A Integrated Studies of the Dynamics of Arsenic Release and Exposure From CCA-Treated Lumber@

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Abstract

Public health concern has increased greatly in the past few years regarding arsenic (As) exposure from direct and indirect contact with CCA lumber due to the realization that As is a far more potent human carcinogen than previously extrapolated from laboratory animal studies. Various national field survey and laboratory studies currently in progress at the Environmental Quality Institute (EQI) do not find a statistically significant relationship between CCA lumber service age and As dislodgement after the first few months of use. Various treatments reduce As dislodgement; however, the effectiveness of water sealants or water-proofing materials appear to last for only about six months, while stains and paints exhibit As-reduction properties through about two years of outdoor exposure.

Clearly, there is a need for CCA lumber treatments which will contain As within the wood for much longer time periods. Several candidate materials are currently under investigation at the EQI using an outdoor accelerated aging set-up involving mirror-intensified sunlight and heat, frequent simulated rainfall and intensive foot traffic. Based on preliminary experimental results and extensive direct observation, we believe that the most effective treatments must include both a penetrant/water repellent material as well as a surface crack sealant.

Keywords: arsenic exposure, CCA lumber, arsenic dislodgement

I. BACKGROUND AND INTRODUCTION

A. Why The Sudden Concern About Arsenic?

For about the past 30 years most lumber sold for outdoor use in North America has been treated with chromated copper arsenate (CCA) to resist insect and fungal decay. Although it has long been recognized that some amount of direct or indirect human arsenic (As) exposure would be associated with the widespread use of CCA lumber, the public health concern has escalated in recent years with the discovery that As is a far more potent skin, bladder, lung and kidney carcinogen than previously believed [1,2]. It is now recognized that inorganic As is one of the relatively rare carcinogens whose cancer potency is much less for laboratory test animals than for humans [3]. In fact, recent epidemiological studies in Bangladesh, Taiwan and Chile, where in individual villages there exists a high and variable range of inorganic As levels in drinking water, have established that inorganic As is approximately 100-200 times greater lung, bladder and kidney cancer risk than extrapolated from laboratory animal studies [1-4].

Also of concern are recently emerging medical studies such as Moore, et al [5] which indicate that inorganic As is not only a potent human carcinogen itself, but also that even very small As exposures cause existing human cancer tumors to grow more rapidly and aggressively. These researchers are finding increased tumor growth rate and significantly lower survival rates for cancer patients with higher As exposure from their environment.

B. Current Cancer Risk Estimates From Contact With CCA Lumber

In 2003 the Environmental Risk Management Authority of New Zealand conducted an extensive independent review of CCA-related cancer risk estimate studies [6] which included five major studies conducted subsequent to the updated As human cancer potency factor developed by the National Academy of Science's Natural Research Council in 2001 [2]. The lifetime cancer risk estimates of these five studies can be briefly summarized as follows: Roberts and Ochoa [7] estimate 502 per million population for skin cancer only; the Gradient Corporation [8] estimates about one per million for skin cancer only; Sharp et al [9]: about 2000 per million population for lung and bladder cancer only; Maas et al [10]: about 1000 per million population for lung and bladder cancer only; and the US

Consumer Products Safety Commission [1]: 51 lung and bladder cancers per million population. The variation of estimated lifetime cancer risks between these studies is considerable and can probably be attributed to: 1) inclusion/exclusion of different types of cancers; 2) degree to which the newest NRC human cancer potency estimates have been incorporated into the estimate or model; 3) different assumptions regarding the amount and timing of contact with CCA lumber; 4) different assumptions of the amount of As transferred per unit contact; and 5) differences in direct and indirect hand-to-mouth ingestion ratios.

All of the afore-mentioned recent studies of As exposure from CCA lumber, including our own at the EQI, have been limited by factors such as: 1) the CCA lumber used was either new or from a very limited number of geographically proximate sites; 2) they have not included reliable estimates of the effectiveness of various stains and sealants over time; and 3) with the partial exception of the recent CPSC study [1], measurements of dislodgeable As have been based on various wipe/swipe methods as opposed to more realistic actual skin contact. Thus, there has been very little data from which to compare As exposures calculated from wipe data with actual hand/skin contact exposure.

Our current research in progress is designed to address these previous experimental limitations by a) testing As dislodgement from over 800 different residential sites representing a wide range of lumber service ages, climate conditions, structure types, and sealant/stain histories, b) specifically comparing standard wipe results with actual handling transfer on adjacent sections of the same CCA boards, and c) determining through controlled outdoor test site experiments the effectiveness over time of various commercially-available and experimental water sealants and stains in reducing As dislodgement.

