitric and hydrochloric acid (suitable for subsequent chromium and copper analyses), whereas only nitric acid was used in the remaining two subsamples (consistent with the requirements of the procedure for arsenic analyses). Once digested, sawdust digestates were analyzed for arsenic, chromium, and copper using an atomic absorption spectrometer (AA) using flame atomization (Perkin Elmer Model AA800, Wellesley, MA, USA) and soil digestates were analyzed using the same instrument except graphite furnace atomization was used due to lower concentrations. Water samples were initially processed by acidifying to a pH less than 1 with 1:1 concentrated nitric acid. These samples were then quantified for arsenic, chromium, and copper using an AA with graphite furnace atomization. Each sub-sample was analyzed in triplicate with flame atomization analysis, and in duplicate with graphite furnace atomization analysis.

Two extraction methods were evaluated for wipe sample processing and compared as part of the preliminary work associated with this study. These methods included a hot acid digestion (U.S. EPA 1996, Method 3050B) and a diluted acid extraction method based upon the use of a 10% solution of HNO<sub>3</sub> heated to 60 °C (U.S. CPSC 2003). In order to evaluate these methods, a set of 18 samples was collected by wiping six different sections of a 4 kg/m<sup>3</sup> wood board in triplicate. Each wipe sample was then split by cutting the wipe samples into quarters. Two of the quarters were subjected to the digestion method and the remaining two were subjected to the dilute acid extraction method, for a total of 36 pairs. A pair consisted of 2, ¼ wipe samples, one processed using the concentrated acid digestion method and the other processed using the diluted acid extraction method. Due to the slightly different digestion methods required for chromium versus arsenic, the entire process was repeated for subsequent chromium analysis. A total of 34 pairs of samples were analyzed for arsenic and 23 pairs were analyzed for chromium. Statistical analysis indicated that the diluted acid extraction and hot acid digestion method provided statistically the same values (alpha,  $\alpha = 0.05$ , T-test,  $p = 0.105$  for arsenic and 0.274 for chromium). The extraction method was chosen for processing all subsequent wipe samples given that it was a simpler procedure providing statistically the same results as the digestion method.

## RESULTS

### Leachable Arsenic and Chromium

**Water Samples:** Physico-chemical data (Table 1) collected from the untreated and CCA-treated decks were statistically the same. The mean pH values between the rainfall, the runoff water, and the infiltrated water were significantly different from each other ( $\alpha 0.05$ , t-Test,  $p < 0.001$ ). The pH of the rainwater at 4.8 was the lowest; the pH of the runoff water was higher at 6.2 and for the infiltrated water the mean pH was at 7.9 to 8.1, indicating that rainwater contact with wood increases the pH of the water. Subsequent contact with the soil results in further increases in pH. The ORP of the rainwater (120 mV) decreased as it came into contact with the wood (40 mV) and as it was collected from below the soil (-70 to -75 mV), indicating that the water becomes more reduced as it passes through the system.

The mean metals concentrations observed in the water samples (Table 2) indicated that rainwater collected from above the untreated and CCA-treated deck was consistently below the 1 ug/L detection limit for both arsenic and chromium. The mean arsenic and chromium concentrations in the runoff water for the CCA-treated deck were  $1001 \pm 770$  ug/L for arsenic and  $99 \pm 79$  ug/L for chromium. The highest concentrations observed during the monitoring period were 4,660 ug/L (Figure 4) for arsenic and 470 ug/L for chromium. The concentrations observed in the runoff water

from the CCA-treated deck contrasted with the concentrations observed in the untreated deck which were consistently below the 1 ug/L detection limit for both chromium and arsenic.

