THE EFFECTS OF POST-TREATMENT APPLICATIONS ON LEACHING FROM CCA TREATED WOOD

Paul A. Cooper and Tony Y. Ung
Faculty of Forestry, University of Toronto
and
Adam Taylor, University of New Brunswick

1. Introduction

Chromated copper arsenate (CCA) treated wood is widely accepted for residential construction because of its low maintenance requirements associated with its acceptable natural green colour and its ability to provide protection of the wood surface against ultra violet light degradation. However, if desired by the homeowner, CCA treated wood may be finished by paints, stains or water repellent coatings and treatment may actually enhance the bond between paint and other finishes and wood. (Feist 1979). This is a commonly used option by home owners who prefer a different colour or wish to add supplementary protection against the weather. Another common treatment for decks and other residential structures that have been in service for some time is the application of brush- or spray-on deck washes, cleaners or brighteners to bring the wood colour back to its original new wood appearance (Anon 1998).

While the good resistance to leaching of CCA preservative treated wood has been well documented, it is known that small amounts of the active preservative components, Copper, chromium and arsenic are leached out of treated wood in service. Users of CCA pressure treated wood are naturally concerned about the potential of the treated wood to contaminate soil and surface and ground water adjacent to the wood (e.g., Stillwell and Gorny 1997, Lively 1998, Risk 1998). Much of the soil contamination around CCA treated poles comes from rain water that strikes the pole above ground and runs down the pole to the soil surface (Cooper *et al* 1997). It should be possible to minimize these impacts by use of surface coatings or treatments that reduce water contact with the wood or stabilize leached components. A number of studies (e.g., Baecker 1993, Baecker1995, Behr *et al* 1996, and Scheffer and Morrell 1997) have shown that application of shrink-wrap or other plastic wraps to wood in ground contact reduces losses of creosote from treated wood and creates a barrier to infection by decay organisms in its own right, thereby reducing the requirements for preservative loading. It is likely that these treatments would also reduce leaching of inorganic wood preservatives such as CCA.

Acknowledgements: The authors gratefully acknowledge the financial support of the Natural Sciences and Engineering Research Council of Canada, and the industrial supporters under the NSERC Industry Collaborative Research Program: LPB Poles Inc., Guelph Utility Pole Co., Timber Specialties Ltd., Hicksons Building Products Ltd., Stella Jones Inc., Pastway Planing Ltd., and Bell Canada.

There have been few studies on the effects of stains, paints and other coatings on leaching of CCA components, although the effects on dislodgeability of preservative from treated wood surfaces have been investigated (CPSC 1990), where the effect of stains on dislodgeability of arsenic was found to be minimal. However, it is generally assumed that coatings would have a positive effect and some jurisdictions specify that treated wood be coated for uses such as playground equipment.. It is also known that iron compounds react with and stabilize arsenic (Pierce and Moore 1980).

There have been several studies on the feasibility of extracting CCA treatment from spent treated wood and wood preservation processing sludges and other wastes. High temperature extraction with organic acids such as citric acid, acetic acid, formic acid and oxalic acid or strong mineral acids such as sulphuric, hydrochloric, nitric and phosphoric acids are relatively efficient at removing CCA components (e.g., Honda *et al.,* 1991; Stephan, *et al.*, 1993, Pasek and McIntyre, 1993, Kazi and Cooper 1998) Also, biodegradation using microorganisms such as bacteria, yeast and fungi can extract CCA from spent wood by the action of their metabolites, essentially the organic acids (Stephan *et al.*, 1993, Stephan and Peek, 1992).

Many of the above compounds that are most effective at removing CCA components from these materials are components of deck brighteners and cleaners (Anon 1998). There is a concern (e.g., Fisk) that the use of these materials on CCA treated decks could result in excessive extraction of CCA components and lead to large levels of contaminants in the soil under treated products. Such an effect could also explain anomalous soil contamination results observed by some investigators (e.g., Stillwell and Gorny 1997)

In this paper we review our studies on the effects of water repellents, surface coatings and treatments and deck cleaning products on the leaching of CCA components from treated wood.

