Release of Total Chromium, Chromium VI and Total Arsenic from New and Aged Pressure Treated Lumber

Richard P. Maas Ph.D
Steve C. Patch Ph.D
Adrienne M. Stork
Jacob F. Berkowitz
Geneva A. Stork

University of North Carolina-Asheville
Environmental Quality Institute

Technical Report

02-093

February 2002

I. Introduction

The majority of lumber sold for outdoor use in the United States is infused with CCA (chromated copper arsenate) solution, using a pressure treatment method for protection against deterioration due to bacteria, fungi, and insects. Although alternative methods exist, CCA pressure-treated wood is by far the most commonly used and widely available, and it is currently somewhat less expensive than alternative treatment methods.

While CCA treated lumber is effective in resisting deterioration for much longer time periods than untreated lumber, there are significant health risks associated with exposure to the chemicals used in the treatment. Arsenic and chromium VI are both well recognized as strong carcinogens, and As has other detrimental health effects including cardiovascular disease, diabetes, anemia, skin lesions, vascular damage, and reproductive, developmental, immunological, and neurological effects (AWWA, 2000). Cr VI is a known teratogen and can also be a powerful and corrosive irritant to the skin and mucous membranes (Conn. Dept. of Public Health, 2001). Both Cr VI and As can be ingested and inhaled, and As can be absorbed through the skin. Thus exposure to As can potentially occur from any contact with CCA treated lumber, whether by using it for construction purposes or by simply handling it during every day activities. Cr VI exposure is greatly heightened by the presence of strong oxidizing agents, such as deck washes (Taylor et al., 2001). Considering the many millions of people who work with, handle, or come into contact with CCA treated lumber, there is currently a high percentage of adults and children who may be at risk for acute, chronic, or long term exposure to either As or Cr VI.

Chromium is applied exclusively in the hexavalent form in CCA solution, although the lumber industry has long contended that it is converted completely to the much less toxic Cr III form within the wood. However, it would seem that the use of strong oxidizing deck wash solutions on CCA treated wood could at least partially oxidize Cr III back to its original, more toxic, hexavalent form.

Potential exposure to As and Cr VI from CCA treated wood is probably not limited to direct contact with the lumber itself, but may also occur as a result of contact with soils under deck and playground equipment, or from chipped wood mulches which often inadvertently contain some CCA pressure-treated lumber. Although small warning labels now often appear on the ends of CCA pressure-treated lumber when it is sold, there is currently limited practical information available to consumers about the long-term risks to their health or about appropriate protection measures when they purchase CCA treated wood. CCA use is restricted in Japan, Denmark, Sweden, Germany, Australia, and New Zealand for safety reasons. CCA is banned in Switzerland, Indonesia, and Vietnam. Thus the purpose of these experiments was to examine and begin to quantify the potential for As and Cr VI exposure from pressure-treated lumber of various in-service ages.

II. Methodology

New CCA treated lumber was purchased at Home Depot and Lowes and identifying information was logged into a chain of custody form. All 6-month and 8.5 year old lumber samples were

acquired from private locations. All boards were labeled and identified according to standard laboratory operating procedures. A description of each piece of lumber used in these experiments is given in Table 1.

CCA pressure-treated lumber obtained at various in-service ages and from two different locations was tested for exposure potential of As and total Cr using several different methods. To determine the As and total Cr present on the wood surfaces, laboratory wipe samples were conducted on 16 newly purchased CCA boards from two separate sources (eight from Lowes and eight from Home Depot), and on five 6-month weathered CCA boards (Home Depot), using U.S. CPSC (Consumer Product Safety Commission, 2001) horizontal sampling methodology. Laboratory assistants conducting these sampling techniques used fresh, sterile poly examination gloves with each wipe sample. The laboratory wipes used were not permitted to come in contact with any substance other than the clean Parafilm placed around the secured template, the clean gloves worn by the laboratory technician, and the lumber sample itself. After sampling, all wipes were placed immediately in 50ml polypropylene vials. The wipes were then digested (see Appendix A) and the concentrations of As and total Cr were determined by atomic absorption spectroscopy (AAS) using a Thermo Jarrel Ash furnace/flame AAS.

Concentrations of As and total Cr leached under simulated rainfall conditions were determined using the USEPA Synthetic Precipitation Leaching Procedure (SPLP) (EPA Method 1312, 1994). The lumber samples tested included new CCA treated lumber as well as six-month weathered CCA lumber. Eight SPLP studies were conducted (four from Lowes and four from Home Depot) on new CCA lumber, and four SPLP studies were conducted on the 6-month weathered CCA lumber. Because the sample sizes had to be relatively small to comply with the SPLP procedure, approximately 1-1/4 inch pieces were cut from the ends of each board to be sampled, with the freshly cut side of the sample sealed with Liquid Nails adhesive to prevent any leaching from that particular side. The logic in this slight adjustment of the standard procedure was that in most normal outdoor situations where CCA lumber is used, as part of a deck or playground equipment, the parts of the board exposed to rainfall on a regular basis would not include freshly cut ends; therefore, these ends were sealed with Liquid Nails in order to better simulate natural conditions as closely as possible. All other aspects of the experiment were conducted as directed in the SPLP procedure. Results are expressed in μg of metal per ft^2 of wood surface area exposed.

SPLP tests were also conducted on 8 samples of new CCA lumber sawdust (four from Lowes and four from Home Depot). The experiments were conducted as specified in the SPLP procedure. Results are expressed as direct leachate solution concentrations and also as μg of metal leached per gram of sawdust.

