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Evaluation of the Effectiveness of Surface Coatings in Reducing Dislodgeable Arsenic from New Wood Pressure-Treated with Chromated Copper Arsenate (CCA)

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Executive Summary

The U.S. Environmental Protection Agency (EPA) granted a request by manufacturers to cancel the registration of CCA for use in wood for most residential structures (e.g., playgrounds, decks, picnic tables, etc.) after December 30, 2003. To address the potential exposure to chemical residues (e.g., arsenic) from existing CCA-treated wood structures, CPSC staff and EPA developed a protocol to examine whether application of surface coatings could reduce dislodgeable chemicals from CCA-treated wood. CPSC staff performed its study on new CCA-treated wood minidecks exposed to natural weathering conditions in Gaithersburg, Maryland for two years. Seven of eight coatings tested reduced available arsenic to a level that was significantly different than the control after one year of natural weathering. Generally, product effectiveness diminished with time and after two years only three coatings had a statistically lower arsenic value than the control. Although a film-forming product was one of the most effective in reducing arsenic levels over the entire duration of the study, with time and weathering it cracked and chipped. This has important implications because the surface would require scraping and/or sanding prior to recoating, which could potentially increase consumer exposure to the wood components, including arsenic.

Overall, the findings suggest that application of oil- or water-based penetrating stains (particularly non-clear, pigment-containing products) to CCA-treated wood structures every one to two years may reduce arsenic availability. Importantly, the results from this study are representative of a single wood source (new CCA-treated wood) weathered in one geographic location (Mid-Atlantic U.S.) with no physical abrasion to simulate actual use. The frequency of reapplication is not only product dependent, but is also influenced by other factors including regional weather conditions, the condition of the wood, and the use patterns associated with the structure.

Evaluation of the Effectiveness of Surface Coatings in Reducing Dislodgeable Arsenic from New Wood Pressure-Treated with Chromated Copper Arsenate (CCA)

Background

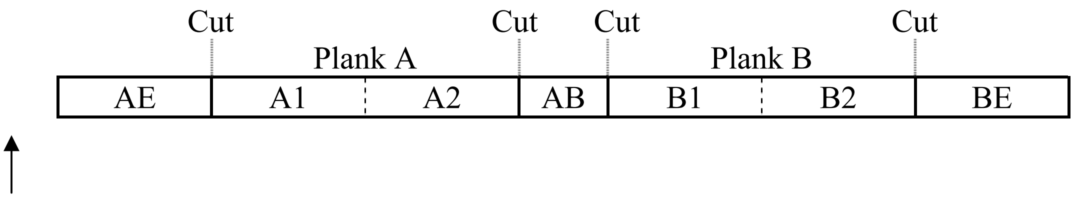
In March 2003, the EPA granted a request by manufacturers to cancel the registration of CCA for use in wood for most residential structures (e.g., playgrounds, decks, picnic tables, etc.) after December 30, 2003. While this action prohibits the residential use of wood treated with CCA, it does not address the potential exposure to chemical residues (e.g., arsenic) from existing CCA-treated wood structures. CCA was first produced over 60 years ago and in 1997 the American Wood-Preservers' Association (AWPA) estimated that there were over 85 million metric tons of "in-service" CCA-treated wood in the U.S. (Cooper, 2004).

In an effort to find ways to mitigate exposure, CPSC staff in collaboration with the EPA, evaluated the ability of surface coatings (e.g., deck stains, sealants, and paint) to reduce chemical migration (e.g., arsenic) from CCA-treated wood under natural weathering conditions. EPA and CPSC staff conducted parallel studies employing similar methodologies with the primary differences being the study location (CPSC: Gaithersburg, Maryland; EPA: Research Triangle Park, NC) and the CCA wood source (CPSC used new CCA-treated wood; EPA used one-year old and seven-year old weathered CCA-treated wood). The studies began in August 2003 and continued for two years. This report provides final results from the CPSC staff study. EPA study results are published separately (U.S. E.P.A., 2006).

Materials and Methods

Surface coatings were tested on small deck structures or "minidecks" made with new southern yellow pine boards (12' x 5/4" x 6") treated to 0.4 pounds per cubic foot (pcf) with Ground Contact CCA-C only (i.e., water repellent was not part of the treatment). Each CCA-treated board was cut into five sections including two 48-inch long planks designated as Plank A and Plank B in Figure 1 (See TAB A for details of the experimental design). The planks were rinsed lightly with tap water after cutting to remove excess sawdust. The end sections (AE and BE) of the board along with sections A1 and B1 of each plank (which formed the west section of each plank on the minidecks, see Figure 2) served as controls to account for variations in dislodgeable arsenic between planks.

Figure 1: Board Sections (nominal board length prior to cutting = 12' x 5/4" x 6").



End Tag (a tag or label on one end of the board that includes the UPC code, preservative type and retention level, board size, etc.)

Each CCA-treated minideck had nine, 48-inch long planks which were randomly assigned so that no minideck had two planks from the same board (Figure 2). Two "control" minidecks were similarly constructed using **non**-CCA-treated boards to determine whether there were other sources of arsenic (e.g., from air, rain, etc.) besides the CCA-treated wood. Only one of the two **non**-CCA minidecks was coated. All planks on each minideck were positioned with the pith facing down to reduce cupping of the wood thereby minimizing pooling or retention of water (or ice in the winter months) on the surface (Figure 3).

Figure 2: Minideck Layout.

Plank	Sampling* Schedule		North	
1	1		West	East
2	2		West	East
3	3		West	East
4	1		West	East
5	2		West	East
6	3		West	East
7	1		West	East
8	2		West	East
9	3		West	East
			South	

* CPSC staff sampled the designated planks according to the following time schedules:
<u>Schedule 1</u>: Plank numbers 1, 4 and 7 were sampled at two weeks and 1, 3, 6, 9, **12,** 15, 18, & **24** months.
<u>Schedule 2</u>: Plank numbers 2, 5, & 8 were sampled at 6, **12,** 18, & **24** months.
<u>Schedule 3</u>: Plank numbers 3, 6, & 9 were only sampled at **12**, **24** months.
Note: All nine planks were sampled at 12 and 24 months.

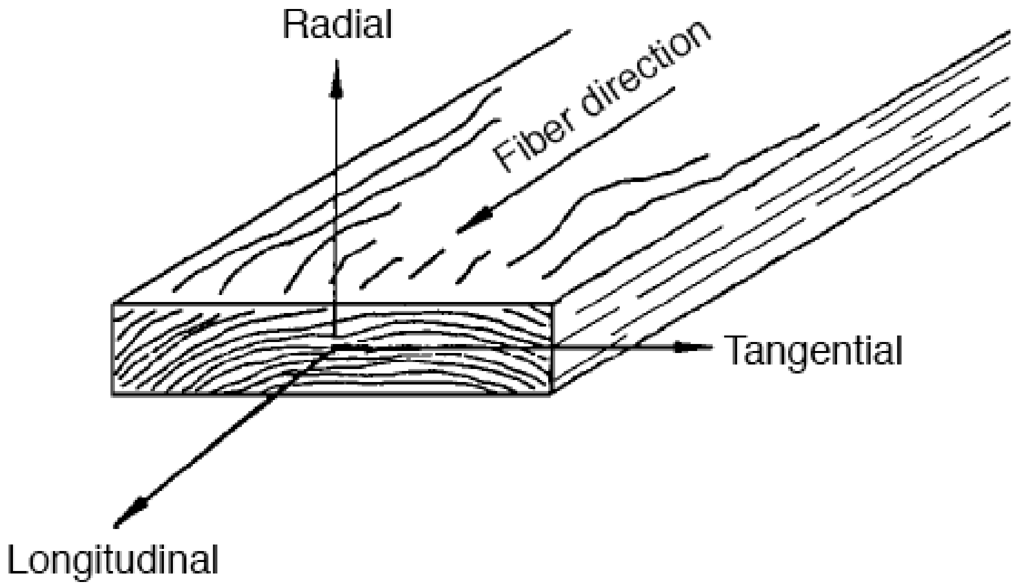


Figure 3. The three main axes of wood (radial, longitudinal, and tangential) in relation to the grain direction and growth rings (Green et al., 1999). The growth rings at the end of the board, which form a semi-circular grain pattern, are oriented in a convex or "pith down" position.

After a weathering period of about 30 days,[1] each CCA-treated minideck was randomly allocated a single commercially available surface coating product that was applied per the manufacturer's instructions (Table 1). One exception was coating #11, which was only applied to four planks on one CCA-treated minideck. Since the CCA-treated wood used in this study was new, there was no specific surface preparation of the planks (e.g., power-washing, etc.) prior to coating.

Table 1. Summary of Coating Application.

Coating ID	Total Weight Applied (grams)	Area Applied square feet (sq ft)	Manufacturer's Stated Coverage (sq ft/gallon)	Number of Coatings Applied
1	369.7	22.8	200 - 400	2
2	219.9	22.8	250 – 300	1
3	208.2	22.8	400 – 600	1
4	299.1	22.8	150 – 250	2
5	391.6	22.8	300 – 700	2
7	321.7	22.8	250 – 300	2
8	407.2	22.8	200 – 400	1
11*	131.5	10.2	400 – 600	1

[1] Depending on the information source, the recommended weathering time before coating new wood structures ranges from several weeks to one year. Structural engineers from the USDA Forest Products Laboratory recommend finishing a new deck as soon as possible or not waiting more than 2 months (Falk and Williams, 1996; Ross et al., 1992).

*** Coating # 11 was applied to only four planks on one CCA-treated minideck.**

CPSC staff evaluated eight products (seven of which are the same as those tested by EPA). Coating application was measured gravimetrically by calculating the difference between the starting aliquot and brush weight and the post-coating aliquot and brush weight. One CCA-treated minideck was left uncoated to serve as a negative control.