2. Methodology

2.1 Evaluaton of water repellent additives

Spruce-pine-fir fence and deck boards and red pine pole sections were treated with CCA with or without one of two (0.5 % WRA and WRB) commercial water repellent additives developed for residential lumber applications. After treatment, the samples were fixed under high humidity conditions at either 21 °C or 60 °C. Some fence board samples treated with CCA-C only were also brushed with a commercial water repellent treatment (Thompsons Water-Seal®). Board samples with or without water repellents were then subjected to laboratory spray leaching tests consisting of alternating fine misting spray for 1 hour and a rest period of 3 hours. Each cycle was approximately equivalent to 6" (150 mm) vertical rainfall (20 liters of water were re-circulated through the spray nozzles during the test period) and samples were subjected to 12 cycles. After each cycle, a water sample was collected and analyzed for CCA components by ion coupled plasma spectroscopy (ICP) and the leach water exchanged with fresh water.

The cumulative amounts of Cu, Cr and As leached out were plotted as a percentage of the total amount of chemical impregnated into the samples. The material was then assembled into fence or deck units and placed in service in Toronto, Ontario. The deck and fence units were equipped with water traps and rain drip water was collected, measured for volume and analyzed for CCA components after each rain storm over a 4 month period. Additional samples were collected from the units over a four week period, after they had been in service for two years. As with the laboratory testing, the cumulative percentage of CCA components leached were estimated over the first natural exposure cycle.

2.2 Evaluation of surface coatings and chemical treatments

Acceptable coatings were sought and evaluated according to the following criteria:

- Ability to adhere strongly to the CCA treated wood in either wet or partially dry condition.
- Cure time
- Toxicity
- Stability to leaching and weathering
- Affordable in bulk quantity
- Ability to reduce CCA leaching significantly.

To evaluate the candidates, coatings under study were subjected to a leach test (non standard) in which the particular coating was applied to CCA treated (and fixed) red pine (3/4" x 3/4" x 6") blocks (between 2 and 5 replications). Treatments were applied to both undried samples and samples dried to 8 % moisture content. The coatings were allowed to cure as required and the samples placed in 300 ml. of distilled water in Polyethylene bags for 2 weeks at room temperature. After 2 weeks, leach water was removed from each specimen bag and analyzed for CCA content by atomic absorption spectroscopy. For formulations that showed promise after this first exposure, this biweekly cycle was repeated several times. Coatings that resulted in arsenic concentrations greater than 5 ppm in the second leach water extraction or were unable to adhere to wet wood were dropped from testing.

The most promising coatings were applied to 2 foot long red pine and southern pine pole sections, previously treated with CCA, fixed and allowed to dry to about 30 % moisture content. These sections were exposed to a spray leaching cycle consisting of six 4 hour cycles of one hour of misting spray followed by 3 hours of rest. This exposure is equivalent to about 36 inches of vertical rainfall. For each pole treatment, 4 pole sections were placed in a polyethylene container and subjected to recirculated misting spray at 20 l per minute At the end of the leaching cycle, a water sample of the recirculated leach water was collected and analysed for copper, chromium and arsenic content by atomic absorption spectroscopy.

2.3 Effects of deck washes and brighteners on CCA leaching

Sixteen one meter square deck units were made with pressure treated southern pine lumber, treated to 6.4 kg/m^3 loading with CCA-C. The samples were fixed at high temperature until all of the chromium was reduced before assembly of the decks. The decks were equipped with a polyethylene collection drape, under the decks and all rain or wash water was collected in polyethylene containers under the decks. The decks were placed out-of-doors in Fredericton, NB in May 1998 and the rain drippage collected, measured for volume and analyzed for copper, chromium and arsenic content by atomic absorption spectroscopy over a 6 week period (5 rain events). Two decks (controls) were scrubbed with 8 liters of water and the water drippage collected for analysis. The remaining decks were treated (two decks per treatment) with seven commercial deck wash or brightener treatments according to manufacturers' recommendations and the decks rinsed with 8 liters of water. The water rinse was collected and analyzed as for the rain water.

3. Results

3. 1 Effect of Water Repellents

All of the water repellents had some effect on the leachate contamination by CCA components (Table 1). After 4 months natural weathering, the leachate concentration for all elements was lowest in samples brush-treated with Thompsons Water-Seal (TWS) and highest for the CCA only treated fence boards. The two commercial water repellent additives applied with the treating solution were less effective, but generally resulted in a lower CCA content in the leachate. This relationship still held after two years in service showing that all water repellents had a positive effect on leachate concentration even after extended service.