Concentrations of As and total Cr leached under simulated landfill conditions were determined using the USEPA Toxicity Characteristic Leaching Procedure (TCLP) (EPA Method 1311, 1992). Tests were performed on eight samples of new CCA lumber (four from Lowes and four from Home Depot), and on 4 samples of 6-month weathered CCA lumber. Because the sample sizes had to be relatively small to comply with the TCLP procedure, 1-1/4 inch cuts were made from the ends of the boards to be sampled. Results from the TCLP tests are expressed as direct solution leachate concentration and also as μg per ft^2 of exposed surface area.

Table 1: Description of Lumber Used in CCA Research Project

Sample ID #	**Description on Lumber Label** (Most, but not all also had a Caution Sticker stapled to the lumber end)	**pci**
R1-Lowes	Pressure Treated Top Choice Lumber Products for ground contact 2x4x8 UPC99796 26000 (Do not recognize logo) 283	.40
R2-Lowes	Pressure Treated Top Choice Lumber Products for ground contact 2x4x8 UPC99796 26000 Willamette KD19 248 #2	.40
R3-Lowes	Pressure Treated Top Choice Lumber Products for ground contact 2x4x8 UPC99796 26000 (Do not rec. logo) KD19 SYP283 #2	.40
R4-Lowes	Pressure Treated Top Choice Lumber Products for ground contact 2x4x8 UPC99796 26000 Willamette KD19 248	.40
R5-Lowes	Pressure Treated Top Choice Lumber Products for ground contact 2x4x8 UPC99796 26000 Willamette KD19 248	.40
R6-Lowes	Pressure Treated Top Choice Lumber Products for ground contact 2x4x8 UPC99796 26000 Willamette KD19 248	.40
R7-Lowes	Pressure Treated Top Choice Lumber Products for ground contact 2x4x8 UPC99796 26000 Willamette KD19 248	.40
R8-Lowes	Pressure Treated Top Choice Lumber Products for ground contact 2x4x8 UPC99796 26000 (Do not rec. logo) 283 #2	.40
R9-Lowes	Pressure Treated Top Choice Lumber Products for ground contact 2x4x8 UPC99796 26000	.40
R10-Lowes	Pressure Treated Top Choice Lumber Products for ground contact 2x4x8 UPC99796 26000	.40
R1-H.Depot	MAX-LIFE AThe All Weather Wood@ 2x4x8 #2 UPC99586 24840 (no legible markings)	.40
R2-H.Depot	MAX-LIFE AThe All Weather Wood@ 2x4x8 #2 UPC99586 24840 Willamette KD19 248	.40
R3-H.Depot	MAX-LIFE AThe All Weather Wood@ 2x4x8 #2 UPC99586 24840 (no legible markings)	.40
R4-H.Depot	MAX-LIFE AThe All Weather Wood@ 2x4x8 #2 UPC99586 24840 no legible markings)	.40
R5-H.Depot	MAX-LIFE AThe All Weather Wood@ 2x4x8 #2 UPC99586 24840 Willamette KD19 248	.40
R6-H.Depot	MAX-LIFE AThe All Weather Wood@ 2x4x8 #2 UPC99586 24840 Willamette KD19 248	.40
R7-H.Depot	MAX-LIFE AThe All Weather Wood@ 2x4x8 #2 UPC99586 24840 (no legible markings)	.40
R8-H.Depot	MAX-LIFE AThe All Weather Wood@ 2x4x8 #2 UPC99586 24840 (no legible markings)	.40
R9-H.Depot	MAX-LIFE AThe All Weather Wood@ 2x4x8 #2 UPC99586 24840	.40
R10-H.Depot	MAX-LIFE AThe All Weather Wood@ 2x4x8 #2 UPC99586 24840	.40
		.40

R1-6-month	H.Depot, MAX-LIFE AThe All Weather Wood@ 2x4x8 #2 UPC99586 24840 Willamette KD19 248	

Table 1: Description of Lumber, continued

Sample ID #	**Description on Lumber Label** (Most, but not all also had a Caution Sticker stapled to the lumber end)	**pci**
R2-6 month	H.Depot, MAX-LIFE AThe All Weather Wood@ 2x4x8 #2 UPC99586 24840 Willamette KD19 248	.40
R3-6 month	H.Depot, MAX-LIFE AThe All Weather Wood@ 2x4x8 #2 UPC99586 24840 Willamette KD19 248	.40
R4-6 month	H.Depot, MAX-LIFE AThe All Weather Wood@ 2x4x8 #2 UPC99586 24840 Willamette KD19 248	.40
R5-6 month	H.Depot, MAX-LIFE AThe All Weather Wood@ 2x4x8 #2 UPC99586 24840 Willamette KD19 248	.40
8.5 yr R1	(No labels stapled to end) GP Arnville, SC Stained Cured SYP	
8.5 yr R2	(No labels stapled to end and no legible markings)	

Cr VI Sample Collection and Analysis Methodology

Glove-wipe Samples:
New CCA treated lumber was purchased at Home Depot and Lowes and appropriate identifying information was logged onto a chain of custody form. All 6 month and 8.5 year old CCA lumber samples were acquired from private locations. All six boards were labeled and each new and used board surface was sampled for Cr VI by collecting laboratory glove wipe samples according to the following methodology. For the new and six month CCA lumber samples a 19.7 in. by 3.5 in. section (445 cm^2) of the board was measured and marked using a standard measuring tape and pencil. Because the 8.5 year old boards were of a wider dimension, a 12.53 in. by 5.5 in. section (445 cm^2) was sampled.

A new powder-free latex glove was fitted on the hand of the sampler. The dry, gloved hand rubbed the designated area, using the pad of the fingertips to apply even pressure over the total surface of the sampled area. This process was conducted for one full minute. The fingers of the gloved hand were then placed into a 110-mL Corning Snap Seal plastic tub. Each contained 50-mL of deionized water. The fingers of the gloved hand were agitated and rubbed together in order to transfer any material associated with touching the CCA treated lumber surface. This rinsing process was continued for exactly 30 seconds. The glove was then removed and disposed of, and the remaining solution was ready to be analyzed for Cr VI.