At the beginning of the monitoring period, the arsenic and chromium concentrations in the infiltrated water below the treated deck were at or near detection limits. As time progressed, the concentrations increased (Figure 4). The highest concentrations observed from below the CCA-treated deck were 24 ug/L for arsenic and 10 ug/L for chromium. Neither arsenic nor chromium were detected above the level of 1 ug/L from most all infiltrated water samples at the untreated deck. Including the below detection limit samples, which were set at 0.5 ug/L, the average arsenic concentration in the infiltrated water below the treated deck was  $6.6 \pm 6.4$  ug/L and  $3.1 \pm 1.9$  ug/L for chromium.

**Soil Samples:** The highest concentrations of arsenic within the soils were found at the surface (0 ~ 2.5 cm depth) below the CCA-treated deck with concentrations decreasing notably with depth. Arsenic concentrations in surface soils collected after the 13 months were considerably larger than those observed in the six-month surface soil samples (Figure 5). The surface concentration was 4.5 mg/kg of dry soil for the six month sample and 11.5 mg/kg for the 13 month sample. Concentrations decreased to less than 1 mg/kg below a 5 cm depth for the 6 month sample and below a 7.5 cm depth for the one year sample. All arsenic soil concentrations collected under the untreated deck were less than 1 mg/kg of dry soil in both the six-month sand samples and 13 month sand samples.

Table 1: Summary of physico-chemical parameters in water samples

Parameter	Rainfall		Runoff		Infiltrated Water	
	untreated deck	treated deck	untreated deck	treated deck	untreated deck	treated deck
Mean	13 mm	13 mm	581 ml	584 ml	42 L	48 L
Standard Deviation	23 mm	23 mm	1174ml	1174 ml	73 L	73 L
Mean	4.78	4.83	6.18	6.25	7.91	8.10
Standard Deviation	0.81	0.81	0.65	0.65	0.89	0.89
Mean	121	117.6	42	37.9	-70	-74.8
Standard Deviation	55	55	32	32	30	30

Table 2: Summary of arsenic and chromium concentration in water samples

Metal	Rainfall, ug/L		Runoff, ug/L		Infiltrated Water, ug/L	
	untreated deck	treated deck	untreated deck	treated deck	untreated deck	Treated deck
Mean	< 1	< 1	< 1	1,001	< 1	6
Standard Deviation	< 1	< 1	< 1	770	< 1	6
Mean	< 1	< 1	< 1	99	< 1	3
Standard Deviation	< 1	< 1	< 1	79	< 1	2