The deck units, on the other hand did not show many consistent and statistically significant reductions in leachate concentrations for the two water repellents applied during treatment

The cumulative results of the laboratory and field leaching tests for fence boards treated with CCA-C only and treated with CCA followed by brush treatment with the commercial water repellent are shown in Figures 1 and 2. For samples fixed at 21 °C, the brush-on application of the water repellent reduced the losses of all CCA components significantly during both the simulated and actual rain exposure. The effect was most apparent during the simulated rain period and for chromium and arsenic leaching. During the 12 accelerated cycles (about 72" rain) and the 4 months of natural weathering, the untreated fence panels lost about 0.15% of the total chromium in the wood, about 0.6% of the total copper content and about 0.4% of the total arsenic content. Application of the water repellent reduced these values to about 0.02% Cr, 0.15% Cu and 0.10% As.

Generally, the leaching losses of all elements were lower in the CCA-C treated panels fixed at 60°C (0.05 % Cr, 0.45 % Cu and 0.25 % As) and the effect of the water repellent additive were less significant and resulted in losses in the same order of magnitude as for the samples fixed at 21°C (Figure 2).

The use of paraffin based water repellents incorporated in the CCA-C solution at 0.5 % concentration did not have a significant effect on simulated rain and actual weathering exposure leaching for the deck units (results not shown).

3.2 Effectiveness of Selected Coatings

Based on the preliminary screening tests after three 2 week leaching cycles, the most promising treatments were Coal Tar Epoxy, with or without Titanium Oxide additives to improve the color of the coating and the Polyurethane Sealant treatment which were effective when applied to either initially dry or wet wood (Table 2). The Elastomeric Tool Coating Compound and the Moisture Cured Isocyanate (MDI) were only effective on dry material. On wet CCA treated wood, excessive moisture caused too vigorous a reaction of the MDI resulting in a porous coating which peeled off readily. The Tool Coating Compound did not bond well to wet surfaces, but provided a good enough seal to the encapsulated samples to reduce leaching. However, it is unlikely that it will perform well on poles or other products in service. The polymer additive concrete was mixed and rubbed on to both wet and dry surfaces and after 4 weeks, appeared to hold effectively on both initially wet and dry samples. This treatment is attractive because of its low cost and ease of application, but it appears to lose its effectiveness with repeated leaching exposures.

The inorganic lime and cement treatments (Calcium Hydroxide -White Wash, calcium oxide and Portland cement) are also of interest. They reduce copper losses dramatically and arsenic leaching by more than 50 %. They are also inexpensive treatments and do not affect other wood properties appreciably..

Saturated ferric ammonium sulfate followed by a calcium carbonate/water slurry application) reduced the arsenic content in the leachate, but the copper and chromium losses were substantially higher than the control. Also, ferric ammonium sulfate alone, ferric chloride (FC) and FC followed by the calcium carbonate slurry had high leaching losses of all components.

The application properties and relative costs of the more successful treatments are summarized in Table 3.

Pole sections coated with some of the more effective treatments confirmed that the coal tar epoxy and polyurethane treatments were effective at reducing leachate concentration for all CCA components (Table 4). The polymer concrete treatment was also very effective at reducing copper and arsenic leaching but not chromium leaching. Since copper and arsenic are of most concern and considering their low cost and good application characteristics, cement based coatings should be evaluated further for this application.

3.3 Effects of Deck Treatments

Of the deck treatments evaluated, a number had adverse effects on the amounts of CCA components leached, and especially on the amounts of copper and chromium extracted. Deck cleaners based on phosphoric acid (Figure 3) or the organic oxalic acid (Figure 4) and citric acid (Figure 5) caused high copper leaching. For example phosphoric acid treatment removed 37 times as much copper as an equivalent amount of water applied the same way (Table 5). The amounts of chromium leached were also increased to some extent by these treatments, partly as a result of conversion of a small amount of the trivalent chromium to soluble hexavalent chromium. Treatments based on strong oxidizing agents such as sodium hypochlorite (Figure 8) and sodium percarbonate (Figure 9) resulted in high chromium losses by oxidizing the trivalent chromium in the wood to the soluble hexavalent state. Since hexavalent chromium is much more toxic and mobile in the environment compared to trivalent chromium, this is a matter for concern and this type of treatment should not be used on CCA treated wood. These treatments also resulted in higher arsenic losses compared to water treatment. Sodium hydroxide based treatment (Figure 7) had a similar, but lesser effect due to the oxidation of chromium under alkaline conditions.

The boric acid based treatment (Figure 6) had no effect on leaching of any of the components.