II. METHODS

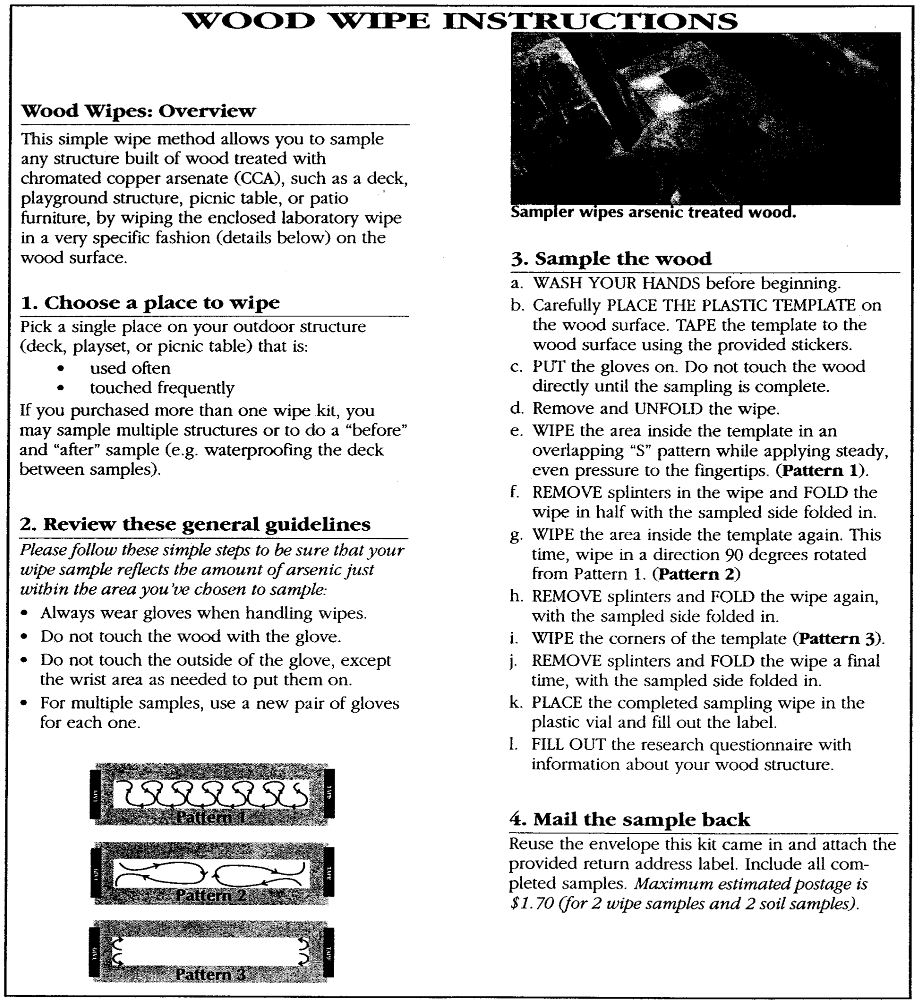
As noted above, the research reported herein encompasses three types of experiments intended to increase the current understanding of As exposure from CCA lumber. These include: a) an ongoing nationwide study of As dislodgement from various in-service CCA structures using samples collected by volunteer participants with a standard wipe-sample kit with sampling templates and detailed instructions; b) controlled experiments comparing arsenic dislodgement on standard wipes versus actual handling transfer; and c) natural and accelerated weathering experiments to determine the As-retainment effectiveness of various commercially-available and experimental CCA wood sealants.

A. National Field Survey Study

Through a wide range of local, regional and national news articles and public service announcements, interested individuals have been alerted to the opportunity to test the As dislodgement from their own CCA structures for a nominal fee as part of this research project. The CCA surface research test kit consists of a thin plastic template which, when taped to the desired CCA lumber surface, delineates an exact 100 cm^2 area (5 cm x 20 cm) for wiping with a standard laboratory Ghost-Wipe™ . The research test kit also includes a pair of disposable laboratory gloves worn during the sample collection, a 50 mL laboratory hot-block digestion vial for storing and returning the test wipe, appropriate sample labeling materials, detailed and illustrated sampling instructions (see Figure 1), and a research questionnaire asking for the type of information listed in Table 1.

Volunteer study participants are instructed to wipe the standard 100 cm^2 surface area by the US EPA/HUD method for dust-wipe lead abatement clearance testing. This procedure specifies wiping across the lumber test surface with a horizontal and vertical “S” pattern followed by a spot wipe of each corner of the exposed rectangle, folding in the wipe after each of the three wipe passes. The folded Ghost-Wipe™ is then placed directly into the labeled hot-block digestion vial, so that no further handling or sample transfer will be required for subsequent digestion and As analysis. All samples and research questionnaires are then returned directly to the EQI laboratory for hot-block

HNO_3 – H_2O_2 digestion and arsenic quantification by graphite furnace atomic absorption spectrophotometry using NIOSH Modified Method 7082 [11]. Although the results are not included in this report, volunteer research participants were also given the option of taking soil samples for As analysis under and/or adjacent to the CCA structure as well as from a background control location at least 10 feet away and not down-gradient from the structure.