All samples were analyzed using a HACH 2010 spectrophotometer. The instrument possessed an internal program specifically for Cr VI determinations. The HACH 2010 utilizes the 1,5-

diphenylcarbohydrazide Method adapted from Standard Methods for the Examination of Water and Wastewater, 1998. The program includes an internal instrument curve, and reads the color development produced by the introduction of a Chroma-Ver 3 Chromium Reagent Powder Pillow™ purchased from the instrument manufacturer.

A blank, a laboratory control sample, a duplicate sample, and a spiked sample was prepared with each set of 10 samples. All solution results were recorded in mg/L, and later converted to μg Cr VI per ft^2 of board surface.

Deck Wash Samples:
Three brands of deck wash (Thompsons, Behr #62, and Wolmans) were applied to a 1 ft^2 area of 6 month and 8.5 year old CCA pressure treated lumber. The deck wash was applied according to manufacturer recommendations, in proportion to the instructed amounts. The amounts of deck wash applied were as follows:

Behr #62 = 17-mL
Thompsons = 15-mL
Wolmans = 30-mL

Each deck wash was applied using a small, new heavy-duty sponge. The applied volume was measured using an acid washed graduated cylinder. Each deck wash was allowed to react with the exposed area for the amount of time specified by the manufacturer. The reaction times are as follows:

Behr #62 = 15 minutes
Thompsons = 10 minutes
Wolmans = 5 minutes

Upon completion of the recommended reaction times, each board was thoroughly scrubbed with a stiff bristled brush prior to rinsate collection. The boards were then placed over a large plastic collection pan. Each section of treated wood was then thoroughly rinsed with 500-mL of deionized water, and the rinsate was carefully collected in the large plastic pan. The collected rinse water was then funneled into a 1-liter plastic sample bottle. The inside of the plastic collection pan was rinsed with deionized water to assure that all deck wash rinsate was collected in the sample bottle. The final volume was then recorded and the sample was ready for colorometric Cr VI analysis.

Between each deck wash sample collection, the stiff bristled brush was placed into a solution of deck wash, followed by a solution of 1% nitric acid. A deionized water rinsate was then collected from the scrub brush and analyzed in order to document that no Cr VI carryover occurred from sample to sample. Also, the funnel and plastic collection pan were acid washed between sample collections to avoid any carryover contamination.

All results were recorded in μg/L, and later converted to μg Cr^{6+} per ft^2 of board surface.

III. Results of Discussion

A. Surface Wipe Experiments

The purpose of these experiments was to determine how much chromium and arsenic would be transferred to a laboratory wipe from new and aged CCA lumber under controlled conditions. These experiments were intended to represent potential human exposure from handling and other skin contact with treated lumber surfaces. The results of these experiments for new CCA lumber

purchased from Home Depot and Lowes are summarized in Tables 2 and 3, respectively. As described in section II above, the wipe method for total Cr and total As was adapted from a recently proposed method by the U.S. Consumer Product Safety Commission (CPSC, 2001) using laboratory wipes, and the 445 cm^2 surface area is very close to the area recommended in this protocol. The average adult hand has a palm and finger grasping area of about 150-200 cm^2, so the 445 cm^2 surface area would typically represent about two to three full hand contacts with a wood surface. The 445 cm^2 wiped area is probably a relatively low estimate of typical contact from activities such as handrail usage, lounging on wooden deck furniture, or especially for a child playing /crawling on a deck.

From Tables 2 and 3 it can be seen that even the relatively minimal extent of handling/contact represented by these wipe experiments results in a mean of about 270:g and 203:g of As transfer from the two types of new treated lumber, respectively, with as much as a factor of 3-6 difference between individual boards. Variability of about 10-50% was observed even between different sections of the same board.

Table 4 summarizes the results of similar wipe experiments using CCA-treated two-by-four lumber purchased at Home Depot and set out for approximately six months of outdoor exposure near Asheville, NC (June 29, 2001 to Dec. 3, 2001). The total As mean of 119.3 :g per wipe is equal to about 44% of the new lumber levels (Table 2).

Table 2. Total Chromium, Chromium VI and Total Arsenic in Wiped Samples of Home Depot New Lumber (445 cm^2 surface area).

Sample ID #	Cr VI (µg/L) *	Total Cr (µg)	Total Cr (µg/ft^2)	As (µg)	As (µg/ft^2)
R1-Home Depot	ND ***	882.2	1835.0	414.1	861.3
R1-Home Depot duplicate **	ND	914.3	1901.7	490.4	1020.1
R2-Home Depot	ND	431.1	896.6	354.0	736.3
R2-Home Depot duplicate	ND	262.7	546.3	191.4	398.1
R3-Home Depot	ND	561.4	1167.7	426.7	887.6
R3-Home Depot duplicate	ND	314.8	654.8	230.3	479.0
R4-Home Depot	ND	134.3	279.4	105.0	218.5
R4 -Home Depot duplicate	ND	192.5	400.4	140.9	293.1
R5-Home Depot	ND	341.7	710.7	316.1	657.6
R5-Home Depot duplicate	ND	453.3	942.8	480.3	998.9
R6-Home Depot	ND	256.3	533.1	264.1	549.4
R6 -Home Depot duplicate	ND	257.3	535.1	287.3	597.7
R7-Home Depot	ND	163.8	340.7	169.7	352.9
R7-Home Depot duplicate	ND	125.6	261.3	169.7	352.9
R8-Home Depot	ND	110.6	229.9	130.3	271.0
R8-Home Depot duplicate	ND	139.7	290.6	143.9	299.4
mean		**346.3**	**720.4**	**269.6**	**560.9**

* Glove Wipe Samples
** Two separate wipes of different sections of the same board.