The types of commercially available surface coatings applied to the minidecks are described in Table 2 and include those characterized as penetrating, film-forming, and encapsulants (Williams and Feist, 1993; Williams, 1995; Knaebe, 1995). The U.S. Department of Agriculture (USDA) Forest Products Laboratory (FPL) has done extensive research on the ability of various surface coatings to protect wood decks from damage (e.g., cracking, raised grain, mildew/mold growth) caused by natural weathering (Williams and Feist, 1993; Williams, 1995; Knaebe, 1995). Penetrating finishes (e.g., oil-based semi-transparent stains, water repellents, and water-repellent preservatives) absorb into the wood allowing the wood to breathe so that the finish typically will not blister or peel even when the moisture content of the wood is high (Williams and Feist, 1993; Williams, 1995; Knaebe, 1995). Conversely, film-forming finishes (e.g., paints, latex and

Table 2. Surface Coatings

CPSC ID Number[a]	Category	Base	Cover	Type	EPA ID Number[b]
1	Paint	Water	Opaque	Film forming	9
2	Sealant	Oil	Clear	Penetrating	6
3	Stain	Oil	Clear	Penetrating	4
4	Sealant	Oil	Clear	Penetrating	1[c]
5	Other		Plastic	Encapsulant	11
7	Stain	Water	Solid (without tint)	Penetrating	8
8	Other		Polymer	Encapsulant	12
11[d]	Stain	Oil	Red Cedar	Penetrating	Not tested by EPA

[a]Note = The coating ID numbers are not sequential. CPSC ID number 6 refers to the control CCA-treated **uncoated** minideck. CPSC ID numbers 9 and 10 are two industrial coatings not readily available to consumers.
[b]The ID number designated by EPA for the same coating.
[c]EPA ID number 1 is identical to CPSC ID number 4 except EPA ID number 1 contains a cedar pigment .
[d]CPSC ID number 11 is identical to CPSC ID number 3 except it has an added red cedar pigment. Also, CPSC ID number 11 was applied to only four planks of a CCA-treated-wood minideck. Two of these planks were sampled following schedule 1 and the other two planks following schedule 2. All four planks were sampled at 12 and 24 months.

oil-based solid-color stains, and varnishes) form a thin layer when applied to a surface and most are not considered suitable for use on wood decks by FPL researchers because of their tendency to trap moisture, leading to cracking and peeling (Williams and Feist, 1993; Williams, 1995). Finally, some products are designed to encapsulate CCA including one that forms a plastic coating on the wood surface.

Wipe sampling and analysis were performed as previously described (Cobb, 2003). Briefly, polyester fabric wetted with 0.9% saline was used to wipe an area of 400 cm^2 with a sampling device designed by CPSC staff. Two 400 cm^2 sections (Figure 2: one east section and one west section) were designated on each plank for wipe testing. Only the west sections were wipe sampled prior to coating and served as controls along with wipe samples from the closest end section of each board (e.g., according to Figure 1, the control for plank A consists of its west section A1 and the end section AE). Both sections (east and west) were wipe sampled post-coating according to the sampling schedule for each of the nine planks on the minidecks (Figure 2). For example, according to Schedule 1, CPSC staff sampled the east and west sections of only three planks (plank numbers 1, 4, and 7) on each minideck after one month of weathering. At 12 and 24 months, both sections of all nine planks on each minideck were sampled corresponding to Schedules 1, 2, and 3. Sampling of the **non**-CCA minidecks followed Schedule 1.

The minidecks were dry before sampling (i.e., at least two days after a significant precipitation defined as >0.1 inch rain within a 24 hr period). The extraction procedure involved placing the polyester wipes in a 10% nitric acid solution overnight at 60^{o} C. The extracts were analyzed for total arsenic using inductively coupled plasma (ICP) atomic emission spectroscopy. The detection limit for this method is 0.4 micrograms (µg) per sample.

The minidecks were exposed to natural weather conditions in an unshaded area at the CPSC test facility in Gaithersburg, MD (see photograph below). Weather data (e.g., temperature, humidity, precipitation type, etc.) were collected on-site. Visual observations of each minideck were documented in writing and via digital photography prior to weathering and at each sampling time.

The photograph shows the CPSC test site in Gaithersburg, Maryland. The minidecks were situated in an unshaded area surrounded by a wire fence.

Results

The CPSC staff evaluated the ability of eight commercially available surface coatings to reduce dislodgeable arsenic from new CCA-treated wood minidecks over a two year (24-month) time period. The study only examined the effects of natural weathering – not physical abrasion. A detailed statistical analysis of the study is provided in Tab A.

Figure 4 shows the geometric mean of the baseline adjusted arsenic values (which adjusts the arsenic value for each plank by the corresponding baseline amount) over time for each coating on the base-10 log scale. Notably, the dislodgeable arsenic does not vary over 24 months on the control CCA-treated uncoated minideck (# 6), whereas all of the coated CCA-treated minidecks showed reductions in arsenic for up to 12 months with coating effectiveness decreasing over time.

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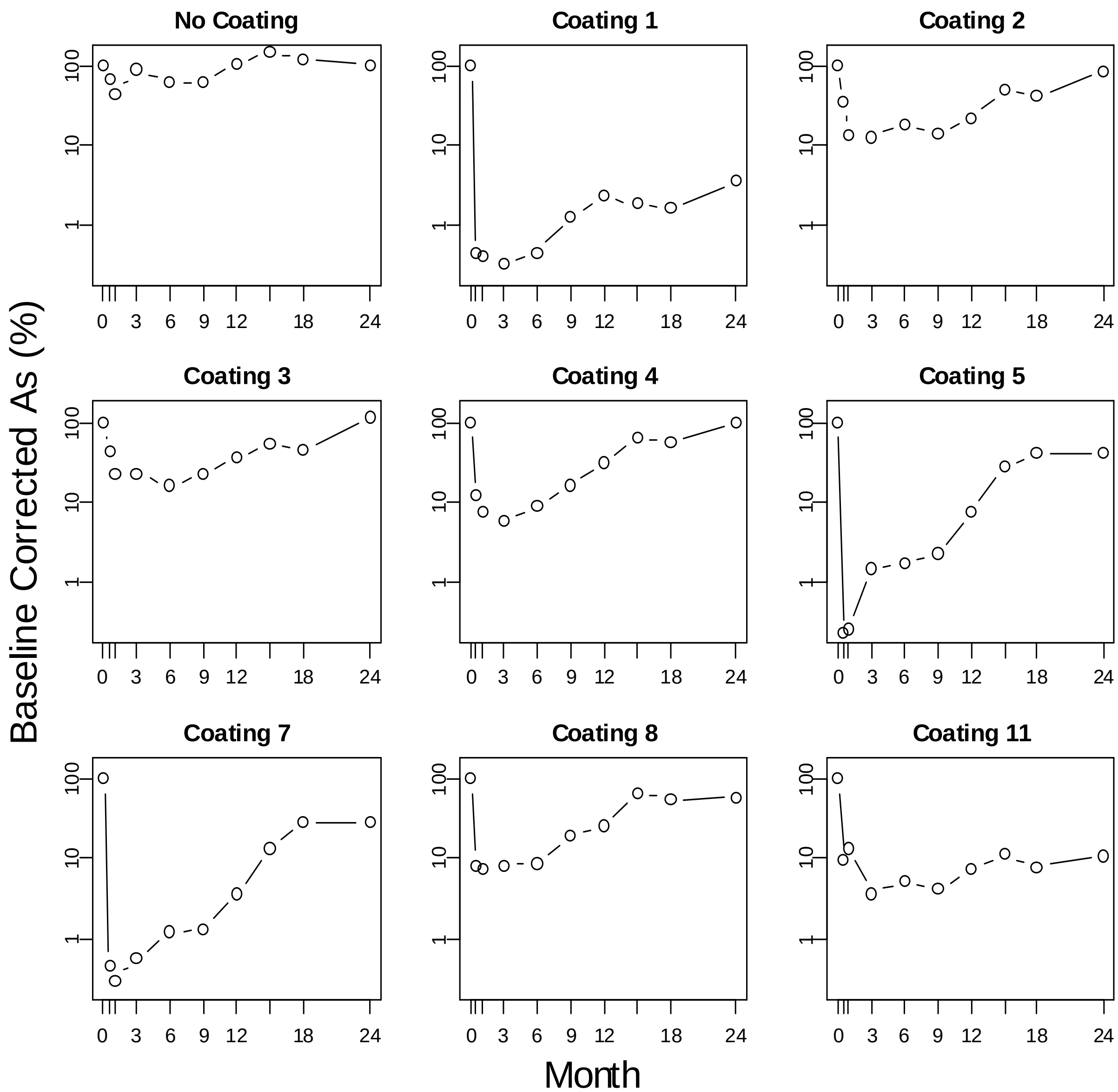
Figure 4. Geometric Mean Baseline Adjusted Dislodgeable Arsenic over Time by Coating (Log Scale).



A comparison of coating effectiveness with the control (uncoated CCA-treated minideck, CPSC ID # 6) at 12 and 24 months is shown in Table 3. The results after 12 months of natural weathering showed that all of the coatings except coating # 3 reduced dislodgeable arsenic to a level that was statistically less than the control. The lowest estimated arsenic value relative to baseline was measured on the CCA-treated minideck with coating # 1, but it was not statistically different from coating # 11 which had the third lowest estimated arsenic value relative to baseline. Moreover, coating #11 was not significantly different from any other coating (Tab A, Table A8).

After 24 months, the estimated dislodgeable arsenic values were higher than those measured at 12 months for all eight coatings (Table 3, Figure 4) with only three CCA-treated minidecks (coatings 1, 7, and 11) having arsenic values that were significantly lower than the control. The result for coating # 1 was significantly lower than all the coatings except coating # 11 (Tab A, Table A9).

Table 3. Comparison of Coating Effectiveness with Control at 12 and 24 Months.

CPSC ID (coating)	12 Months Estimate	12 Months Control/ Estimate	12 Months p-value	24 Months Estimate	24 Months Control/ Estimate	24 Months p-value
6 (control)	107.336			99.542		
1	2.268	47.326	<0.0001	3.504	28.406	<0.0001
2	21.801	4.923	0.0004	86.436	1.152	0.5000
3	35.957	2.985	0.1249	116.004	0.858	0.5000
4	31.333	3.426	0.0403	99.661	0.999	0.5000
5	7.455	14.397	<0.0001	39.703	2.507	0.3097
7	3.590	29.895	<0.0001	29.404	3.385	0.0451
8	25.209	4.258	0.0033	57.641	1.727	0.4984
11	7.192	14.924	<0.0001	10.886	9.144	<0.0001

Note: Estimates are in percent of arsenic relative to the amount present prior to coating and are based on n = 304 measurements. Attained significance (p-values) from one-tailed upper test of hypothesis. See Tab A for more details.

The study included the following controls: 1) an uncoated CCA-treated minideck (referred to above); and 2) two minidecks made with wood <u>not</u> treated with CCA or any other pesticide. At the 12- and 24-month time periods, the estimated arsenic values on the uncoated CCA-treated minideck were similar to the baseline (Table 3, Figure 4). Arsenic values for the **non-CCA-**treated minidecks were very low (most below the detection limit) indicating that there were minimal background levels of arsenic from other sources (e.g., atmospheric deposition).

A summary of visual observations for each minideck after 24 months of weathering is in Table 4. Photographs of the minidecks at the beginning of the study and after 12 and 24 months of weathering are in Tab B. The minideck boards with coating # 11 had the best overall appearance after 24 months of weathering. The effect of an added pigment is dramatically illustrated when comparing the boards with coating # 11 to those on the minideck with coating # 3, the same product except in a clear formulation (i.e., without the pigment). Boards with coating # 3 looked faded and gray, while coating # 11 retained its original color with only some fading. Although the minideck with coating #1 (the film former) generally had the lowest estimated values of arsenic relative to baseline throughout the study, it was substantially cracked and chipped after 24 months of weathering.

Table 4. Visual Observations of Minidecks after 24 Months of Natural Weathering.