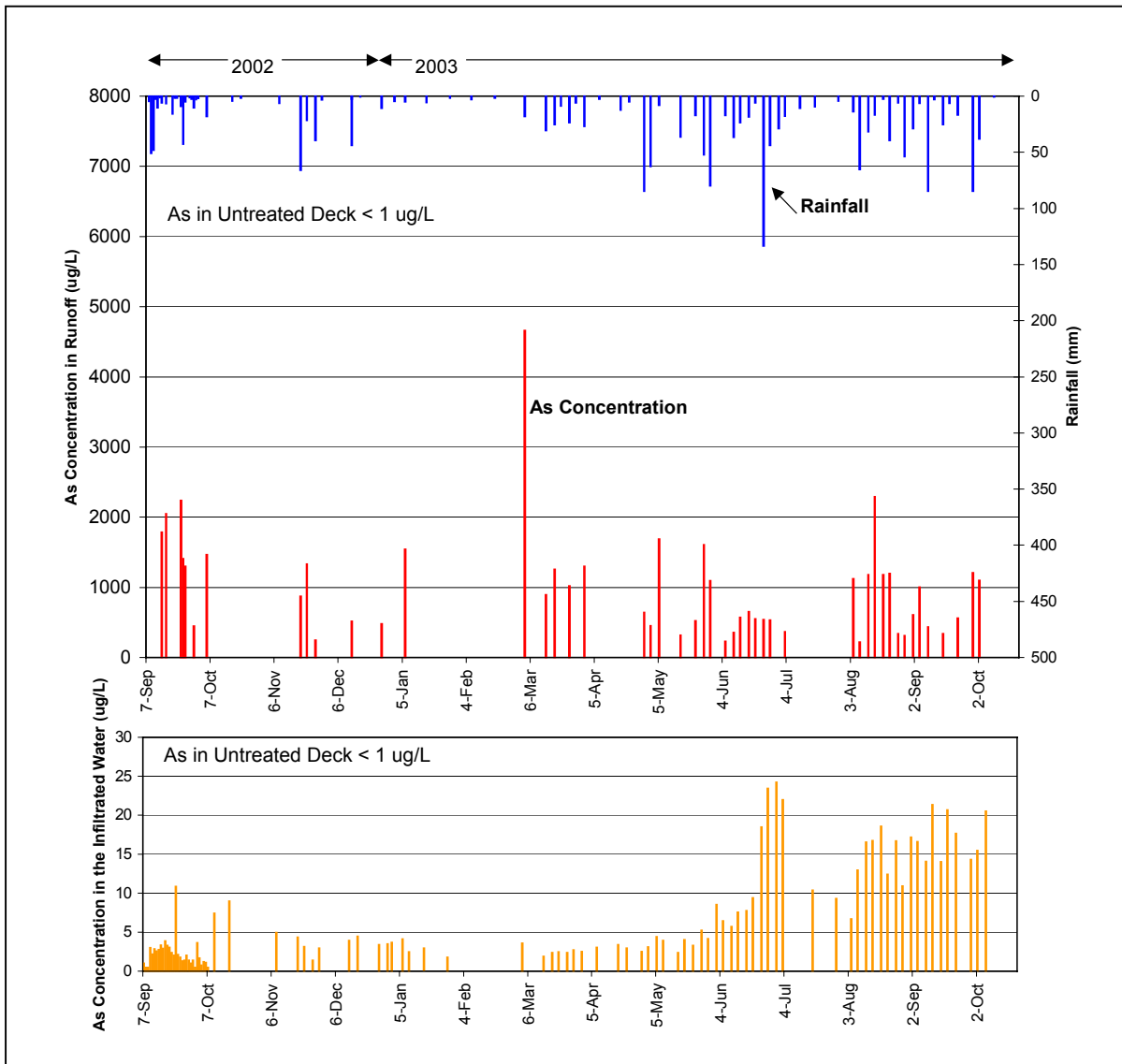


Figure 4: Arsenic concentrations (ug/L) in runoff and infiltrated water from the CCA-treated wood Deck