WOOD WIPE INSTRUCTIONS

Wood Wipes: Overview

This simple wipe method allows you to sample any structure built of wood treated with chromated copper arsenate (CCA), such as a deck, playground structure, picnic table, or patio furniture, by wiping the enclosed laboratory wipe in a very specific fashion (details below) on the wood surface.

1. Choose a place to wipe

Pick a single place on your outdoor structure (deck, playset, or picnic table) that is:

- used often
- touched frequently

If you purchased more than one wipe kit, you may sample multiple structures or to do a "before" and "after" sample (e.g. waterproofing the deck between samples).

2. Review these general guidelines

Please follow these simple steps to be sure that your wipe sample reflects the amount of arsenic just within the area you've chosen to sample:

- Always wear gloves when handling wipes.
- Do not touch the wood with the glove.
- Do not touch the outside of the glove, except the wrist area as needed to put them on.
- For multiple samples, use a new pair of gloves for each one.

Pattern 1

Pattern 2

Pattern 3

Sampler wipes arsenic treated wood.

3. Sample the wood

a. WASH YOUR HANDS before beginning.
b. Carefully PLACE THE PLASTIC TEMPLATE on the wood surface. TAPE the template to the wood surface using the provided stickers.
c. PUT the gloves on. Do not touch the wood directly until the sampling is complete.
d. Remove and UNFOLD the wipe.
e. WIPE the area inside the template in an overlapping "S" pattern while applying steady, even pressure to the fingertips. (**Pattern 1**).
f. REMOVE splinters in the wipe and FOLD the wipe in half with the sampled side folded in.
g. WIPE the area inside the template again. This time, wipe in a direction 90 degrees rotated from Pattern 1. (**Pattern 2**)
h. REMOVE splinters and FOLD the wipe again, with the sampled side folded in.
i. WIPE the corners of the template (**Pattern 3**).
j. REMOVE splinters and FOLD the wipe a final time, with the sampled side folded in.
k. PLACE the completed sampling wipe in the plastic vial and fill out the label.
l. FILL OUT the research questionnaire with information about your wood structure.

4. Mail the sample back

Reuse the envelope this kit came in and attach the provided return address label. Include all completed samples. *Maximum estimated postage is $1.70 (for 2 wipe samples and 2 soil samples).*

Figure 1 **B**rochure Wood Wipe Instructions

Table 1 Information requested on CCA lumber research questionnaire

- Lumber surface orientation (i.e. horizontal, vertical, inclined)
- Exposure to sun (% of the day)
- Exposure to rain (yes/no)
- Location on structure (i.e. handrail, decking, seat, etc.)
- Type of structure (i.e. picnic table, play set, deck, etc.)
- Age of structure (years, months)
- Purchase location (store and city)
- Brand of CCA lumber (i.e. Osmose, TP, etc.)
- Lumber moisture condition at sampling time (dry, moist, wet, very wet)
- Last sealant/stain treatment (i.e. none, water sealant, stain, paint, unknown)
- Time since last treatment (months or years)
- Estimated average child use (minutes or hours per week)
- Estimated average adult use (minutes or hours per week)

Statistical analysis of the field survey data consisted of applying a general linear model to the log-transformed arsenic values to examine which of the factors mentioned above are statistically significant in the presence of all the other factors. Confidence intervals for the median arsenic amounts for each level of each factor were calculated by reverse-transforming results from the linear model back to the original units. Statistical significance for a given factor is declared when the individual p-value from the linear model is less than 0.05.

B. Wipe Handling Contact and Arsenic Dislodgement Relationships

The purpose of these experiments is to correlate arsenic dislodgement to wipes with arsenic transferred to hands from typical lumber surface contact and to examine the relationships between surface area contacted and As dislodged. CCA boards were marked off in randomized section pairs. These template-marked sections were then wiped by either the EPA/HUD or CPSC method, while the immediately adjacent section was wiped with a single pass of the bare hand. The dislodged As was then immediately removed from the bare hands by wiping them thoroughly with a clean laboratory wipe followed by a rinsing with 5% acetic acid and combining the rinsate with the wipe as a single sample for subsequent digestion. Repeated post-testing documented that this procedure removed virtually all As from the hands. Coordinated experiments simultaneously examined the relationship between total board surface area contacted and mass of As dislodged.