*** Not detected with detection limit of approximately 10 µg/L for all Cr VI samples.

Table 3. Total Chromium, Chromium VI and Total Arsenic in Wiped Samples of Lowes New CCA Lumber (445 cm^2 surface area)

Sample ID #	Cr VI (µg/L) *	Total Cr (µg)	Total Cr (µg/ft^2)	As (µg)	As (µg/ft^2)
R1-Lowes	ND ***	559.4	710.1	341.4	710.1
R1-Lowes duplicate **	ND	389.0	657.6	316.1	657.6
R2-Lowes	ND	138.7	317.2	152.5	317.2
R2-Lowes duplicate	ND	110.6	231.1	111.1	231.1
R3-Lowes	ND	194.0	371.8	178.8	371.8
R3-Lowes duplicate	ND	152.8	303.6	145.9	303.6
R4-Lowes	ND	123.6	236.3	113.6	236.3
R4-Lowes duplicate	ND	371.9	705.9	339.4	705.9
R5-Lowes	ND	184.9	298.3	143.4	298.3
R5-Lowes duplicate	ND	150.8	271.0	130.3	271.0
R6-Lowes	ND	168.8	366.6	176.2	366.6
R6-Lowes duplicate	ND	165.8	310.9	149.5	310.9
R7-Lowes	ND	194.0	431.7	207.6	431.7
R7-Lowes duplicate	ND	290.4	596.6	286.8	596.6
R8-Lowes	ND	262.3	532.6	256.0	532.6
R8-Lowes duplicate	ND	235.2	419.1	201.5	419.1
mean		**230.8**	**422.5**	**203.1**	**422.5**

* Glove Wipe Samples
** Two separate wipes of different sections of the same board.
*** Not detected with detection limit of 10 µg/L.

Table 4. Total Chromium, Chromium VI and Total Arsenic in Wipe Samples of Home Depot CCA Lumber with About Six Months of Exposed Outdoor Service (445 cm^2 surface area).

Sample ID #	Cr VI (µg/L) *	Total Cr (µg)	Total Cr (µg/ft^2)	As (µg)	As (µg/ft^2)
6 month R1	ND ***	123.7	257.3	109.6	227.9
6 month R1 duplicate **	ND	115.1	239.5	100.0	208.0
6 month R2	ND	209.1	434.9	201.0	418.1
6 month R2 duplicate	ND	221.7	461.1	181.8	378.1
6 month R3	ND	128.8	267.9	87.9	182.8
6 month R3 duplicate	ND	90.9	189.1	71.2	148.1
6 month R4	ND	115.6	240.5	92.9	193.3
6 month R4 duplicate	ND	132.3	275.2	95.4	198.5
6 month R5	ND	139.9	291.0	118.2	245.8
6 month R5 duplicate	ND	160.1	333.0	134.8	280.5
mean		**143.72**	**298.9**	**119.28**	**248.1**

* Glove Wipe Samples
** Two separate wipes of different sections of the same board.
*** Not detected with detection limit of approximately 10 µg/L.

While undoubtedly the As wipe transfer amounts shown in Tables 2-4 correspond to a wide range of possible cancer risk depending on the amount of CCA lumber contact, intensity of hand-to-mouth contact, and other variables, the approximate cancer risk for three plausible lumber contact scenarios are discussed below:

Example 1. Adult Using CCA-Treated Lumber as a Stair and Deck Handrail

The National Academy of Science, after a recent extensive review of epidemiological and toxicity research information estimates that consuming 6.0 :g/day of arsenic translates to a lifetime cancer risk of approximately 1/1000 (NAS, 2001). This estimate is combined with the following contact assumptions as follows.

1. Deck stair handrail is 10 ft long and is composed of CCA-treated 2x4 laid flat.
2. Person uses handrail twice per day (leaving and returning to home) but only actually contacts one-half of the handrail surface.
3. Handrail starts out new and contact occurs for only two years.
4. Twice per week this person spends some time on their deck, touching the top railing and deck surfaces 12 times on each occasion for a total contact area of 24 x 200 cm^2 = 5.17 ft^2/ week.
5. Hand-to-mouth transfer efficiency of As is 10%.

The amount of surface area contacted on each trip up or down the stairs is:

(1.5 in + 3.5 in + 1.5 in) x 10 ft x 0.5 = 2.71 ft^2, which using the mean As transfer per ft^2 from Tables 2 and 3 gives an As transfer estimate of 1524 :g/trip or 3048:g/day when the lumber is new. After six months the estimated daily transfer would be 44% of this value or 1343 :g/day. For this example we assumed that daily exposure would drop by another factor of two over the next 18 months to an average daily exposure of 671:g/day by the end of the two year period. This rate of decline may probably be either somewhat high or low depending on factors such as whether the stair rail is covered by a porch roof or receives direct precipitation.

Mathematically, the mean daily As exposure for the first six months is approximately 2793 :g/day, and the approximate daily average for the next 18 months is 1279 :g/day, assuming a linear rate of surface As dissipation. With a hand-to-mouth ingestion transfer efficiency of 0.1, a total of 1.2 $x10^5$:g of As is ingested, which spread over a 70 year lifetime represents a daily As exposure of about 4.7 :g/day. This translates to about a 1/1275 cancer risk just for this two years of lumber contact activity. Obviously, the calculated risk would be significantly greater if the stairway and deck was used more often per day or for longer than two years, and especially if other CCA deck related usage and contact during other parts of the person's lifetime was added to the above calculations.

Example 2: Baby Crawling On CCA Lumber Deck
Assumptions:

1. Baby crawls across 25 ft deck and back just twice on two occasions per week for one year.
2. Hands touch deck at one-foot intervals for a total of 100 hand touches on each occasion or 200 touches per week.
3. Baby's total hand area is 40 cm^2.
4. Hand-to-mouth As transfer efficiency is 50%, the value used by CPSC for product hazard evaluation.
5. Unit surface area As levels decrease by another 25% between six months and one year.