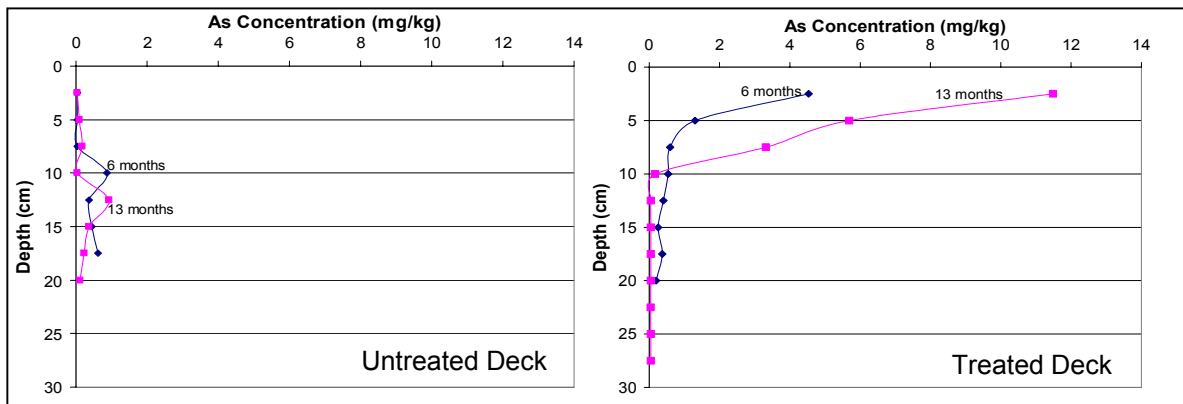


Figure 5: Arsenic in soil under the decks

## Dislodgeable Arsenic and Chromium

**Retention Level Effect:** Wood with increasing retention level resulted in greater amounts of dislodged arsenic (Table 3). The average amount of arsenic for the 4 kg/m<sup>3</sup> wood samples was 74 ± 32 ug/wipe. This increased to 1200 ± 245 ug/wipe for the 40 kg/m<sup>3</sup> wood samples. These differences were statistically significant (p ≤ 0.001).

Table 3: Dislodged arsenic from different retention levels

Retention			Retention			Retention		
Sample ID <sup>a</sup>	Level (kg/m <sup>3</sup> )	Arsenic (ug/wipe)	Sample ID	Level (kg/m <sup>3</sup> )	Arsenic (ug/wipe)	Sample ID	Level (kg/m <sup>3</sup> )	Arsenic (ug/wipe)
WA-0S	0	<0.5	WA-4S	4	45	WA-40S	40	970
WB-0S	0	<0.5	WB-4S	4	52	WB-40S	40	1,152
WC-0S	0	<0.5	WC-4S	4	42	WC-40S	40	1,606
WD-0H	0	<0.5	WD-4S	4	112	WD-40S	40	1,112
WE-0H	0	<0.5	WE-4S	4	90	WE-40S	40	1,307
WF-0H	0	<0.5	WF-4S	4	105	WF-40S	40	949
Mean		<0.5			74			1183
Std dev		---			32			245

<sup>a</sup> W corresponds to outdoor wipe stations but these data were collected before the wood was placed outside.

**Sapwood Versus Heartwood:** Results from the 36 wipe samples showed that the amount of arsenic dislodged from the sapwood side of CCA-treated wood (81 ± 79 ug/wipe) was greater than from the heartwood side (50 ± 47 ug/wipe (Table 4). Although the quantity of dislodged arsenic on the sapwood side was relatively greater than the heartwood side, the mean dislodged arsenic from these two surfaces were statistically the same for all of the data collectively (p = 0.064). When the data for the first repetition only were compared, the amount of dislodged arsenic was significantly greater from the sapwood side as compared to the heartwood side (p = 0.021).

**Effects of Repetitive Wipes:** The amount of dislodged arsenic and chromium notably decreased as the number of consecutive sets of wipes increased on the same area (Table 4). The amounts dislodged from the first set of wipes decreased significantly after the second set of wipes (p ≤ 0.001 for arsenic; p ≤ 0.001 for chromium). From the second set of wipes to the third set of wipes, the amounts dislodged also decreased significantly (p = 0.004 for arsenic; p = 0.002 for chromium). Although the mass of arsenic and chromium dislodged decreased with repeated wipes, the masses were much higher in the first wipe taken after 12 months compared to the third wipe taken after 6 months (Table 5), indicating the replenishment of the wood surface with the CCA chemical. Results for a subset of the data evaluated are shown in Figure 6.

**Effects of Long Term Weathering:** The amount of dislodged arsenic was 52 ± 43 ug/wipe from the CCA-treated deck after 6 months of weathering, and 41 ± 26 ug/wipe after 12 months of weathering (Table 5, Figure 7). For chromium, the mean amount of dislodged arsenic was 75 ± 56 ug/wipe for the 6-month period and 54 ± 29 ug/wipe for the 12-month period. The mean amounts of dislodged chromium were significantly larger than arsenic (p ≤ 0.024) for both sampling periods. The average quantities of dislodged arsenic and chromium decreased from the six-month to the 12-month period. However, the mean amount of dislodged arsenic and chromium collected after six months versus 12 months was statistically the same (p = 0.140 for arsenic; p = 0.041 for chromium). The amounts of arsenic and chromium collected by wiping action on the surface of the untreated deck were below 1 ug/wipe in both the six month and 12-month samples.