Coating Number	Base	Cover/Type	Observations
Control CCA/uncoated			Faded, gray, light mold. Boards show moderate cracking.
1	Water	Opaque/film-forming	Faded, moderate to extensive cracking &/or chipping of the coating. Water still beads on top.
2	Oil	Clear/Penetrating	Faded, gray, with light mold.
3	Oil	Clear/Penetrating	Faded, very gray with light mold. Some/most boards moderately cracked.
4	Oil	Clear/Penetrating	Faded & gray. Most boards moderately cracked.
5		Elastic vinyl/Encapsulant	Faded, gray, cracking & peeling of the coating. Moderate to heavy mold.
7	Water	Solid (no tint)/ Penetrating	Faded, gray, coating eroded on some boards. Moderate to heavy mold.
8	Water	Polymer/ Encapsulant	Faded, gray, light mold. Light to moderate cracking of most boards. Splinters form when wipe testing.
11	Oil	Red Cedar/ Penetrating	Pigment mildly faded with light mold. Boards show light to moderate cracking.

The CPSC staff examined two other variables in this study, the "section" or re-rub effect of the actual wipe test and the "sampling schedule effect," which relates to the total number of times a board was sampled. To address whether the actual wipe test to collect samples from the minidecks reduces the amount of available arsenic, baseline measurements were taken from the west side of each plank prior to coating the entire plank (Figure 2). Measurements were then taken from both the east and west sides of the plank throughout the study at the designated sampling times. The results showed that after 24 months, there was no statistically significant difference between the west and east section measurements ($p = 0.8261$, see Tab A, Figure A5). Additionally, the study included three sampling schedules or time intervals for wipe-testing the boards (Figure 2) with schedule 1 being the most frequent – *i.e.*, boards in this group were sampled the most number of times. After 24 months, there were minor differences in the measurements among the three sampling schedules (Tab A, Figure A6) with those for schedule 1 appearing to be slightly lower. Overall, the schedule effect was nearly statistically significant (p-value = 0.0637**)**.

Discussion

The CPSC staff and EPA studies are the first to examine the ability of individual surface coatings to reduce dislodgeable chemicals from CCA-treated wood in a controlled natural setting over an extended time period. Apart from the study location (Maryland versus North Carolina), the major difference between these studies was the source of wood used to construct the minidecks. CPSC staff used new CCA-treated wood, which was still available to the public when the study began in August 2003, to complement the two sources of in-service, weathered CCA-treated wood used in the EPA study. New CCA-treated wood lacked the variability of the weathered wood, had a smooth, flat surface for optimal coating adherence and sampling, and it did not require the varied surface preparation steps necessary prior to coating weathered CCA-treated wood. Ultimately, the results show that coating effectiveness was similar between the two studies, regardless of the wood source.

All of the coatings except # 3 were statistically more effective in reducing dislodgeable arsenic compared to the control for the first 12 months, with coatings 1, 7, and 11 remaining effective over the entire 24 months of the study. However, coating # 1 is a film-forming paint. Studies by the U.S.D.A. Forest Products Laboratory (FPL) show that paint products typically do not penetrate the wood but form a film on its surface (Williams and Feist, 1993; Lebow, 2002). Over time this film may crack, peel, or chip from weathering and use of the structure. Moreover, limited data show that exposure to metals (e.g., arsenic and chromium) in wood dust generated from sanding or sawing CCA-treated wood can occur in occupational settings (Decker et al., 2002; Nygren et al., 1992). Based on this information, film-forming products have not been recommended for use on CCA-treated wood by CPSC staff, EPA, and others because consumers may sand or scrape the wood potentially increasing their exposure to the wood components, including the wood preservative chemicals (Williams and Feist, 1993; Williams, 1995; Lebow, 2002). After one year of weathering, coating # 1 began cracking or chipping, which became more extensive over time (Tab B). Abrasion from actual use of a coated CCA-treated wood structure could worsen this effect. EPA also observed chipping with film-formers.[2] These observations underscore concerns about the use of film-forming products on CCA-treated wood. More studies are needed to examine potential exposures to metals from sanding and scraping CCA-treated wood.

Four products that were statistically more effective in reducing dislodgeable arsenic for the first 12 months were those for which the manufacturer recommended application of two coats (Table 1). However, the meaning of this is unclear given that the study did not test multiple coats of the same product. Also, multiple coats of some penetrating products are not necessarily better in terms of general performance. FPL researchers (Falk and Williams, 1996) have shown that over-application of semi-transparent oil-based stains can form a film on the wood surface which can crack (similar to coating # 1, the film-former).

These data also suggest that the pigment component may enhance effectiveness since coating # 11 with the red cedar pigment performed better in reducing dislodgeable arsenic (relative to the

[2] EPA found elevated arsenic, chromium, and copper concentrations in paint chips from CCA-treated minidecks coated with film-forming paints (U.S. E.P.A., 2006).

uncoated control, CPSC ID # 6) and qualitatively in appearance than coating # 3 (the same product without pigment) after 24 months of weathering.

Previous studies, each with its own limitations, have shown that surface coatings can reduce the leaching or release of chemicals from CCA-treated wood (Lebow, 2002; Lebow et al., 2003; Maas et al., 2003; Stilwell, 1999). In one study, individual CCA-treated boards were brushed with either one of three coating regimens before exposure to simulated rainfall episodes over a three week period to approximate the national average rainfall (Lebow, 2002). The coatings tested in this study were: 1) a latex primer followed by one coat of outdoor latex paint; 2) an oil-based primer followed by one coat of oil-based paint; or 3) two coats of a penetrating oil deck stain that also contained a water repellent (Lebow, 2002). While this study was preliminary and only examined the effects of one aspect of weathering – *i.e.*, simulated rainfall, the results showed that all of these surface treatments were over 99% effective in reducing the leaching of arsenic, chromium, and copper compared to controls or uncoated boards (Lebow, 2002). It was suggested that the effectiveness of the coatings was related to their ability to limit water movement into and out of the wood (Lebow, 2002).

A follow-up study examined the effects of ultraviolet (UV) radiation (via a xenon-arc weathering chamber) and water repellent content on chemical release from CCA-treated wood exposed to simulated rainfall (Lebow et al., 2003).[3] These data showed that the water repellent significantly reduced the release of arsenic, chromium, and copper in the runoff water collected from the CCA-treated wood, but no difference was observed between the three concentrations of water repellent tested (1%, 3%, and 5%). Additionally, UV exposure produced a significant increase in chemical leaching from both coated and uncoated boards which was considered possibly due to fiber loss from surface erosion and the increased surface area caused by weathering (Lebow et al., 2003).

In a field study of almost 800 sites across the U.S. where volunteers collected samples from in-service residential structures (*e.g.,* decks, playsets, picnic tables, etc.) made with CCA-treated wood using a standard wipe-sample kit, Maas et al., (2003) concluded that water sealants reduce arsenic release, but are only effective for six months, whereas stains and paints are effective for up to two years. However, the variables considered (*e.g.,* treatment, age, region, sun exposure, and structure type) in this study along with the sample collection technique were not controlled making these data difficult to interpret. For example, the age, geographic location, and level of sun exposure of the structures treated with water sealants are not identified so the conclusion made about water sealant effectiveness may be due to these other factors as well. Also, the paint and sealant data were combined due to small sample size, making it difficult to determine which product types were most effective.

Conclusion

The objective of this study was to identify surface coatings that could reduce arsenic availability from CCA-treated wood, the main component of many outdoor residential structures. While surface coating formulations frequently change and the precise component(s) (*e.g.,* pigment,

[3] Simulated rainfall (about 838 mm) and UV radiation exposure (1200 hours) over a 5.5 month period corresponded to about one year of outdoor exposure averaged across the mainland U.S. (Lebow et al., 2003).

repellent, binder, etc.) that play a role in reducing chemical release from CCA-treated wood have not been well defined (Lebow et al., 2003), this study showed that after one year of weathering seven of eight coatings tested significantly reduced dislodgeable arsenic compared to the control. Apart from the film-former (# 1), which chipped or cracked and the CCA encapsulant (# 5), which peeled and had substantial mold growth, the best performing coatings were 2, 4, 7, 8, and 11. Furthermore, coatings 1, 7, and 11 remained effective after two years of weathering.

EPA found similar results in its study – *i.e*., application of some surface coatings to weathered CCA-treated wood under natural weather conditions in North Carolina substantially reduces dislodgeable arsenic for about 12 months with weathering decreasing coating effectiveness over time (U.S.E.P.A., 2006). Moreover, a few identical products tested in both studies showed similar characteristics related to chipping/peeling, mold growth, and overall appearance.

The findings suggest that coating CCA-treated structures with oil- or water-based penetrating stains, particularly those that are non-clear or pigmented, every one to two years can reduce arsenic availability without requiring extensive surface preparation (*e.g.,* sanding, scraping, etc.) prior to re-coating. Notably, this study did not examine the effectiveness of re-coating the structures once the products failed to reduce arsenic levels below the control. It should also be emphasized that the results from this study are representative of a single wood source weathered in one geographic location with no physical "wear and tear" component. Apart from the product type, the frequency of re-application will depend on other factors including regional weather conditions (*e.g.,* increased UV radiation, heat, and humidity as observed in the south), the condition of the wood, and the use patterns (light versus heavy foot traffic, duration of use, etc.) associated with the structure.

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TAB A
STATISTICAL ANALYSIS

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Experimental Design

The CPSC staff CCA mitigation experiment was designed to compare the effectiveness of various coatings at reducing potentially dislodgeable arsenic from wood treated with CCA. Based on previous CPSC staff studies of sampling wood for dislodgeable arsenic, several factors were accounted for in the design of the experiment (Levenson et al., 2004, Thomas et al., 2004). These factors included (1) the large variability in dislodgeable arsenic both within and among samples of CCA-treated wood and (2) the reduction in dislodgeable arsenic from prior sampling of the CCA-treated-wood surfaces. Also, various controls were employed to standardize results and ensure that the measured arsenic derived from the wood.

The experiment involved the use of *minidecks*, small deck-like structures, exposed to natural weathering (see Materials and Methods section in the main report). A minideck consisted of nine planks of wood. Two sections were defined on each plank: a *west* section and an *east* section. Figure A1 displays a graphical representation of a minideck. The planks were cut from boards (nominal 12’x5/4’’x6”). Each board provided two planks. Figure A2 displays a graphical representation of a board. Sections A1 and A2 would form one plank, and sections B1 and B2 would form a second plank. Sections A1 and B1 were positioned as the west sections of their respective planks. Likewise, sections A2 and B2 were positioned as the east sections of their respective planks. The end sections, sections AE and BE, were not used in the construction of the minideck but as described below were used as controls. Section AB, a short section, was not used.

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Figure A1
Minideck Sections and Sampling Schedule

Plank	Sampling Schedule		North	
1	1		West	East
2	2		West	East
3	3		West	East
4	1		West	East
5	2		West	East
6	3		West	East
7	1		West	East
8	2		West	East
9	3		West	East
			South	

Figure A2
Board Sections.