Calculations: total As ingestion:

200 touches/week x 40 cm^2/touch x 1 ft^2/929cm^2 x mean 6 month As transfer of 804:g/ft^2 x 0.50 transfer efficiency x 52 weeks/year = 1.8 $x10^5$:g/year.

Given that a lifetime exposure of 1.53$x10^5$:g (i.e. 6:g/day x 365 day/yr x 70 yrs) equates to about a 1/1000 cancer risk, the calculated cancer risk for a baby crawling/playing on a new deck as observed above is 1/850, even assuming he/she never had any more contact with CCA pressure-treated lumber for the remainder of their life. Obviously, there would be a high percentage of situations where the childhood exposure related to contact with pressure-treated lumber surfaces would be significantly greater than this relatively conservative example. In fact, the more likely scenarios would seem to be the ones where examples similar to those described above would occur during several such time periods over the course of one's lifetime with additive cancer risks.

Example 3: Occasional Amateur Carpenter
For examples 1 and 2 above it is readily evident that the cancer risk of a professional carpenter who would frequently and extensively handle CCA-treated lumber as well as breathing sawdust

would probably be very great. However, in this example we attempt to estimate the As exposure and cancer risk a typical amateur carpenter who would build only four 250 ft^2 CCA decks, stairs and railings over their entire lifetime. Our basic approach is to try to estimate the number of times per hour the person would take a fresh grip on the wood surfaces during buying, loading, unloading, measuring, cutting, leveling and setting 4x4 or 4x6 posts; carrying, measuring, cutting and installing joists; carrying, measuring, cutting, laying and nailing decking lumber, along with similar activities for stairs and railings, and handling waste pieces. Based on extensive personal experience the average person would handle the wood at least twice per minute while working. (In some operations a new grasp would occur every few seconds, while at other times several minutes could elapse between contacts.) The other assumption and approximations we used included:

1. Each deck and associated railings would take the amateur carpenter seven- eight hour workdays to complete (total of 224 hours for four decks).
2. Person does not wear gloves or respiratory mask.
3. Hand-to-mouth ingestion transfer rate is 10%.
4. 175 cm^2 (0.189 ft^2) hand grasp contact areas.
5. New CCA lumber.

Using the mean As wipe data from Tables 2 and 3 and a total of 26,880 grasps (224 hours x 60 minutes/hr) results in a total of 5080 ft^2 of board area handled. Using the wipe means from Table 2 (560.9 and 472.5 ug/ft^2 gives a total As hand transfer of 2.50 x 10^6 µg and thus an estimated ingestion of 2.50 x 10^5 µg. This neglects what is probably substantial direct ingestion and inhalation of fine airborne sawdust produced by the hundreds of saw-cuts required. Over a 70 year lifetime just the hand contact ingestion would result in an average daily ingestion of 9.8 µg/day which translates to an estimated 1/612 cancer risk. This estimated risk is probably substantially increased if the afore-mentioned exposures related to sawdust inhalation are considered.

B. Chromium VI Wipe Experiments

Chromium is added to CCA treated wood in the hexavalent form (i.e. chromate) with the assumption that it will be reduced in the wood to the much less toxic chromium III species. The Cr VI data presented in Tables 2-4 would appear to support this hypotheses, as no Cr VI was detected at a digested solution detection limit of approximately 10 :g/L even though digestate solutions were routinely observed to contain thousands of :g/L of total Cr (Appendix A). As might be expected from the stoichiometry of chromated copper arsenate, chromium III releases to wipes were approximately equal to arsenic releases as shown in Tables 2-4.

C. Synthetic Precipitation Leaching Procedure (SPLP) Experiments.

One purpose of these experiments was to begin to determine how much As, Cr VI and Cr-total would be leached out of new and six-month aged CCA lumber which would then become available for contaminating nearby soil, water bodies, etc. Although it is widely recognized that the standard USEPA SPLP procedure is at best only an approximate surrogate measure of actual leaching from precipitation, the procedure was chosen for these studies due to its widespread acceptance as a relative and comparative measure. The results summarized in Table 5 indicate even using relatively large blocks of CCA lumber (typically about 1" x 3.5" x 1.5") with lower associated surface areas than would have been produced by the smaller pieces, that at all of the

blocks produced results greatly exceeding the usual guidance limits (ie ground water standards) of 100 µg/L for Cr-total and 50 µg/L for As. The SPLP results for As after six months of outdoor weathering and aging (mean 806.4 µg/L) were still about 73% and 47% of new Lowes

Table 5. Synthetic Precipitation Leaching Procedure (SPLP) Results for Blocks of New and Six-Month Aged CCA Lumber: Total Chromium, Chromium VI, and Total Arsenic (µg/L).