Table 4: Dislodged arsenic (ug/wipe) from sapwood versus heartwood

Sapwood Side					Heartwood Side				
Sample ID	Retention Level (kg/m <sup>3</sup> )	Repetition Number	As (ug/wipe)	Cr (ug/wipe)	Sample ID	Retention Level (kg/m <sup>3</sup> )	Repetition Number	As (ug/wipe)	Cr (ug/wipe)
LB-4S <sup>a</sup>	4	1	174	132	LA-4H <sup>a</sup>	4	1	109	11
		2	31	56			2	27	15
		3	21	31			3	11	12
LD-4S <sup>a</sup>	4	1	254	12	LC-4H <sup>a</sup>	4	1	169	10
		2	50	17			2	32	8
		3	11	12			3	24	4
LF-4S <sup>a</sup>	4	1	303		LE-4H <sup>a</sup>	4	1	169	
		2	32				2	69	
		3	16				3	26	
DB6-4S	3.2	1	123	162	DA6-4H	3.2	1	130	175
		2	34	48			2	47	69
		3	23	29			3	30	43
DB12-4S	3.2	1	100	94	DA12-4H	3.2	1	52	105
		2	44	59			2	39	52
		3	39	49			3	32	40
					DC6-4H	3.2	1	41	83
				2			23	39	
				3			15	26	
					DC12-4H	3.2	1	37	46
				2			13	21	
				3			13	19	
Mean			84	58				53	43
Std. Dev.			91	48				49	43

<sup>a</sup>Data shown are the average from two splits from the same wipe.