	Plank A			Plank B		
AE	A1	A2	AB	B1	B2	BE

End Tag

Prior to the coating of the minidecks, samples of dislodgeable arsenic were taken from the west sections (A1 and B1) and the end sections (AE and BE). These measurements were used as baseline controls for each plank to account for the variations in dislodgeable arsenic among the planks. The east sections were not sampled prior to the coating of the minideck, and thus, would not have experienced any possible reduction of arsenic from the sampling prior to coating. After the application of the coatings, both the west and the east sections were each sampled at all time periods.

Initially, the study called for seven minidecks constructed of CCA-treated wood. Thirty-two CCA-treated boards from a single source were randomly allocated for the construction of the seven minidecks. The randomization had the restriction that no two planks from a single board were allocated to the same minideck, thus reducing the effect of the variability among boards in comparing results from different minidecks.

Each of six coating types was then randomly allocated to one of the seven CCA-treated-wood minidecks. One of the seven minidecks remained uncoated to act as a positive control. The coatings were applied as described in the Material and Methods section.

Two additional minidecks were constructed of wood that was not treated with CCA. Boards were randomly allocated to these minidecks as was done for the CCA-treated-wood decks. One of these two minidecks remained uncoated. The planks of the other minideck were each coated with a coating type used for CCA-treated-wood minidecks. These two minidecks were used as negative controls to determine if there was any accumulation of CCA from environmental sources.

After the assignment of boards and planks to these nine minidecks, it was decided to create two additional CCA-treated-wood minidecks in order to evaluate additional coatings. One of these minidecks was coated with a single coating as was done for the initial seven CCA-treated-wood minidecks. This analysis uses data from that minideck. The other minideck had three coatings types applied to distinct planks. Two of these coatings were industrial coatings not readily available to consumers. Data from those coatings are excluded from the analysis. The third coating (Coating 11), was applied to four of the nine planks of that minideck. The study contains arsenic measurements from these four planks where Coating 11 was applied.

Following the coating of each minideck the planks were sampled following one of three sampling schedules. The schedules are given in Table A1. Figure A1 displays the allocation of the planks to the sampling schedules. The use of the three sampling schedules allowed for the effect of sampling on the dislodgeable arsenic to be determined. Both the west and east sections were each sampled at the scheduled times. For the coating applied only to four planks of a CCA-treated-wood minideck, two of the four planks were sampled at schedule 1 and the other two were sampled at schedule 2. The sampling was performed with the sampling template developed by CPSC staff using a wet polyester wipe that is a surrogate for the human hand (Thomas et al., 2004).

Table A1
Sampling Schedules

Schedule Number	Schedule
1	2 weeks and 1, 3, 6, 9, 12, 15, 18, 24 months
2	6, 12, 18, 24 months
3	12, 24 months

The results section below contains both an exploratory analysis of the reduction in arsenic associated with each coating and a formal statistical analysis. The exploratory analysis contains data from measurement made at 12 and 24 months and all intermediate times as shown in the sampling schedules above. The formal statistical analysis uses only measurements taken at three times from the coated minidecks and the positive control deck. These were at baseline (before coating), and at 12 and 24 months. As apparent from Table A1, all planks were sampled at 12 and 24 months.

There were a total of 304 measurements used in the formal statistical analysis. These were as follows:

- For the minidecks with Coatings 1-5, 7 and 8, there were two measurements on each plank (west and east sections), in two time periods (12 and 24 months) on 9 different planks in each minideck. This produced a total of 288 measurements.
- For the minideck with Coating 11, there were 2 measurements on each plank (west and east section), in two time periods (12 and 24 months) on 4 different planks. This produced a total of 16 additional measurements.
- There were 76 unique combinations of planks and minidecks. Minidecks with Coatings 1-5, 7 and 8 had 9 planks each (planks 1-9) and the minideck with Coating 11 had 4 planks (planks 6-9).

Results

Outcome Measure

The basic outcome measure used in the statistical analysis, referred to as the baseline adjusted arsenic, is given in Equation (A1). The measure adjusts the arsenic value for each plank by the corresponding baseline amount. The baseline amount is the average of the west section and end section measurements taken prior to the application of the coatings for the plank. The one-year interim report contains discussion of other outcome measures (Cobb et al. 2005).

$$R_p = \frac{A_p}{B_p} \qquad \text{(A1)}$$

Where: R_p = Baseline adjusted dislodgeable arsenic for plank p (%)
A_p = Dislodgeable arsenic for plank p (µg)
B_p = Dislodgeable arsenic for baseline of plank p (µg)

As stated in the Materials and Methods section, the detection limit for arsenic was 0.4 µg per sample. Prior to the statistical analysis, arsenic amounts below the detection limit were assigned the value of one-half the detection limit, equal to the value of 0.2 µg.

Exploratory Analysis

Figure A3, located at the end of this appendix, displays the geometric mean of the baseline adjusted arsenic measurements across time for each coating.[5] Note that due to the sampling schedules and coating allocation (*i.e.,* Coating 11 was only applied to four planks

[5] The geometric mean is the *nth root* of the product of *n* numbers. The usual way to calculate the geometric mean is to transform the data to logs, compute the arithmetic (conventional) mean of the converted data, then convert the mean back to the original units.

rather than nine planks as were all the other coatings) as described above, the means at different time points were based on different numbers of measurements.

There are some common patterns among the coated minidecks. For each coating, the mean values across time exhibit a generally smooth increasing pattern. Figure A4 displays the mean of the baseline adjusted arsenic measurements on the base-10 log scale. An important first observation from this figure is that the dislodgeable arsenic from the positive control, no coating minideck (Coating 6) does not seem to vary over time. For the coated minidecks, all show reductions in arsenic up to one year but all the graphs show an increasing pattern indicating that the coatings' effectiveness seems to decrease over time.

Figures A5 and A6 display the section and sampling schedule effects on the 24-month measurements. Figure A5 does not reveal any differences between the west and east section measurements. However, Figure A6 suggests some small differences in the measurements among the three sampling schedules as measured at the 24 month point. Recall that as shown in Table A1, Schedule 1 involved measurements at nine different times, Schedule 2 at 4 different times and Schedule 3 at two different times. As noted in the figure, all coatings except Coating 11 followed all three schedules, but Coating 11 followed only Schedules 1 and 2. The figure shows that Schedule 1 measurements for various coatings appeared to have slightly lower values. This suggests that the amount of arsenic decreases with increasing amount of sampling. In looking at the Schedule main effects, however, one needs to be careful in the interpretation because the deck with Coating 11 had one of the lowest arsenic levels but did not have any measurements on Schedule 3.

As mentioned previously, the 12-month and 24-month time points were chosen as the basis of the formal statistical analysis. Since the overall pattern of dislodgeable arsenic for each coating is generally smooth and increasing, the values at these two time points summarize the overall magnitudes well for each coating. Also, staff felt information at these two time points would be useful for consumers considering the application of a coating to CCA-treated wood. Another reason for limiting the formal statistical analysis to 12 and 24 months was that these were the time points when all the planks were sampled.

Statistical Analysis: Part 1, Models for Coating Effectiveness

At each of the 12-month and 24-month time points, there were nine measurements from the west section and nine measurements from the east section available for each minideck with the exception of the minideck with Coating 11, that had only four measurements from each section.[6] The west section measurements differed from those from the east section in that they received a single sampling prior to coating. The measurements can also be classified into three classes corresponding to the three sampling schedules (planks finished with Coating 11 were sampled following Schedules 1 and 2. The planks measured at Schedule 1 were sampled the most, whereas, those measured using Schedule 3 were sampled only at the 12 months and 24 months.

[6] As mentioned previously, the other planks had an industrial coating not available to consumers.

A linear mixed regression model was fit to test the statistical significance of the sections and schedule effects (McCulloch and Searle 2001). The model was fit to the 12-month and 24-month measurements. The form of the model is given in Equation (A2). The model contains the term *Plank* that allows for correlation among repeated measures on individual planks.

$$\log(R_p) = Plank + Coating + Time + Coating * Time + Section + Schedule + RandomError \quad (A2)$$

Where: R_p = Baseline adjusted dislodgeable arsenic for plank *p* (%)
Plank = Plank effect (random effect, 76 levels=one per plank)
Coating = Coating effect (fixed effect, 9 levels)
Time = Time effect (fixed effect, 2 levels)
*Coating*Time* = Coating-Time interaction effect (fixed effect 9*2=18 levels)
Section = Section effect (fixed effect, 2 levels)
Schedule = Schedule effect (fixed effect, 3 levels)
RandomError = Measurement effect (random effect, 304 levels=one per measurement).

Logs are base 10 in keeping with the exploratory analysis.

The estimates from equation (A2) are shown in Table A2. The reference groups in that table are the Control Coating (Coating 6), 12 month time period, Schedule 3 and Section 2.

Table A2
Parameter Estimates for Equation (A2)

Effect	Estimate	Standard Error	Degrees of Freedom	t statistic	p-value
Intercept	2.1093	0.0801	65	26.33	<.0001
Coating 1	-1.6751	0.1019	218	-16.44	<.0001
Coating 2	-0.6923	0.1019	218	-6.80	<.0001
Coating 3	-0.4750	0.1019	218	-4.66	<.0001
Coating 4	-0.5347	0.1019	218	-5.25	<.0001
Coating 5	-1.1583	0.1019	218	-11.37	<.0001
Coating 7	-1.4756	0.1019	218	-14.48	<.0001
Coating 8	-0.6292	0.1019	218	-6.18	<.0001
Coating 11	-1.1337	0.1310	218	-8.66	<.0001
Time 24Months	-0.0327	0.0457	218	-0.72	0.4746
Coating 1 Time 24	0.2217	0.0646	218	3.43	0.0007
Coating 2 Time 24	0.6309	0.0646	218	9.76	<.0001
Coating 3 Time 24	0.5414	0.0646	218	8.38	<.0001
Coating 4 Time 24	0.5353	0.0646	218	8.28	<.0001
Coating 5 Time 24	0.7591	0.0646	218	11.74	<.0001
Coating 7 Time 24	0.9460	0.0646	218	14.63	<.0001
Coating 8 Time 24	0.3919	0.0646	218	6.06	<.0001
Coating 11 Time 24	0.2128	0.0824	218	2.58	0.0105
Section 1	0.0035	0.0157	218	0.22	0.8261
Schedule 1	-0.1268	0.0586	218	-2.16	0.0315
Schedule 2	-0.1141	0.0586	218	-1.95	0.0528

Notes: Equation (A2) estimated using Proc Mixed (SAS, 2004), with the REML option (McCulloch and Searle, 2001). Values shown are in logs (base 10). P-values are not adjusted for multiple comparisons. Based on n=304 measurements.