Sample ID #	Sample weight (g)	Cr VI (µg/L)	Total Cr (µg/L)	As (µg/L)	Total µg [Cr] normalized to 100g sample	Total µg [As] normalized to 100g sample
Lowes untreated control	41.11	ND*	1.3	0.0	3.16	0.0
R5- Lowes CCA treated	41.23	ND	500.5	1188.6	1213.92	2882.9
R6- Lowes CCA treated	40.75	ND	888.3	1478.4	2179.88	3628.0
R7- Lowes CCA treated	54.96	ND	232.3	848.1	422.67	1543.1
R8- Lowes CCA treated	49.70	ND	630.0	1169.7	1267.61	2353.5
mean			**562.8**	**1171.2**	**1271.0**	**2601.9**
standard deviation			**273.0**	**257.6**	**718.6**	**878.3**
R5- Home Depot CCA treated	49.74	ND	606.0	1491.3	1218.34	2998.2
R6- Home Depot CCA treated	43.83	ND	2030.1	1812.9	4631.76	4136.2
R7- Home Depot CCA treated	45.96	ND	485.1	2134.5	1055.48	4644.3
R8- Home Depot CCA treated	49.08	ND	5547.6	2456.1	11303.18	5004.3
mean			**2167.2**	**1973.7**	**4552.2**	**4195.7**
standard deviation			**2360.3**	**415.2**	**4793.2**	**874.2**
R1b -6 month aged	44.04	ND	606.9	850.5	1378.1	1931.2
R2b -6 month aged	49.48	ND	497.7	980.7	1005.9	1982.0
R3b -6 month aged	52.21	ND	117.6	483.0	225.2	925.1
R4b -6 month aged	49.63	ND	344.4	911.4	693.9	1836.4
mean			**391.65**	**806.4**	**825.8**	**1668.7**
standard deviation			**212.1**	**222.1**	**488.4**	**499.4**

* Not detected with detection limit of approximately 10 µg/L.

and Home Depot CCA boards, respectively, indicating that in actual service, high levels of As are leached by precipitation for extended time periods. Again, no Cr VI was detected in the SPLP leachate from these CCA-treated lumber samples.

The SPLP procedure was also applied to sawdust produced from cutting new CCA lumber with an electric skillsaw and results are summarized in Table 6. For all of the samples the As leachate concentrations vastly exceed the SPLP guidance limits for protecting groundwater, with a range from about 12,900 µg/L to nearly 20,000 µg/L. These higher leachate concentration results are not unexpected given the much larger exposed surface area of the sawdust compared to the wood block pieces, and they indicate the strong potential of CCA sawdust at a deck or playground construction site to contaminate underlying groundwater.

All of the lumber samples also vastly exceeded the SPLP guidance limit for Total Cr. With this increased exposed surface area two of the samples produced detectable levels (10 µg/L) of Cr VI, although in both cases this represented less than 0.3% of the total chromium leached by the

experiments. Table 6 also shows the mass of Cr and As leached per gram of sawdust. This calculation was derived by dividing the observed leachate concentration by the sawdust sample weight and incorporating the fact that the SPLP test produces two liters of leachate.

Table 6. Synthetic Precipitation Leaching Procedure (SPLP) Results for New CCA Lumber Sawdust (µg/L).

Sample ID #	sample weight (g)	Cr VI (µg/L)	Total Cr (µg/L)	µg of Cr released / g of sawdust	Total As (µg/L)	µg of As released / g of sawdust
R4- Lowes	103.45	ND *	3353.2	64.8	17868.9	345.5
R5- Lowes	106.32	10	3888.5	73.2	17587.5	330.8
R6- Lowes	105.82	ND	4009.7	75.8	16884.0	319.1
R8- Lowes	104.38	ND	4040.0	77.4	19818.6	379.7
mean			**3822.9**	**72.8**	**18039.8**	**343.8**
standard deviation			**319.9**	**5.6**	**1256.2**	**26.3**
R1- Home Depot	100.83	10	3464.3	68.7	12884.1	255.6
R2- Home Depot	103.80	ND	5447.1	105.0	15657.9	301.7
R4- Home Depot	109.71	ND	3464.3	63.2	15899.1	289.8
R6- Home Depot	107.43	ND	4848.0	90.3	13004.7	242.1
mean			**4305.9**	**81.8**	**14361.5**	**272.3**
standard deviation			**1002.1**	**19.4**	**1640.0**	**28.1**

* Not detected at detection limit of approximately 10 µg/L.

D. Toxic Characterization Leaching Procedure (TCLP) tests.

The TCLP test is routinely employed as a screening procedure to determine the relative leaching potential of landfill wastes and to determine whether they should be categorized as hazardous wastes for regulatory purposes. Two liters of a specified solution with a target pH of 4.93 (± 0.05) is tumbled with a known amount of waste for 16-20 hours. A number of TCLP tests were conducted as part of this research, and the results are summarized in Table 7 for individual small (1.2" x 1.5" x 3.5") blocks of CCA-treated wood similar to what would typically be taken to a municipal landfill as construction waste. In several experiments two such blocks (131-148 g total) were used for comparison. The standard TCLP test pH of 4.93 is intended to approximate an acidic worst case for contaminant leaching. As seen in Table 7, in almost every case, total Cr and As leachate concentrations of over 1000 µg/L were produced per 100 g of wood sample, even utilizing only a single end piece of wood. On average the six-month aged pieces still leached about 74% as much As as new lumber pieces and about 58% as much total Cr. Two of the samples exceeded the current TCLP limit for As of 5 mg/L when extrapolated to 100 g samples. With the recent lowering of the As drinking water standard from 50 µg/L to 10 µg/L, it seems reasonable that the TCLP level, which is intended to protect groundwater will also be lowered, theoretically from 5 mg/L to 1 mg/L, a level exceeded by virtually all the new and aged wood block samples tested.

The standard TCLP test at the pH of 4.93 is intended to maximize total metal leaching. However in the case of Cr VI, this acid solution actually represents more of a "best case" scenario because,

as previously demonstrated by Bartlett and James (1978) and others, lower pH inhibits the conversion of Cr III to Cr VI. For this reason we conducted two additional TCLP tests using an extraction solution pH of about 8.5 which probably represents a reasonable upper pH bound for landfill leachate. As shown in Table 7, at this moderately basic pH, detectable levels of Cr VI were observed, although they represented about 0.5 to 0.8 % of the total Cr leached. Further new TCLP experiments were conducted using CCA lumber sawdust rather than blocks of wood, and these results are summarized in Table 8. Not unexpectedly, especially at pH 4.93 (± 0.05), very high [total Cr] and [As] leachate solutions were produced with concentrations generally exceeding current regulatory TCLP hazardous waste limits. To assess more realistically the approximate upper limits for Cr VI formation, we again conducted two sawdust TCLP tests using a leachate solution pH of approximately 8.5. As shown in Table 8, these experiments produced measurable levels of Cr VI (10 μg/L and 20 μg/L), although these represented only about 0.7 % to 1.1 % of the total Cr. Previous research by Bartlett and James (1979) has indicated that the pH must be raised above 9.0 to achieve significant oxidation of Cr III to Cr VI without the presence of oxidized manganese in the solution. Of course, in many landfill situations sufficient oxidized Mn probably exists to cause significant Cr III oxidation, but the investigation of this phenomenon was beyond the scope of this initial research project.