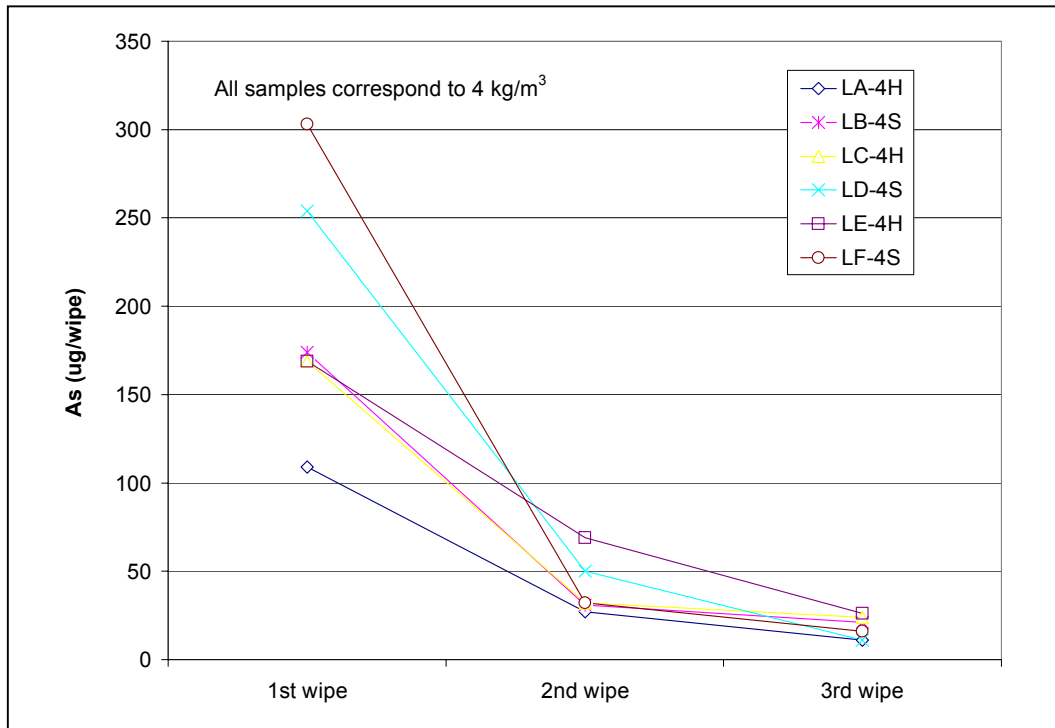


Figure 6: Effects of repetitive sets of wipes on dislodged arsenic

Table 5: Dislodged arsenic and chromium after long-term weathering

Sample ID <sup>a</sup>	Repetition Number	Arsenic, ug/wipe <sup>b</sup>		Chromium, ug/wipe <sup>b</sup>	
		6 months	12 months	6 months	12 months
DA-4H	1	130	52	175	105
	2	47	39	69	52
	3	30	32	43	40
DB-4S	1	123	100	162	94
	2	34	44	48	59
	3	23	39	29	49
DC-4H	1	41	37	83	46
	2	23	13	39	21
	3	15	13	26	19
Mean		52	41	75	54
Std dev.		43	26	56	29

<sup>a</sup>The letter “D” in the Sample ID corresponds to the CCA-treated deck. The letter “H” in the Sample ID corresponds to Heartwood Side and the letter “S” corresponds to Sapwood.

<sup>b</sup>Results for the untreated control were below the 0.5 ug/wipe detection limit for the 6 and 12 month samples.

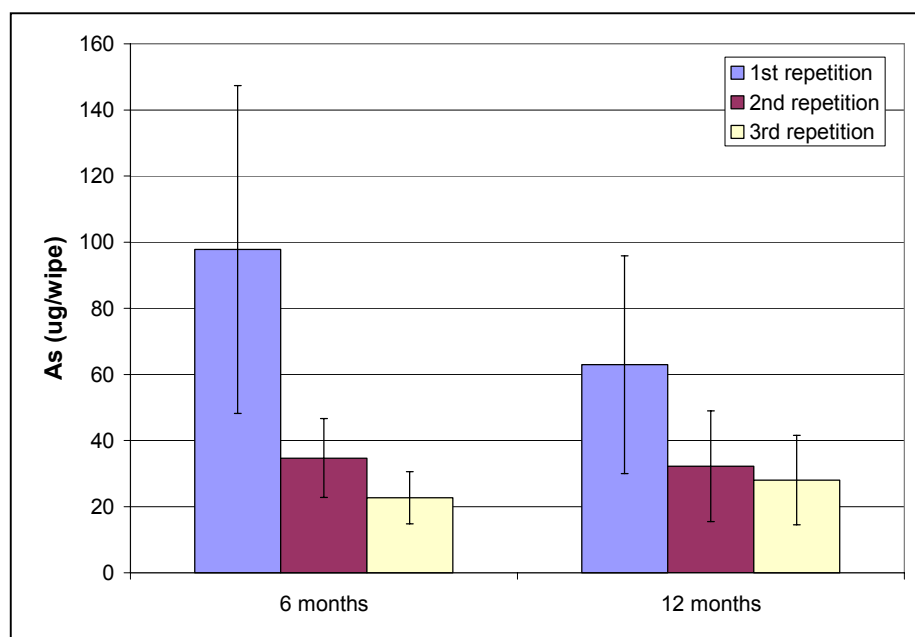


Figure 7: Dislodged arsenic after 6 and 12 months of weathering

## DISCUSSION AND CONCLUSION

The results of this study were consistent with other studies that show that metals leach from CCA-treated wood throughout its in-service use (Townsend et al. 2000; Stilwell and Gorney 1997; and others). The mean concentrations of arsenic in the runoff and infiltrated water were significantly greater than the concentrations of chromium, although the initial retention level of chromium was greater.