C. Natural Accelerated Sealant Effectiveness Study

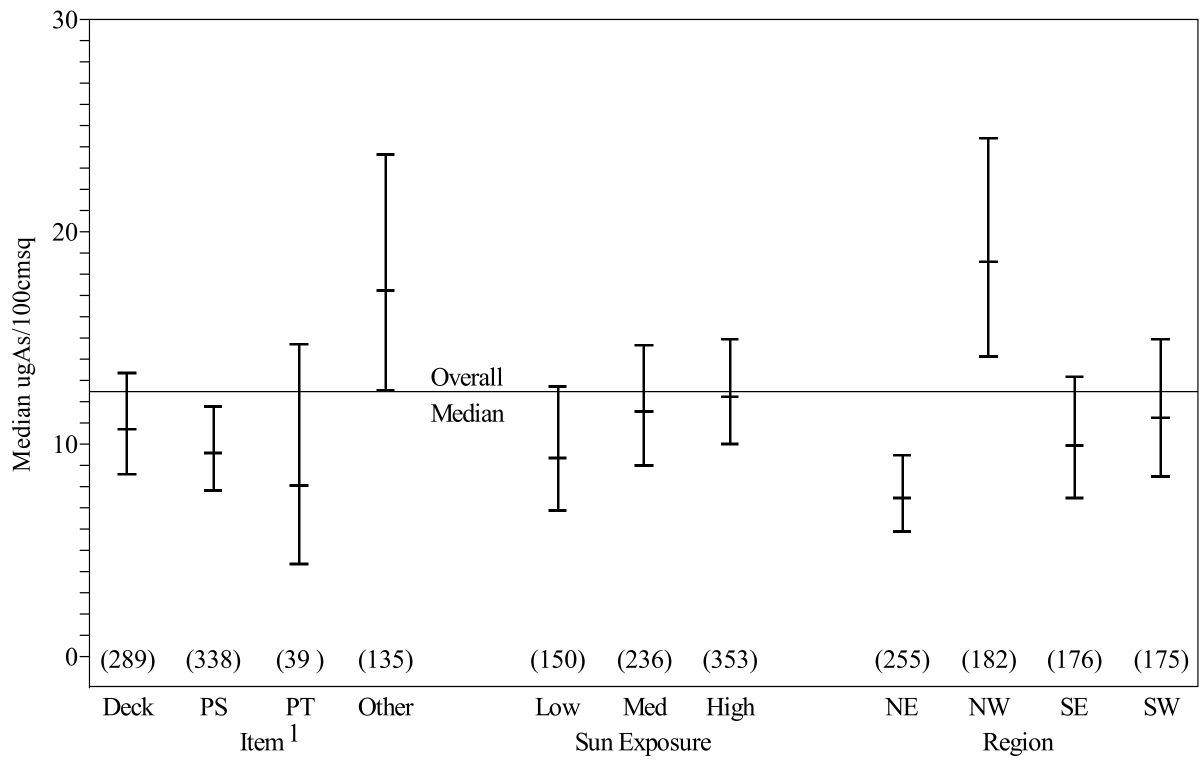
These recently initiated experiments involve treating new and aged CCA lumber with various commercially-available or experimental/proprietary materials. The lumber surfaces are then weathered outside under either natural or accelerated conditions. The weathering acceleration is accomplished by the combination of a) mirrors to reflect and intensify day time sunlight and heat onto the exposed lumber surface; b) a simulated rainfall cycle to increase the number of precipitation/evaporation cycles experienced by the test lumber; and c) almost daily controlled foot-traffic abrasion which we believe will have a major influence on the As-reduction longevity of typical sealants and stains.

III. CURRENT RESULTS AND DISCUSSION

A. National Field Survey Study

The database is constantly being expanded by the inclusion of additional voluntary participant sites. The results shown here were presented in New Zealand in June 2003 [12]. Slightly over 800 sites are included in the analysis and, as shown in Table 2, each of the four major geographic quadrants of the United States are represented with approximate weight of its relative population. The mean As dislodgement mass (AsDM) across all CCA surface types, service ages, geographic areas, and treatment types is just under 64 µg/100 cm^2 with a median AsDM of 12.2 µg/100 cm^2. Table 2 shows the percent of samples which fall into designated AsDM categories for various CCA lumber types and conditions. From Table 2 it can be seen that typically between about 15% and 30% of samples had AsDM values in excess of 50µg/100 cm^2 with the exception of CCA lumber which had been water-sealed, stained or painted within the previous six months.

Figures 2 and 3 [12] show estimated medians and 95% confidence limits for various lumber conditions. From Figure 2 it can be seen that the As released from decks, play sets and picnic tables was similar while the "other" category which included miscellaneous structures such as handrails, columns, garden borders, gazebos, etc. tended to release higher amounts of As (median ≈ 17.0 µg/100cm^2). The amount of sun exposure appears to have some effect on the AsDM, with low sun exposure associated with lower As dislodgement measurements. One striking result shown in Figure 2 is that CCA surfaces sampled in the Northwest US are releasing significantly more As (median ≈ 18.5 µg/100 cm^2) than samples from the other regions (median ≈ 9.7 µg/100 cm^2).