It would seem likely however, that the use of strongly oxidizing or highly basic deck washes might strongly facilitate the oxidation of CR III to Cr VI. The results of the deck washing experiments shown in Table 9 appear to be consistent with this hypothesis. Only six-month and 8.5 year aged CCA lumber was used for these experiments, given the improbability that new lumber would be deck-washed under ordinary circumstances.

The Behr #62 produced relatively high levels of Cr VI in the rinsate (3.9% to 14.4% of the total Cr) in all four TCLP tests. The primary active ingredient labeled on this brand of deck wash is sodium hypochlorite which is a relatively strong oxidizing agent and produces a somewhat basic solution. The USEPA has also specifically noted in the case of drinking water that sodium hypochlorite even at low ppm concentrations, can oxidize Cr III to CR VI (Scharfenaker, 2001). It is noteworthy that elevated levels of Cr VI were produced even from the 8.5 year aged CCA lumber.

Table 7. Toxic Characterization Leaching Procedure (TCLP) Results for Blocks of New and Six-Month Aged CCA Lumber: Total Chromium, Chromium VI and Total Arsenic (µg/L).

Sample ID #	pH	sample weight (g)	Cr VI (µg/L)	Total Cr (µg/L)	Total As (µg/L)	Totalµg [Cr] normalized to 100 g sample	Totalµg [As] normalized to 100 g sample
R1- Lowes	4.93	35.1	ND *	1212.0	1646.3	3453.0	4690.3
R2- Lowes	4.95	37.5	ND	545.4	1302.9	1454.4	3474.4
R3- Lowes	4.91	40.0	ND	959.5	1555.4	2398.8	3888.5
R4- Lowes	4.89	39.8	ND	898.9	2110.9	2258.5	5303.8
R9 - Lowes	4.89	148.33	ND	1853.4	3974.4	1249.5	2628.3
R10- Lowes	8.43	140.19	10	2030.1	2302.8	1448.1	1642.6
mean				**1249.9**	**2136.2**	**2043.7**	**3604.7**
standard deviation				**579.3**	**938.7**	**835.6**	**1339.1**
R1- Home Depot	4.92	45.51	ND	1100.9	1302.7	2419.0	2862.4
R2- Home Depot	4.88	34.02	ND	1646.3	1424.1	4839.2	4186.1
R3- Home Depot	4.91	43.89	ND	999.9	1020.1	2278.2	2324.2
R4- Home Depot	4.96	52.26	ND	2585.6	4433.9	4947.6	8484.3
R9- Home Depot	4.90	132.70	ND	1497.4	3100.7	1128.4	2336.6
R10- Home Depot	8.53	131.19	10	1252.4	2160.0	954.6	1646.5
mean				**1513.8**	**2240.3**	**2761.2**	**3640.0**
standard deviation				**577.8**	**1310.9**	**1753.8**	**2520.9**
R1a - 6 month aged	4.93	38.17	ND	686.8	1411.2	1799.3	3697.1
R2a - 6 month aged	4.92	49.27	ND	262.6	695.1	533.0	1410.8
R3a - 6 month aged	4.93	53.91	ND	767.6	1089.9	1423.9	2021.7
R4a - 6 month aged	4.91	51.20	ND	951.3	1862.7	1858.0	3638.1
mean				**667.1**	**1264.7**	**1403.5**	**2691.9**
standard deviation				**291.5**	**494.7**	**611.4**	**1154.1**

* Not detected at detection limit of approximately 10 µg/L.

Table 8. Toxic Characterization Leaching Procedure (TCLP) Results for New CCA Lumber Sawdust.

Sample ID #	pH	Sample weight (g)	Cr VI (µg/L)	Total Cr (µg/L)	Total As (µg/L)	µg of Cr released / g of sawdust	µg of As released / g of sawdust
R10 - Home Depot	4.90	102.37	10	6954.6	7312.4	135.9	142.9
R10 - Lowes	4.91	100.47	10	4803.9	13860.0	95.6	275.9
R10 -Home Depot	8.57	100.46	10	1535.2	2706.8	30.6	53.9
R10 - Lowes	8.43	100.70	20	1898.8	7150.8	37.7	142.0

The Wolmans Deck and Fence Brightener product produced very high Cr VI rinsate concentrations (490 µg/L and 300 µg/L) from the six-month aged lumber, but Cr VI was non-detectable in the 8.5 year lumber. In the six-month aged lumber, these Cr VI levels represented 16.1 % and 22.5 % of the total Cr leached. The active ingredient in the Wolman's product is disodium peroxydicarbonate which is a moderately strong oxidizing agent. Notably, the Thompson's Water Seal Deck Wash which is shown in Table 9 produced no measurable amounts of Cr VI in the rinsate, contains no corrosive or alkaline or oxidizing agents requiring warning on the product label. As shown in Table 9, however, all of the deck wash solutions were strongly basic, suggesting that perhaps both an oxidizing agent as well as elevated pH are necessary to produce significant Cr VI formation.

Table 9. Chromium VI. Total Chromium and Arsenic Leaching from CCA Treated Lumber When Treated with Commercially Available Deck Wash Solutions.