The average arsenic concentrations of 1.0 mg/L in the runoff water from the CCA-treated deck were significantly higher than the U.S. EPA drinking water standards (U.S. EPA 1974) which includes a Maximum Contaminant Level Goal (MCLG) of 0 mg/L and the Maximum Contaminant Level (MCL) of 0.050 mg/L (0.010 mg/L as of January 23, 2006, U.S. EPA 2002). The arsenic concentration in the runoff water was also higher than the Florida Criteria for Surface Water Quality Classifications (FDEP 1996), which includes a maximum permissible concentration of 0.050 mg/L for all water classes (I to V). The average chromium concentration in the runoff water from the CCA-treated deck (0.1 mg/L) was near the U.S. EPA drinking water standard of 0.1 mg/L (MCL and MCLG) and higher than the Florida Criteria for Surface Water Quality Classifications of 0.05 mg/L for Class II, III (fresh), and V (predominantly marine) and 0.011 mg/L for Class I, III (marine), IV, and V (predominantly fresh).

The arsenic and chromium leached from the CCA-treated wood drained into the soil below the deck. Arsenic concentrations in the surface soil below the CCA-treated deck after 6 and 13 months of leaching were 4.5 mg/kg and 11.5 mg/kg, respectively. These concentrations are higher than the U.S. EPA soil screen level (SSL) of 0.4 mg/kg (U.S. EPA 1996) and Florida's Soil Cleanup Target Levels (SCTLs) (FDEP 1999) of 0.8 mg/kg for residential areas and 3.7 mg/kg for industrial areas. The arsenic concentrations observed in the surface soils were relatively smaller than earlier studies that showed an average of 76 mg/kg (3 to 305 mg/kg) in Connecticut (Stilwell and Gorney 1997) and 28.5 mg/kg on average (1 to 217 mg/kg) in Florida (Townsend et al. 2001). The arsenic concentration in the soil did not exceed the Florida SCTLs of 29 mg/kg for leaching to groundwater. It should be noted that in this study, the soil was sandy and had been receiving runoff from the CCA-treated deck for only 1 year. The 1 year study period was significantly shorter than the age of the decks (2 to 19 years) used in the Florida study (Townsend et al. 2001). Given the increasing trend for arsenic concentrations in the surface soil between 6 and 13 months, it is likely that the surface soil concentrations may increase with time to higher levels as observed in other studies.

Arsenic (7 ug/L on average) and chromium (6 ug/L on average) were also detected in the infiltrated water located below the CCA-treated deck. Overall the concentrations increased from detection limits at the beginning of the study to upwards of 20 ug/L. Although the majority of the arsenic introduced from the CCA-treated deck was sorbed by the sand, "break-through" of the metals was still observed through the 2 foot sand layer, resulting in concentrations that could present a threat to groundwater drinking water supplies.

This study supported earlier studies that showed that arsenic and chromium could be dislodged by wiping the surface of CCA-treated wood (U.S. CPSC 1990; Stilwell et al. 2003). The average mass of dislodged arsenic from the rated 4 kg/m<sup>3</sup> wood was 72 ug/wipe. This value was larger than the 39 ug/wipe measured by the U.S. CPSC (2003). The current study also showed that the amount of dislodgeable arsenic decreased with repeated rubbing for wood that had been weathered up to 1 year. It would be of interest to evaluate whether repeated wipes result in reduced dislodgeable arsenic levels for wood that has been weathered for longer periods of time.

Overall this study provided important information that could be used in the development of risk assessments for possible human exposures to leachates and dislodgeable metals from CCA-treated wood. CCA-treated wood will be phased-down for residential applications in the future; however, many CCA-treated structures currently exist. It will be important to evaluate the impacts of these existing structures, as well as the impacts of the CCA-treated wood that will continue to be produced for non-residential uses and for residential uses exempted from the EPA mandated CCA phase-down. The results of this study may be helpful in identifying feasible recommendations concerning mitigations efforts aimed at existing playgrounds and other CCA-treated structures. Additional work should concentrate on documenting further the potential impacts of CCA-treated wood leachates to groundwater as an additional environmental and human exposure risk.

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