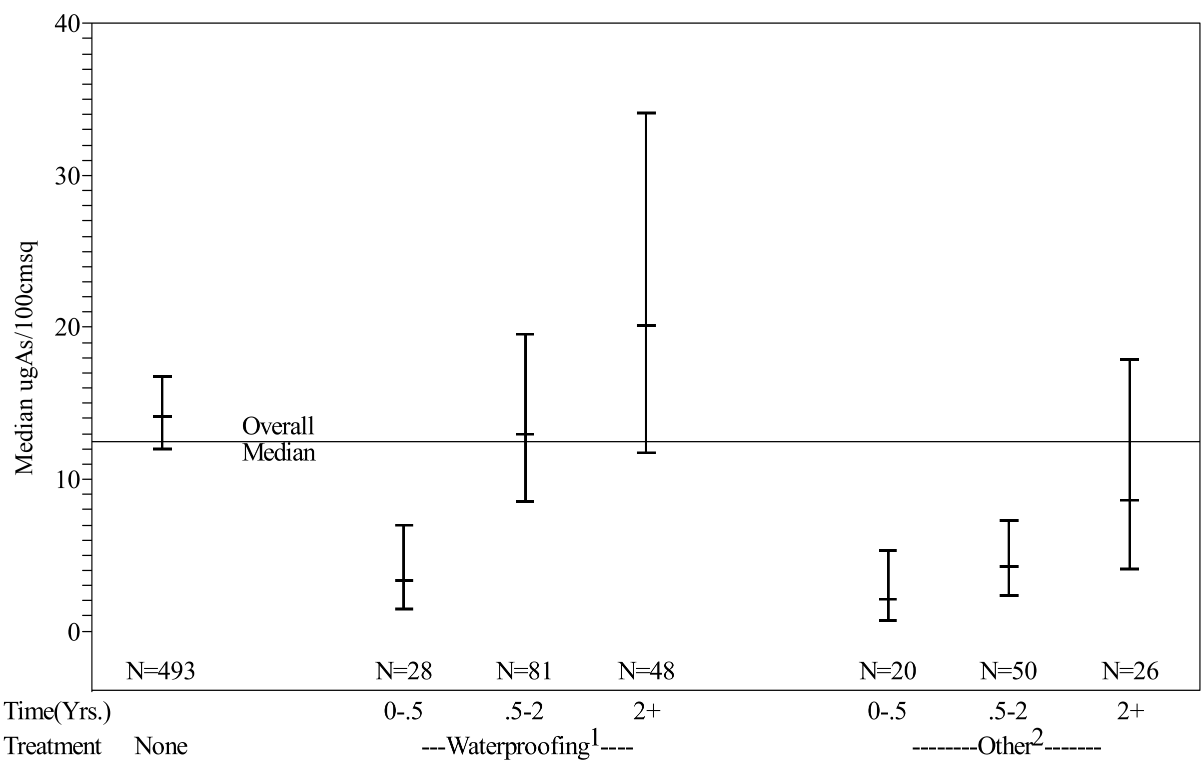


1 - PS=Playsets, PT=Picnic Tables

Figure 2 Estimated median As per 100 cm^2 and 95% individual confidence limits for significant effects with sample size in parenthesis.

Figure 3 illustrates results pertaining to the effectiveness of water sealants, stains and paints over time. Unfortunately, at this point in the study it is necessary for us to combine stains, paints, polyurethane and combinations into one treatment category in order to increase the sample size sufficiently to achieve a reasonable 95% confidence limit. As our national field survey sample size increases, it should become possible to break out various stains, paints and urethane treatments to statistically determine their individual As encapsulation effectiveness over time. A large part of the current information limitation stems from the fact that 66% of the study participants have never applied any type of sealant or coating to their CCA structure.

As shown by Figure 3, the waterproofing type materials were associated with reductions in As dislodgement for the first 0.5 years after application (reduction in median AsDM of about 74%); however, the effect disappears in the 0.5 – 2.0 year age-since-application category. After 2.0 years the median As release is actually higher than for CCA lumber that has never been treated. These results are consistent with those of Stillwell and Gorney [13], who found no statistical difference between As dislodged from CCA lumber treated with water repellents and CCA lumber with no treatment when samples were taken one year after the water repellent application. In the case of the combined stain, paint, polyurethane treatment, As release appears to be reduced for about two years on average with a mean reduction in median AsDM of approximately 69% during the period. The 31% decrease compared to the overall study median for treatment intervals greater than two years is not statistically significant based on the currently relatively small sample [12], but may be found to be statistically significant as the survey study population continues to grow. Clearly more research and product development is needed to address the critical issue of whether As can be contained for extended periods by some type of treatment of existing CCA lumber structures.