Sample ID #	Deck Wash Brand	Initial Solution pH	Rinsate volume (L)	Cr VI (µg/L)	Total Cr (µg/L)	Total As (µg/L)
1D	Behr #62 - Six month aged R1a	12.27	0.56	170	1292.8	515.1
2D	Behr #62 - Six month aged R2	12.27	0.555	320	2222.0	1516.2
3D	Thompson's Six month aged R3	12.52	0.57	10	939.3	900.9
4D	Thompson's Six month aged R4	12.52	0.62	10	1595.8	1157.1
5D	Wolmans - Six month aged R5	10.40	0.64	490	3050.2	2232.3
6D	Wolmans - Six month aged R1b	10.40	0.62	300	1333.2	1887.9
7D	Behr #62 - 8.5 year aged R1a	12.27	0.695	160	1262.5	1060.5
8D	Behr #62 - 8.5 year aged R2a	12.27	0.61	60	1535.2	828.2
9D	Thompson's 8.5 year aged R1b	12.52	0.70	ND	305.8	363.6
10D	Thompson's 8.5 year aged R2b	12.52	0.76	ND	518.7	700.7
11D	Wolmans - 8.5 year aged R1c	10.40	0.75	ND	646.4	616.1
12D	Wolmans - 8.5 year aged R2c	10.40	0.69	ND	1353.4	1414.0

Overall, these experiments clearly indicate that commercially-available deck wash products that contain basic oxidizing or chlorine bleach type agents will produce elevated levels of Cr VI when applied to in-service CCA pressure treated lumber. As shown in Table 9 the use of any of these deck wash solutions produces a rinsate with very high total Cr and As concentrations, even from 8.5 year service age lumber.

IV. Summary and Conclusions

In every experiment conducted as part of this research project new and/or aged CCA-treated lumber released relatively large quantities of total chromium and total arsenic. Contact scenarios for either adults or children related to arsenic produce relatively high estimated cancer risks, generally in the range of 1/100 to 1/1000. With tens of millions of US citizens coming in frequent skin contact with CCA pressure-treated lumber, it would appear from the experiments that the continued sale and use of such lumber represents a significant public health issue. With new scientific, epidemiological and scientific review evidence showing that arsenic is a much

more potent carcinogen than previously believed, it would appear to be a worthwhile national public health priority to steer away from the continued use of CCA-treated lumber especially in situations with human contact potential.

Our studies indicate that CCA-treated lumber leaches high concentrations of Cr and As under a variety of precipitation, landfill leaching, and deck washing situations, further adding to potential direct and indirect human exposure routes.

Potential exposure to Cr VI from CCA lumber is an issue that warrants further study. Our initial studies generally did not observe significant Cr VI formation, with the one very important and notable exception of deck washing. Two of the three commercial deck washes tested produced a rinsate containing very high levels of hexavalent chromium.

Economically and structurally viable alternatives to CCA-treated lumber exist in the form of new plastic/wood composites, and particularly with the continuing development of equally effective and economically competitive alternative pressure treatment solutions such as ACQ (ammonium chloride quat.) Our experiments indicate that making a national transition from CCA-treated lumber products to these rapidly emerging alternatives would have a significant positive health impact, especially in terms of arsenic exposure to the US population.

However, existing CCA lumber structures will continue to be in service for decades. Further research is urgently needed to determine and quantify the extent to which various water sealants, deck stains and deck paints can reduce the release of Cr and As from already in-service CCA-treated lumber. Although some preliminary work has been attempted, more in-depth studies are needed to determine more precisely the As release reductions from these products, especially in terms of the required frequency of reapplication.

Acknowledgements

The UNC-Asheville Environmental Quality Institute is an independent public university environmental research center which takes pride in conducting objective and independent research of environmental issues of practical importance to the US public. We gratefully acknowledge the Healthy Building Network for their funding of the research presented in this technical report.

References

1. Scharfenaker, M.A. 2001. Chromium VI: A review of Recent Developments; *Journal of the American WaterWorks Association*. Vol 193 (11) pp 20-26.

2. Arsenic in Drinking Water. Subcommittee on Arsenic in Drinking Water, Committee on Toxicology. Board on Environmental Studies and Toxicology. Commission on Life Sciences, National Research Council. National Academy Press. Washington DC. 1999. pp 83-149.

3. Connecticut Department of Public Health. "Fact Sheet: What You Need to Know About Pesticides Used in Pressure-Treated Wood." Connecticut Department of Public Health, Division of Environmental Epidemiology & Occupational Health. Hartford, CT Feb. 2001. www.dph.state.ct.us/

4. Bartlett, R., B. James. 1979. "Behavior of Chromium in Soils: III Oxidation". *Journal of Environmental Health*. Vol 41.

5. Press Room, Fact Sheets: Arsenic. American Water Works Association. www.awwa.org/pressroom/arsenic.htm.

6. Taylor, A., P.A.Cooper, Y.T.Ung. 2001. Effects of Deck Washes and Brighteners on the Leaching of CCA Components. *Forest Products Journal*. Vol 51, no.2, pp 69-72.

7. Federal Register 40 CRF Ch.1 (7-1-89 Edition) Appendix 1. Toxicity Characteristic Leaching Procedure (TCLP).

8. USEPA Office of Solid Waste. SW-846. Test Methods for Evaluating Solid Wastes Physical/Chemical Methods. Method 1310. Synthetic Precipitation Leaching Procedure. Revision 0. September 1994.

9. Standard Methods for the Examination of Water and Wastewater. Method 3500-Cr B. Colorimetric Method. 20th Edition. 1998.

10. Consumer Products Safety Commission. 2001. Proposed Protocol for Horizontal and Vertical Wiping of CCA-treated Lumber Surfaces. Available from CPSC. Washington DC.