The reader needs to apply considerable caution in interpreting Table A2. It is not correct to read the main effects, and immediately deduce that all coatings are significantly different from the control coating (and some may be different from each other), for two reasons. As follows:

1. The issue is not if coatings are significantly different from control, but if coatings are significantly different from control at both 12 and 24 months. This includes consideration of the Time main effect (-0.327) and the interactions of Coating and Time (e.g. Coating 1 Time 24 = 0.2217, etc.) as well as the estimate for the Coating effects (e.g. Coating 1 = -1.6751).[7]

[7] Despite the negative Time main effect estimate at 24 months, the positive values of all the Coating-Time interactions in Table A2 suggest some loss of effectiveness at 24 months. Recall that the reference level is Coating 6 (control), and there is not much variation in the arsenic levels in that coating over time.

2. The t-statistics and p-values shown in Table A2, are not adjusted for multiple comparisons. The adjustment of p-values for multiple comparisons and estimates for coating effectiveness will be presented later in this document.[8]

Table A2 indicates that the Section effect is not significantly different from zero. To determine if the Schedule effect is significant, it is necessary to examine the fixed effects analysis of variance. Results from that analysis are shown in Table A3. This table shows that Coating, Time and the Coating-Time interactions were statistically significant.[9] The Section effect was not statistically significant (*p-value*= 0.8261), and the Schedule effect was nearly statistically significant (*p-value*=0.0637).

Table A3
Analysis of Variance for Equation (A2)

Effect	Numerator Degrees of Freedom	Denominator Degrees of Freedom	F statistic	p-value
Coating	8	218	51.10	<.0001
Time	1	218	726.55	<.0001
Coating * Time	8	218	39.53	<.0001
Section	1	218	0.05	0.8261
Schedule	2	218	2.79	0.0637

See notes for Table A2.

The effectiveness of the coatings at the 12-month and 24-month time points were estimated using equation (A3). This equation is the same as equation (A2), except that the Section and Schedule Effects were omitted. As noted above, neither effect was statistically significant at α= 0.05. To the extent that either Section or Schedule effects exist, then the variance of the *Random Error* term will be estimated to be slightly larger in the model of Equation (A3). In turn, this will result in slightly higher standard errors for the other estimates, larger confidence intervals for the estimates, and larger p-values.

$$\log(R_p) = Plank + Coating + Time + Coating * Time + RandomError \qquad \text{(A3)}$$

Where: R_p = Baseline adjusted dislodgeable arsenic for plank *p* (%)

[8] Correcting for multiple comparisons increases the *p-values* or lowers the acceptable value of the Type I error (α) at which the associated null hypotheses are rejected. As a result, estimates that are not significantly different from zero without correcting for multiplicity, will not be significant after correction. For more details on the theory of multiple comparisons see Hsu (1996).
[9] The reader may be curious as to why the Time main effect is not significant in Table A2, but is significant in Table A3. The test in Table A3 involves comparing the model in equation (A2) against a model where the particular effect is not included. Removing the Time variable for the comparison involves removing both main and interaction effects.

Plank = Plank effect (random effect, 76 levels)
Coating = Coating effect (fixed effect, 9 levels)
Time = Time effect (fixed effect, 2 levels)
*Coating*Time* = Coating-Time interaction effect (fixed effect 9*2=18 levels)
RandomError = Measurement effect (random effect, 304 levels=one per measurement)

Tables A4 and A5 present the parameter estimates and analysis of variance statistics for equation (A3). As in the last two tables, the control coating (Coating 6) and Time 1 (12 months) are the reference levels.

Table A4
Parameter Estimates for Equation (A3)

Effect	Estimate	Standard Error	Degrees of Freedom	t statistic	p-value
Intercept	2.0307	0.0737	67	27.54	<.0001
Coating 1	-1.6751	0.1043	219	-16.06	<.0001
Coating 2	-0.6923	0.1043	219	-6.64	<.0001
Coating 3	-0.4750	0.1043	219	-4.56	<.0001
Coating 4	-0.5347	0.1043	219	-5.13	<.0001
Coating 5	-1.1583	0.1043	219	-11.11	<.0001
Coating 7	-1.4756	0.1043	219	-14.15	<.0001
Coating 8	-0.6292	0.1043	219	-6.03	<.0001
Coating 11	-1.1739	0.1329	219	-8.83	<.0001
Time	-0.0327	0.0456	219	-0.72	0.4736
Coating 1 Time 24	0.2217	0.0645	219	3.44	0.0007
Coating 2 Time 24	0.6309	0.0645	219	9.78	<.0001
Coating 3 Time 24	0.5414	0.0645	219	8.39	<.0001
Coating 4 Time 24	0.5353	0.0645	219	8.30	<.0001
Coating 5 Time 24	0.7591	0.0645	219	11.77	<.0001
Coating 7 Time 24	0.9460	0.0645	219	14.67	<.0001
Coating 8 Time 24	0.3919	0.0645	219	6.08	<.0001
Coating 11 Time 24	0.2128	0.0822	219	2.59	0.0103

See notes for Table A2.

As expected, there is very little difference in the estimates between the two equations. The standard errors are slightly larger for the coatings, about the same for the Time main effect and slightly less for the Coating-Time interaction. The analysis of variance results for the fixed effects from the model without Schedule or Section effects (equation A3) are in Table A5. There are almost no differences in the value of the F-statistics between this table and the analysis of variance in Table A3, that shows the model that includes Schedule and Section effects (equation A2).

Table A5
Analysis of Variance for Equation (A3)

Effect	Numerator Degrees of Freedom	Denominator Degrees of Freedom	F statistic	p-value
Coating	8	219	48.97	<.0001
Time	1	219	729.72	<.0001
Coating * Time	8	219	39.71	<.0001

See notes for Table A2.

Statistical Analysis: Part 2, Comparing the Effectiveness among Coatings

The remainder of the formal statistical analysis is based on the model with Coating and Time main effects and Coating*Time interactions (equation A3).

Table A6 provides estimates of the percent of arsenic relative to the baseline amount for each of the coatings at 12 months and 24 months. This table also contains simultaneous (or experiment-wise) 95 percent confidence intervals from the Scheffé method (Hsu, 1996, pages 14-16, 130-132). This method allows comparing any confidence interval against any other confidence interval (across time or between coatings), while keeping the experiment-wise Type I error probability at $\alpha=0.05$.[10] Another way to put this is that the confidence intervals are corrected for multiple comparisons. Confidence intervals were computed in the log 10 scale, then transformed back to the original scale, i.e., the baseline adjusted dislodgable arsenic in percent. Figure A7 provides a graphical version of the estimates and confidence intervals of Table A6.

[10] In comparing two confidence intervals, if two $(1-\alpha/2) * 100\%$ confidence intervals do not overlap, then the estimates are significantly different from each other with a Type I error probability of α. However, overlapping intervals may also be statistically significantly different at the same value of α. A statistical test of the differences is presented later in this report in Table A7.

Table A6
Percent of Arsenic Relative to the Amount Present at Baseline
Measured at 12 and 24 Months

	12 Months		24 Months	
Coating	Estimate	95% CI	Estimate	95% CI
6 (No Coating)	107.336	43.445, 265.185	99.542	40.291, 245.929
1	2.268	0.918, 5.603	3.504	1.418, 8.658
2	21.801	8.824, 53.862	86.436	34.986, 213.549
3	35.957	14.554, 88.834	116.004	46.954, 286.601
4	31.333	12.683, 77.413	99.661	40.339, 246.223
5	7.455	3.018, 18.419	39.703	16.07, 98.091
7	3.590	1.453, 8.87	29.404	11.901, 72.645
8	25.209	10.204, 62.283	57.641	23.331, 142.408
11	7.192	1.852, 27.929	10.886	2.803, 42.274

Notes: Estimates computed from equation (A3). Standard errors computed in Proc Mixed (SAS, 2004) as shown in Table A4. Confidence intervals corrected for multiple comparisons using the Scheffé method. The computation is based on 17 and 219 degrees of freedom and evaluates to 5.328. The corresponding normal distribution theory 95% confidence interval multiplier that is not corrected for multiple comparisons is 1.96.

As noted earlier, the comparison of confidence intervals between coatings in Table A6 does not provide an accurate statistical test of the null hypothesis that the two coatings are the same. This is done with a formal hypothesis test. The setup for the test is as follows:

$$H_0 \text{ (null hypothesis): } \mu_{control} \leq \mu_{coating}$$
$$H_a \text{ (alternate hypothesis): } \mu_{control} > \mu_{coating}$$

where μ is the population mean amount of dislodgeable arsenic relative to baseline in percent for a particular coating. The alternate hypothesis expresses the idea that the coating has reduced the amount of arsenic more than the control. Accordingly, the test is one-tailed with the rejection region in the upper tail. The population means are estimated from the parameter estimates in the regression model given by equation (A3) and as labeled "estimate" in Table A6. As these estimates are derived from a model using base 10 logs, the test statistic is proportional to $Estimate_{control}$ divided by $Estimate_{coating}$ rather than proportional to $Estimate_{control}$ minus $Estimate_{coating.}$ The test statistic is compared to the quantile of the *F* distribution adjusted for multiple comparisons (Scheffé method) and the p-value is then computed. Most analysts regard p-values that are less than 0.05 as statistically significant.

Table A7
Comparison of Coating Effectiveness at 12 and 24 Months with Control

CPSC ID (coating)	12 Months Estimate	12 Months Control/ Estimate	12 Months p-value	24 Months Estimate	24 Months Control/ Estimate	24 Months p-value
6 (control)	107.336			99.542		
1	2.268	47.326	<0.0001	3.504	28.406	<0.0001
2	21.801	4.923	0.0004	86.436	1.152	0.5000
3	35.957	2.985	0.1249	116.004	0.858	0.5000
4	31.333	3.426	0.0403	99.661	0.999	0.5000
5	7.455	14.397	<0.0001	39.703	2.507	0.3097
7	3.590	29.895	<0.0001	29.404	3.385	0.0451
8	25.209	4.258	0.0033	57.641	1.727	0.4984
11	7.192	14.924	<0.0001	10.886	9.144	<0.0001

Notes: Estimates are from equation (A3) and are in percent of arsenic relative to the amount present prior to coating. Based on n=304 measurements.

In table A7, the second column under each period shows the estimate for the control coating divided by the estimate for the other coating (labeled as Control/Estimate). For example, for Coating 1, in the first 12 month period, the ratio of the control coating to that coating was (107.336/2.268 =) 47.326, indicating that on average there was about $1/47^{th}$ the relative amount of arsenic in wood coated with Coating 1 than Control at the end of 12 months. In this table, large numbers for the Control/Estimate ratio indicate that the particular coating resulted in a substantial reduction in the available arsenic as compared to the control.

The results in Table A7 indicate that in the first 12 months, all coatings except Coating 3 resulted in a statistically significant reduction in arsenic. Coating effectiveness, as shown in figures A3 and A4, began to decline during the 24 months. At the end of that period, only Coatings 1, 7 and 11 continued to provide statistically significant reductions as compared with the control coating, Coating 6.