1-Waterproofing=Waterseal,Waterproofing; 2-Other=Stains,Paints,Polyurethane,Combination

Figure3 Estimated median As per 100 cm^2 and 95% individual confidence limits for different treatments and time since treatment applied.

Table 2 Arsenic amounts on wipes by types of sample for field study

			% of Samples with As Amount		
		n	***0-10 µg/100 cm²***	***10-50 µg/100 cm²***	***> 50 µg/100 cm²***
Age	0-1 years	130	50.0	31.5	18.5
	1-5 years	311	45.0	27.7	27.3
	> 5 years	316	44.6	34.1	21.1
Treatment and Years Since Treatment (WS= Waterseal) (Other = Paint, Stain, PolyUr., etc.)	None	493	39.8	32.3	28.0
	WS 0-0.5	28	78.6	17.9	3.6
	WS 0.5-2	81	44.4	30.9	24.7
	WS 2+	48	29.2	45.8	25.0
	Other 0-0.5	20	85.0	5.0	10.0
	Other 0.5-2	50	76.0	20.0	4.0
	Other 2+	26	42.3	42.3	15.4
Item	Deck	289	48.4	29.8	21.8
	Play Set	338	47.3	32.3	20.4
	Picnic Table	39	56.4	23.1	20.5
	Other	135	37.0	28.2	34.8
Sun Exposure	0-33%	150	49.3	30.7	20.0
	33-66%	236	47.9	30.1	22.0
	67-100%	353	43.1	30.9	26.1
Region	Northeast	255	54.9	28.6	16.5
	Northwest	182	31.9	35.2	33.0
	Southeast	176	50.6	31.3	18.2
	Southwest	175	45.7	25.7	28.6

Overall, there is no significant association between the service age of the CCA structure and the amount of As dislodged in these experiments (p-value = 0.36) from our survey study [12]. Also, as seen from Table 2, the percentage of samples in the low (< 10 μg/100 cm^2), medium (10 – 50 μg/100 cm^2) and high (>50 μg/100 cm^2) categories is approximately equal for the < 0.5 year, 0.5 – 2.0 year and >2.0 year service age categories, respectively. This field survey observation agrees with our various published and yet-to-be-completed laboratory studies which show the AsDM to decrease by 40 – 70% over the first three to 26 weeks of outdoor exposure, with no observable further reduction thereafter [10].

B. Hand-Wipe-Contact Area Relationships

Over the past 18 months we have initiated various experiments to try to determine the relationships between As dislodgement from actual handling compared to using wet laboratory wipes, considering the potential intervening factors of amount of surface area wiped and the moisture condition of the hand and/or board surface. These relationships are proving to be more complex than anticipated, as there appear to be interactions between the variables of hand moisture content, board surface moisture condition and amount of board surface contacted.

Table 3 shows the AsDM values observed for once-over dry hand and standard laboratory wipe contact with dry new CCA lumber as a function of the surface area contacted. These results indicate that the amount of As dislodged to either dry bare hands or to wipes increases approximately linearly over the range of 465 cm^2 to 7432 cm^2 (i.e. 0.5 – 9.0 ft^2). The CPSC's recent risk estimates assume that hands reach an approximate saturation point (i.e. one "hand-load") at 7.6 μg of As [1]. However, as shown in Table 3, our results clearly indicate that far more than 7.6 μg of As can be built up even on dry hands from contact with relatively small areas of CCA lumber surface. Thus, this 2003 CPSC study [1], as well as the original August 2000 CPSC staff assessment [14], may seriously underestimate As exposure for people who make several hand contacts over fresh lumber surfaces. From Table 3 it can also be noted that the once-over dry hand contact transfers only about 12.3% as much As on average as a standard wet laboratory wipe on a dry CCA board surface using the CPSC wipe method.

Subsequent experiments have indicated that when the hand and/or the board surface itself is moist, the hand behaves much more like the moist laboratory wipe, and the AsDMs observed are much closer. Our preliminary experiments indicate that the EPA/HUD wipe method illustrated previously in Figure 1 provides a unit area AsDM about twice that of the CPSC method. Thus, we have previously estimated the ratio of the EPA/HUD wipe to actual hand contact As DM to be about 15.6 for dry hands and about 6.9 for damp hands and/or board surfaces [12]. Obviously, over months or years of actual skin contact with CCA lumber, there will be some mix of wet and dry hand and board surface conditions which will depend on precipitation patterns and, especially for infants and young children, on the frequency and extent of hand-to-mouth activity. Establishing more quantitatively this complex interactive relationship between wipe versus hand contact conditions will be important in developing more reliable and accurate estimates of As exposure from CCA lumber.

Table 3 Arsenic dislodgement (μg) as a function of surface area contacted for once-over dry hand and laboratory wipes.

Surface Area (ft^2)	Dry Hand #1	Dry Hand #2	Dry Hand Mean	Laboratory Wipe #1	Laboratory Wipe #2	Laboratory Wipe Mean	Laboratory Wipe/ Dry Hand Ratio
0.5	7.1	56.0	31.6	104.0	157.1	130.6	4.13
1.0	139.6	101.4	120.5	887.4	364.6	626.0	5.20
2.0	281.5	341.8	311.7	3668.0	1123.0	2396.0	7.69
4.0	239.8	159.9	200.0	1640.0	1652.0	1646.0	8.23
8.0	426.7	818.9	622.8	9270.0	8792.0	9031.0	11.00

C. Natural and Accelerated Sealant Effectiveness Study

With the current phase-out of the manufacture and sale of CCA lumber, the important and practical issue related to As exposure from CCA lumber has now become whether the dislodgement of As can be greatly reduced for periods of five years, 10 years, or even longer by the application of specific sealants, water-proofers, stains or paints. As noted above, our nationwide field survey studies indicate a significant reduction from currently available products of only 0.5 years to about two years, with evidence that As dislodgement may rebound to even greater levels if care is not taken to repeatedly reapply treatments at appropriate time intervals.

To address this critical issue of whether specific existing or newly-developed treatment materials can successfully reduce As dislodgement for more extended periods, in October 2003 we initiated natural and accelerated outdoor aging experiments using new and old (10 year service age) CCA lumber with existing and experimental/proprietary sealant/water repellent formulations. These experiments are being conducted simultaneously with similar weathering experiments recently initiated jointly by the US EPA and the CPSC (using only commercially available treatment materials) [15]. Hopefully, the information obtained from these two separate studies will be complementary in providing practical solutions to the ongoing issue of As and in-service CCA lumber.

In an effort to accelerate the weathering/aging of these experimental treatments, we have set up an accelerated experimental design which includes 1) increasing the amount and intensity of daytime heat and sunlight by optimally-positioned mirrors; 2) greatly increasing the number of lumber surface precipitation/evaporation cycles by applying 0.60 cm of simulated rainfall three times per week in addition to any natural precipitation events; and 3) applying intensive daily (5/week) foot traffic equivalent to about 12 shoe-bottom contact abrasions per unit area per day. A photograph of the accelerated aging experimental set-up is shown below as Figure 4.

Figure 4 Photograph of accelerated aging experimental set-up with reflectors and sprinkler.

Table 4 below lists what we believe to be general experimental considerations for accurately and cost-effectively determining the As dislodgement reduction capabilities of current and experimental treatments in a time-efficient manner. Also included in Table 4 are specific experimental details which we believe are critical to obtaining accurate and reliable results.

Table 4 General and Specific Experimental Considerations for Determining the Long-Term As Dislodgement Reduction from CCA Lumber Treatments

I. General Design Considerations
A. Age brand new lumber outside through 2-4 precipitation/evaporation cycles to produce a more realistically pre-conditioned and As-stable "new lumber."
B. Take at least three "pre-treatment" wipe samples from all boards immediately before applying experimental treatment to establish baseline As dislodgement.
C. Apply treatments according to manufacturer's instructions.
D. Use both "new" and previously in-service CCA lumber since specific treatments may work differently on the two ages of boards.
E. Divide experiments into natural and accelerated aging trials.
F. Accelerate aging by increasing heat and sunlight using adjustable mirrors, adding simulated rainfall/evaporation cycles three times per week, and applying foot traffic.
G. Test all treatments at least in duplicate with appropriate non-treated controls.
H. Take simultaneous wipe samples for As analysis at least monthly, noting moisture condition of board at the time of sampling.
I. Determine AsDM reduction by comparing monthly wipe sample results with both pre-treatment and coated AsDMs.
J. To determine how much acceleration of aging is actually being accomplished, compare the natural and accelerated AsDM results over time for a material (such as conventional water seal) which will wear off even from the naturally-aged board surfaces within one year.
II. Specific Experimental Details
A. Adjust mirrors frequently to maximize light/heat reflection to board surface with season.
B. Pre-mark out all 100 cm^2 surfaces on each board for subsequent wipe samples.
C. Buy long CCA lumber so that many treatment and control sections can be produced from the same board.
D. Rotate boards within the accelerated experiments to even out the amount of heat and light reflection.
E. Physically separate treated and untreated (control) boards during natural or simulated precipitation events to prevent splattering of As from control to treated board surfaces.
F. Use separate designated boots for control and experimental board foot traffic to prevent possible As cross-contamination from daily boot bottoms.