The final set of tables compares coatings among each other. Like Table A7, the statistic shown in the tables is the ratio of coatings, although in these tables, the ratio is the row coating divided by the column coating. For example, in Table A8, the first entry, 0.104 , is the result of dividing the row coating arsenic percent (Coating 1 at 2.268) by the column coating percent (Coating 2 at 21.801). The form of the null hypothesis is different from the way that the null hypothesis was previously stated and then tested in Table A7. This is because coatings can be different in two ways (a) either the row coating has larger arsenic values than the column coating or (b) the row coating has smaller values than the column coating. Accordingly the null and alternate hypotheses are as follows:

$$H_0 \text{ (null hypothesis): } \mu_{\text{row coating}} = \mu_{\text{column coating}}$$

H_a (alternate hypothesis): $\mu_{\text{row coating}} \neq \mu_{\text{column coating}}$

Similar to the previous tests, the test statistics are proportional to $\text{Estimate}_{\text{row coating}}$ divided by $\text{Estimate}_{\text{column coating}}$ and are again adjusted for multiple comparisons using the Scheffé method. However as the form of the null hypothesis has changed, these tests are required to be two-tailed rather than one tail as used previously when comparing various coatings with the control uncoated minideck.

Table A8
Comparison of Effectiveness among Different Coatings
Estimates of Arsenic for Each Coating Divided by Estimates for Other Coatings
12 Months

	Comparison Coating (Estimate)							
Coating	***1*** (2.268)	***2*** (21.801)	3 (35.957)	***4*** (31.333)	***5*** (7.455)	***7*** (3.590)	***8*** (25.209)	***11*** (7.192)
1	-	***0.104***	***0.063***	***0.072***	0.304	0.632	***0.090***	0.315
2		-	0.606	0.696	2.924	***6.072***	0.865	3.031
3			-	1.148	***4.823***	***10.015***	1.426	5.000
4				-	***4.202***	***8.727***	1.243	4.357
5					-	2.077	0.296	1.037
7						-	***0.142***	0.499
8							-	3.505
								-

Notes: Column and row labels refer to coatings. Labels in ***bold italics*** indicates the coating is significantly different from control at $p<0.05$, one tail test as shown in Table A7. Entries in the body of the table in ***bold italics*** indicate significant differences between coatings at $p<0.05$. Tests are two-tailed, corrected for multiple comparisons using the Scheffé method.

Table A8 shows results for 12 months. As shown in table A7, only Coating 3 (not bold italic above in Table A8) was not statistically significantly different from control at 12 months. Among the coatings that were significantly different from control at 12 months, Table A8 shows that Coating 1 was significantly different (better) than Coatings 2, 3, 4 and 8; Coating 7 was significantly better than Coatings 2, 3 and 4 and 8; and Coating 5 was significantly better than Coatings 3 and 4. Although Coating 11 had the third smallest relative proportion of dislodgeable arsenic, that coating was not significantly better than or worse than any other coating. Recall that Coating 11 had fewer samples collected than the other coatings.

Table A9
Comparison of Effectiveness among Different Coatings
Estimates of Arsenic for Each Coating Divided by Estimates for Other Coatings
24 Months

	Comparison Coating (Estimate)							
Coating	***1*** ***(3.504)***	2 (86.436)	3 (116.004)	4 (99.661)	5 (39.703)	***7*** ***(29.404)***	8 (57.641)	***11*** ***(10.886)***
1	-	***0.041***	***0.030***	***0.035***	***0.088***	***0.119***	***0.061***	0.322
2			0.745	0.867	2.177	2.940	1.500	***7.940***
3				1.164	2.922	***3.945***	2.013	***10.656***
4					2.510	3.389	1.729	***9.155***
5						1.350	0.689	3.647
7							0.510	2.701
8								***5.295***

See notes for table A8.

Table A9 shows the results for 24 months. Only three coatings, Coating 1, 7 and 11 were statistically lower than controls, as shown in Table A7. Note that Coating 1 was significantly lower than all other coatings except coating 11. Coating 11 was significantly lower than coating 2, 3, 4 and 8. Coating 7, was significantly greater than Coating 1, and lower than Coating 3.

To summarize the 24 month results from Tables A7 and A9, Coatings 1, 7 and 11 provided statistically significantly better protection than control. Coating 1 was significantly better than Coating 7, but not significantly better than Coating 11. Coating 11 in turn, was not significantly better than Coating 7.

The results from the two minidecks constructed of untreated wood (negative controls) were analyzed to determine if there were any sources of arsenic other than the CCA-treated wood that would affect the results. Figure A9 displays the results for the two untreated (non-CCA)-wood minidecks. Deck 8 was not coated. Six of the nine planks of Deck 9 were coated with one of the distinct coatings evaluated on the CCA-treated-wood minidecks. Many of the measurements for the two minidecks were below the detection limit. As mentioned above, such measurements were assigned the value of 0.2 μg. For the two minidecks, the two highest measurements throughout the year were 5.2 μg and 2.1 μg. The mean value over all the measurements, including the re-assignment of values below the detection limit, was 0.47 μg. This indicated that there were no practically significant sources of arsenic aside from the CCA treatment.

Discussion

Seven of the eight coated CCA-treated minidecks had statistically lower values of baseline adjusted arsenic at 12 months as compared with the positive control deck. These minidecks were those finished with Coatings 1, 2, 4, 5, 7, 8 and 11. The CCA-treated minideck finished with Coating 1 had the lowest estimated value relative to baseline, although it was not statistically different from coating 11. Coating 11 had the third lowest estimated value relative to baseline, although it was not statistically different from those of CCA-treated minidecks finished with the other coatings at 12 months.

The estimated dislodgeable values at 24 months, as shown in Table A7, were higher than those at 12 months for all eight coatings, indicating that the coatings were wearing out to some extent. Still at 24 months, there were statistically significant reductions in dislodgeable arsenic from Coatings 1, 7 and 11. Coating 1 was significantly lower than coating 7, but not significantly lower than coating 11.

The measurements on the positive and negative controls helped in interpreting the data. For the uncoated minideck (Coating 6) the estimated values at 12 months and 24 months were similar to the amount of arsenic measured before coatings. The amount of arsenic did not vary significantly between 12 and 24 months. The values for the non-CCA-treated minideck were very low, implying no practically important sources of arsenic outside the CCA-treated wood.

The experiment made use of boards from a single source of wood and entailed natural weathering at a single location in Maryland (see Materials and Methods section). No mechanical wear representing usage of the minidecks was employed. Therefore, caution must be used in generalizing the results to other wood sources, weathering conditions, and wear conditions. However, the results should provide information on the relative effectiveness of various coatings, particularly in conjunction with the results of the parallel EPA experiment.

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Figure A3: Geometric Mean Baseline Adjusted Dislodgeable Arsenic over Time by Coating.

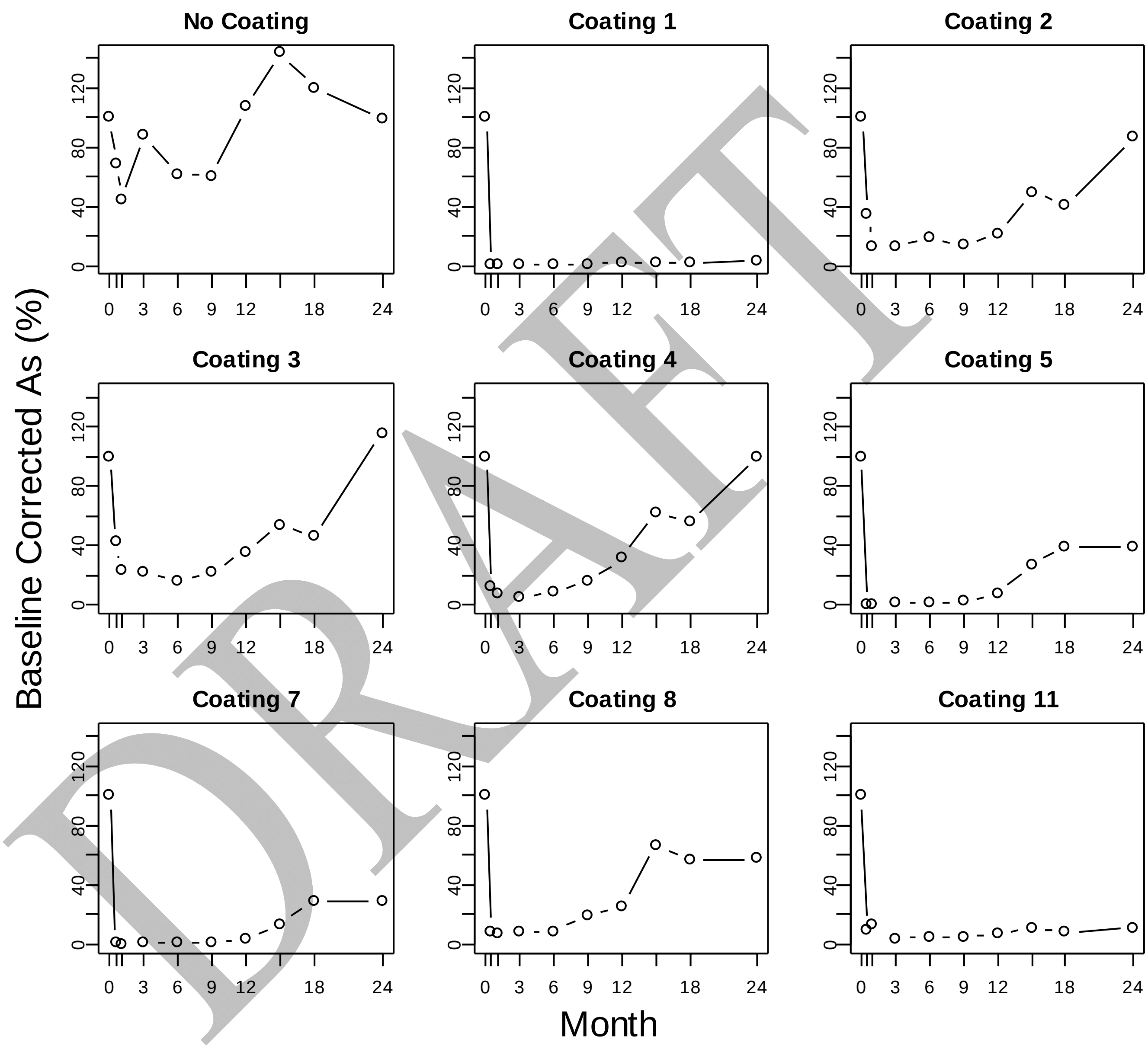

Figure A4: Geometric Mean Baseline Adjusted Dislodgeable Arsenic over Time by Coating (Log Scale).

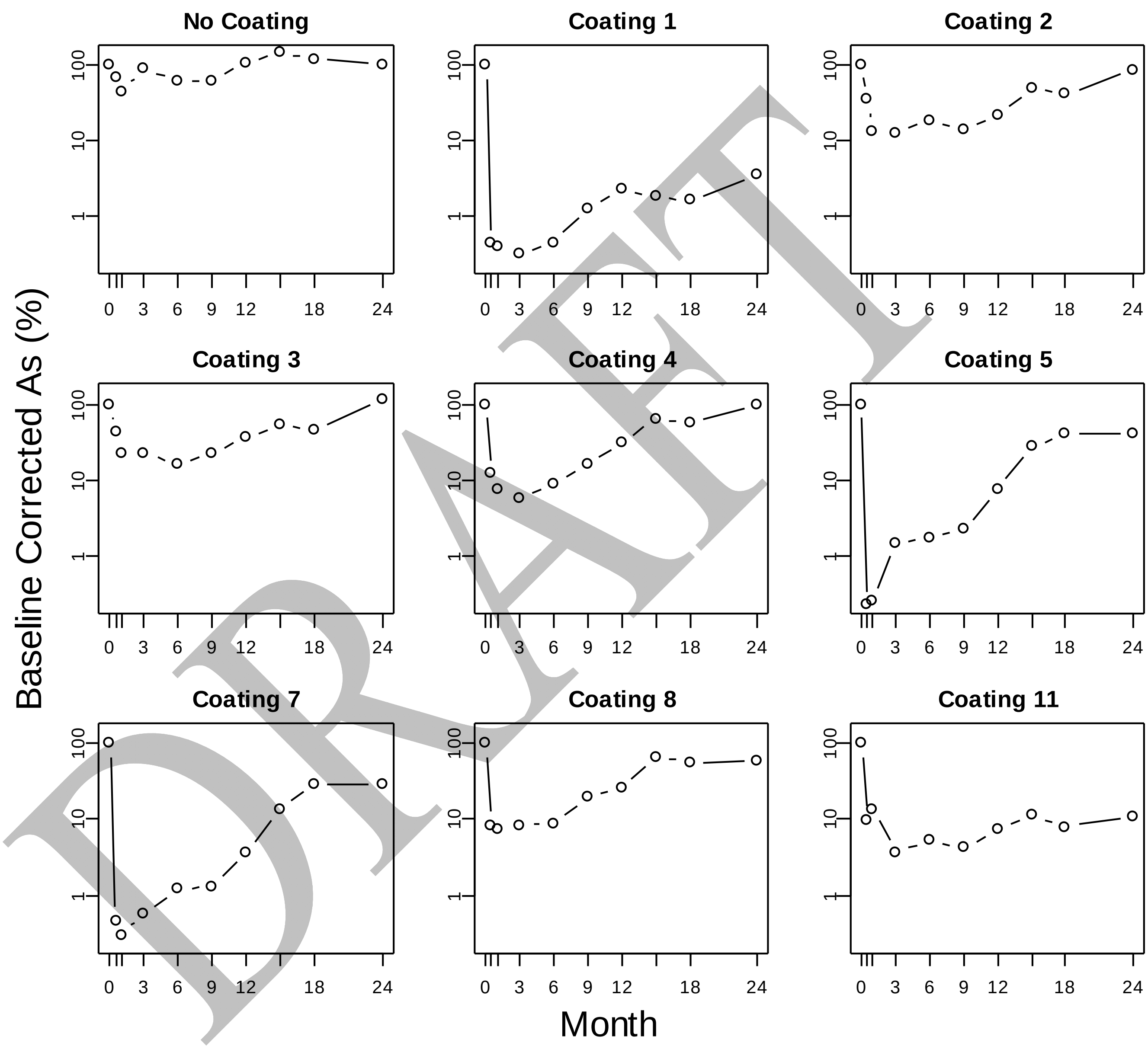

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Figure A5: Baseline Adjusted Dislodgeable Arsenic at 24 Months by Section and Coating (Log Scale). Section 1 = west section; Section 2 = east section. **Note**: Coating 11 was applied to only four planks.

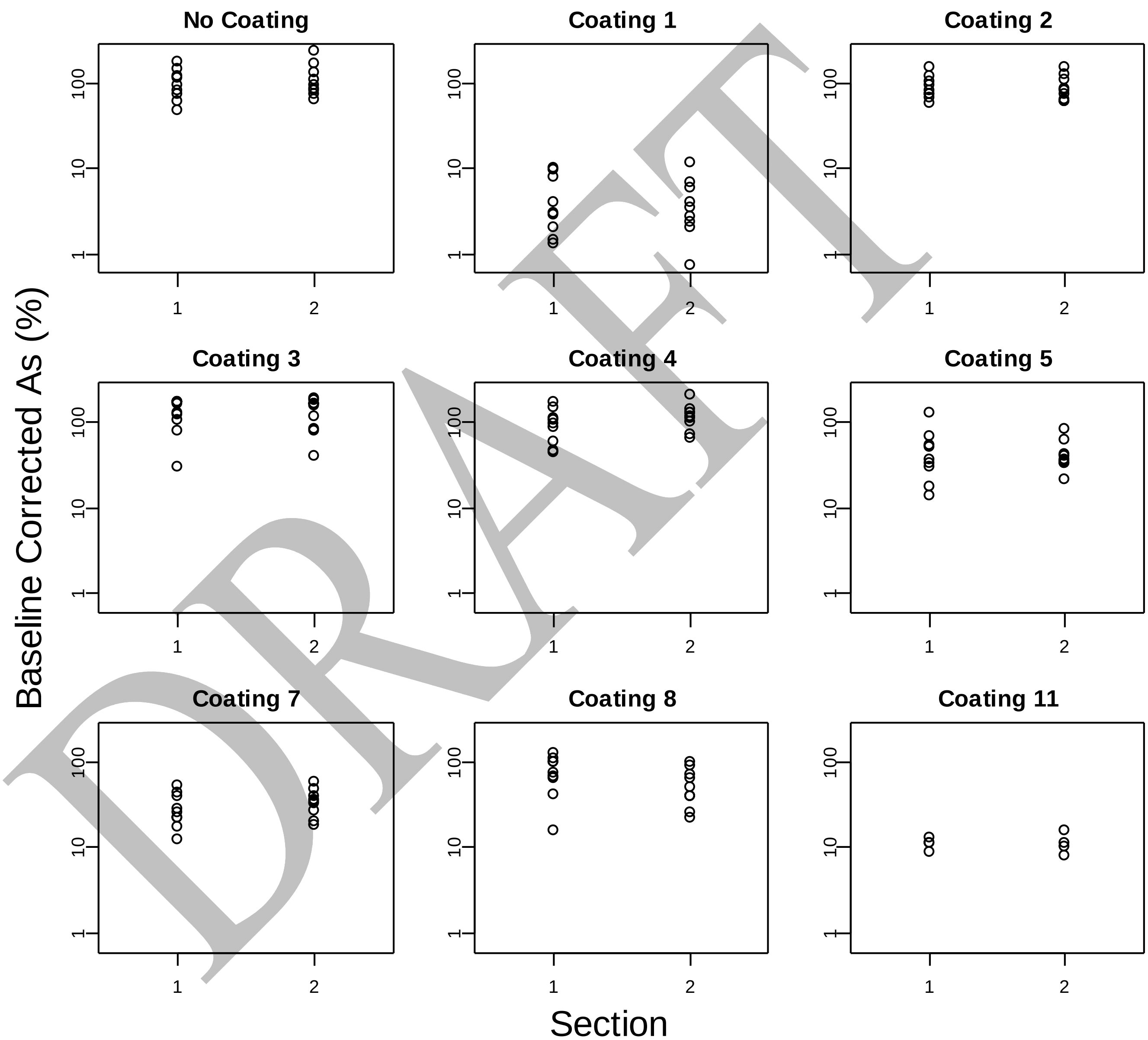


Figure A6: Baseline Adjusted Dislodgeable Arsenic at 24 Months by Schedule and Coating (Log Scale). **Note**: Sampling for coating 11 followed only schedules 1 and 2.

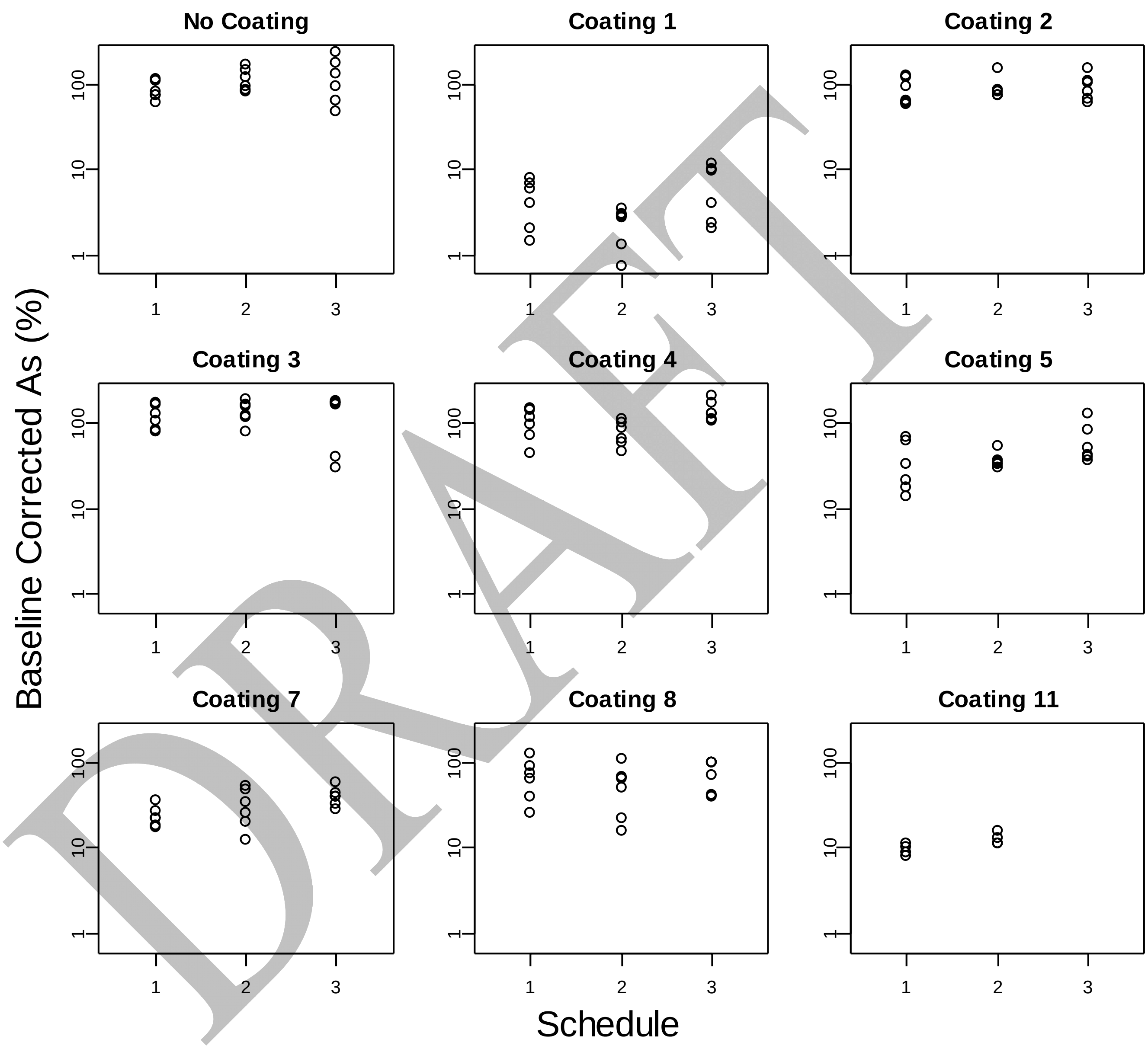


Figure A7: Coating Effectiveness (percent of arsenic relative to the amount present prior to coating) at 12 Months and 24 Months.