We believe that the natural and accelerated aging experiments described above (Figure 4 and Table 4) will produce reliable measurements of As dislodgement reductions (even for treatments providing observable effectiveness for 4-8 years) within one to two years. Two factors are essential to achieve this goal. First, the experimental conditions must be sufficient to significantly accelerate natural aging of the board treatment. Our hypothesis is that aging of the As-reduction treatment is significantly affected by the following three factors:

a) The degree of fluctuation of diurnal board surface heat and sunlight conditions which in turn influences the rate of surface crevice, fissure, and fracture formation thereby allowing water to penetrate more deeply and dissolve out additional CCA salt.

b) The total number of precipitation and evaporation/drying cycles. Each time precipitation penetrates into the wood and dissolves more internal CCA, subsequent drying and evaporation should transport this dissolved CCA to the board surface where it will be left behind as a micro salt crust after complete water evaporation.

c) Especially for colored stains, we have visually observed that the stain is physically removed (with corresponding increases in As dislodgement) in areas of a deck with heavier foot traffic. We believe that this will prove to be a very important acceleration factor for stain-type treatments.

Second, the experimental design must be able to allow the acceleration factor to be estimated with some accuracy. Specifically, in our experiments we are using a popular conventional water sealant for this purpose. Both our field survey study and our preliminary outdoor experiments indicate that conventional water seal will deteriorate substantially in terms of its arsenic retention properties within six to 10 months. Thus, if its arsenic reducing properties are found to deteriorate by 75% for instance after eight months on the naturally-aged boards, and the same degree of As retention deterioration is observed on the accelerated-aging boards after only two months, it would be a reasonable estimate that the aging rate has been increased by a factor of about four.

Lastly, based on extensive direct physical observation and As dislodgement measurements over the past three years, we believe that for a CCA lumber treatment (or treatment system) to be effective in preventing As dislodgement for five to 10 years, it must possess the ability to: 1) penetrate to a substantial depth into the wood (at least 0.3 cm); 2) effectively repel both incoming precipitation water and outgoing internal CCA solution water; and 3) seal surface fractures so that such fractures do not continue to expand more deeply into the lumber, thereby exposing (and allowing water access to) new CCA salt.

It is visually apparent that currently available water sealers, water repellents and oil- or water-based stains effectively repel water, at least for a time, but they are not designed to seal larger cracks or fissures, especially when applied to highly weathered CCA lumber. Conventional outdoor deck paints, on the other hand, seal surface cracks and fissures very effectively, but by their more viscous and particulate nature, they do not provide the necessary penetrating water repellent layer once the paint surface begins to crack from weathering or from foot/hand abrasion.

While it is theoretically possible to produce a treatment mixture wherein individual chemical components might possess each of these necessary properties, it seems more likely that the desired long-term results would be best achieved by a two-step As containment system. This would probably entail an initial penetrant/water repellent application followed perhaps several hours later by a surface crack-sealing flexible coating. At least two of the experimental products we are currently testing meet this general description, and it will be most interesting to observe experimentally over the next 1-2 years how they perform relative to public health needs and compared to currently-available products.

IV. CONCLUSIONS

The three studies discussed in this paper are all still in progress, and they should provide a better understanding of the dynamics of arsenic exposure from CCA lumber as they are continued and completed in the near future. However, a considerable body of knowledge related to dislodgement of

As from CCA lumber has already become evident from these and other studies. Our national field survey study shows clearly that a high percentage of actual in-service CCA lumber is still releasing high levels of As upon contact. Statistically, the amount of As dislodged does not decrease over time following an initial period of weeks or a few months during which a 40-70% decrease is observed. All types of CCA structures show similar As dislodgement levels, with structures from the Northwest part of the US having the highest levels. Overall, water sealers and water-proofing compounds appear on average to be effective in reducing potential As exposure for only about six months, while there is preliminary evidence that stains and paints generally show some effectiveness for at least two years.

Our experiments show that standard laboratory wipes probably overestimate actual hand contact dislodgement by a factor between about six and 15 depending on the moisture condition of the hand and of the area wiped. The relationship is rather complex and needs further controlled study to better estimate human As exposure from CCA lumber. The amount of As dislodged and transferred by hand contact appears to be approximately linear over a range of 0.5 ft^2 to 8.0 ft^2 of lumber surface area.

Although the manufacture and sale of CCA lumber has now been curtailed in the US, there exists an important public health need to develop sealant materials which can greatly reduce As dislodgement from existing CCA structures for periods of time up to a decade or more. We are currently testing a number of such experimental materials, and from our experience and observations, we believe that the most effective materials will be ones that contain both a penetrating water repellent as well as a surface fracture sealant.

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