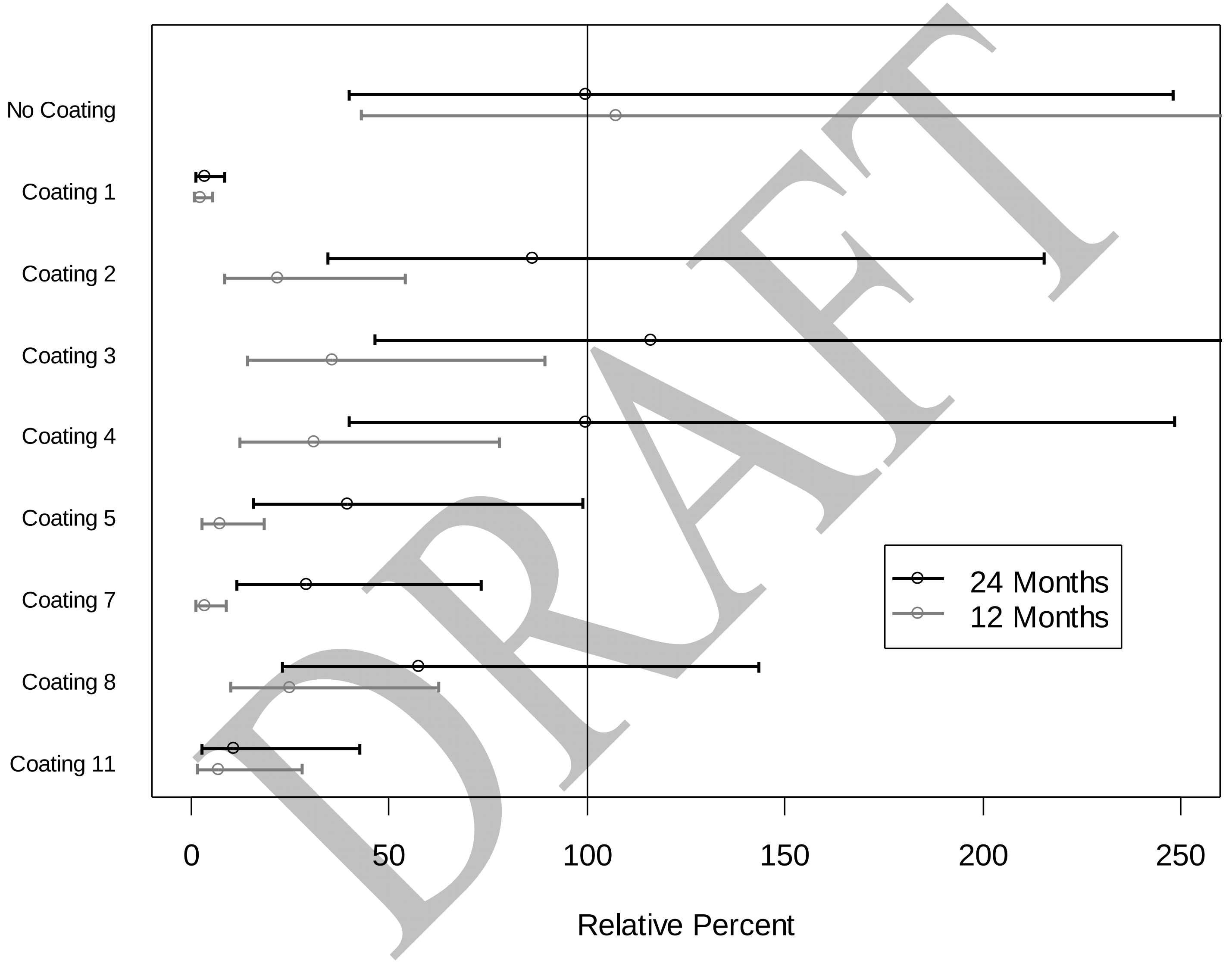
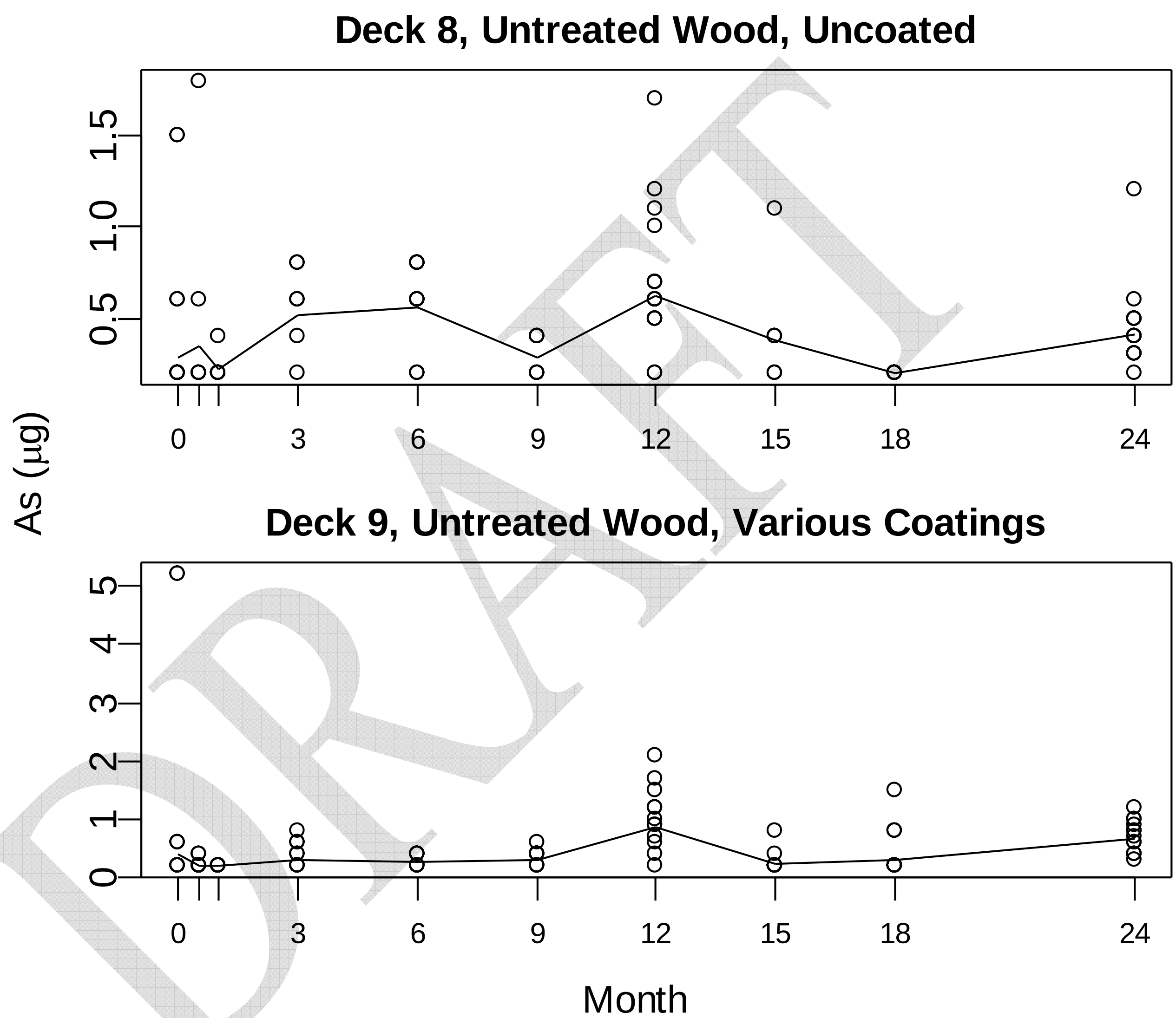


Figure A9: Dislodgeable Arsenic for Untreated Minidecks.



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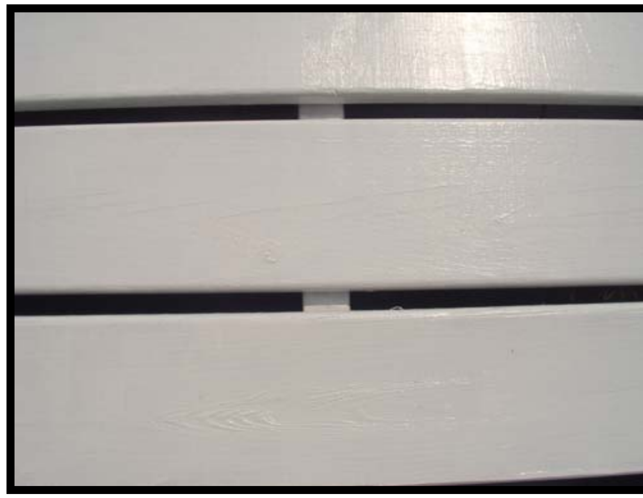
Minideck Photos **TAB B**

Coating 1

2 week



12 months

24 month

Coating 2

2 week

12 months

24 months

Coating 3

2 week

12 months

24 months

Coating 4

2 week

12 months

24 months

Coating 5

2 week

12 months

24 months

Coating 7

2 week

12 months

24 months

Coating 8

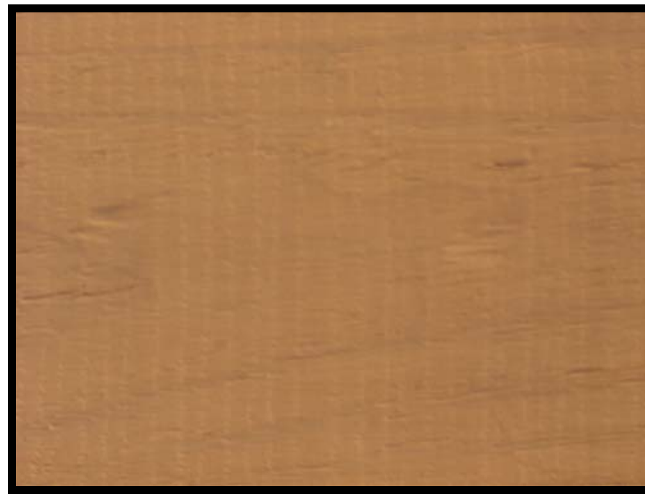
2 week

12 months

24 months

Coating 11

3 months



12 months

24 months

No Coating
CCA

2 week

12 months

24 months

No Coating, Non-CCA

2 week

12 months

24 months

Coated, Non-CCA

2 week

12 months

24 months