To put these leaching losses in perspective, The amounts of CCA components removed are expressed as a ratio of the average amounts removed during natural rainfall during the summer of 1998 in Fredericton New Brunswick. Because of the higher amounts of water trapped on the average the amounts of chemicals extracted during washing of the decks is not appreciably higher than that obtained through normal rain leaching. For the 5 rain events monitored, an average of 21 liters of drippage was collected from each deck of average concentration: Cu, 3.8 ppm; Cr, 0.9 ppm and As, 2.8 ppm (Table 6). When the amounts of elements extracted under these conditions are compared to the amounts released when the decks were washed with the deck treatments and rinsed with 8 liters of water, the amounts are in the same order of magnitude or lower (Table 7). The main difference is for the hexavalent chromium levels when oxidizing chemicals are used, since virtually no hexavalent chromium is released from properly fixed treated wood exposed to normal water leaching.

4. Summary and Conclusions

1. The inclusion of a compatible wax in the CCA treating solution resulted in slight reduction of CCA component losses from treated fence boards but the effect was less important on deck units. It is possible that by increasing the additive concentration in the treating solution, the benefits to reducing leachate concentration would be greater.

2. Application of a commercial water repellent finish to treated fence boards after

treatment significantly reduced the leaching losses of all CCA components, even after 2 years of natural weathering. It appears that homeowner maintenance of treated wood by periodic application of brush-on water repellents would reduce leaching of CCA components from residential decks and fences.

3. Deck washes may result in higher leaching of CCA components, depending on the active ingredients. The most significant effects are higher copper extraction by phosphoric acid, oxalic acid and citric acid based treatments and conversion of trivalent chromium to leachable hexavalent chromium by strong oxidizing treatments such as sodium hypochlorite, sodium hydroxide and sodium percarbonate. These latter treatments should not be used on CCA treated wood since the hexavalent chromium is relatively toxic and mobile in the environment.

5. References

Anon. 1998. Rx for discolored decks. Building Products Digest. March:14-15.

Baecker, A.A.W. 1993. A non-pressure method of protection based on the hurdle theory to control the spectrum of internal environmental factors which affect the decay of poles in soil contact. Int. Res. Group on Wood Preserv. Doc. IRG/WP/93-20005.

Baecker, A.A.W. 1995. Biostatic film as a primary treatment against pole failure in soil . Int. Res. Group on Wood Preserv. Doc. IRG/WP/95-40053.

Behr, M.R., G.D. Shelver and A.A.W. Baecker. 1996. Field liners prevent creosote migration from transmission poles to soil during service. Int. Res. Group on Wood Preserv. Doc. IRG/WP/96-40067.

Consumer Products Safety Commission. 1990. Project on playground equipment. Estimate of risk of skin cancer from dislodgeable arsenic on pressure treated wood playground equipment. CSPC, Washington, D.C.

Cooper, P.A., Y.T. Ung and J.-P. Aucoin. 1997. Environmental impact of CCA poles in service. Int. Res. Group on Wood Preserv. Doc. IRG/WP/97-50087.

Feist, W.C. 1979. Protection of wood surfaces with vhromium trioxide. USDA Paper FPL-339, Forest Products Laboratory, Madison, WI.

Honda, A., Kanjo, Y., Kimoto, A., Koshii, K. and Kashiwazaki, S. 1991. Recovery of copper, chromium and arsenic compounds from the waste preservative-treated wood.

Document No/.: IRG/WP/3651, 22nd. Annual Meeting, Kyoto, Japan.

Kazi, K.M.F. and P.A. Cooper. 1998. Solvent extraction of CCA-C from out-of-service wood. Int. Res. Grouyp on Wood Preserv. Doc. IRG/WP/98-50107.

Lively, R. 1998. Does pressure treated wood belong in your garden. Kitchen Garden No. 15 (June/July 1998):55-59.

Pasek, E.A. and McIntyre, C.R. 1993. Treatment and recycle of CCA hazardous waste. Document No.: IRG/WP 93-50007, Orlanda, USA.

Pierce, M.L. and C.B. Moore. 1980. Adsorption of arsenite on amorphous iron hydoxide from dilute aqueous solution. Environmental Sci. and Techn. 14(2):214-216.

Rist. C. 1998. Arsenic and old wood. This Old House.March/April 1998,:118-125.

Scheffer, T.C. and J.J. Morrell. 1997. Ability of polyethylene boots to protect the below ground portion of small stakes against decay. Forest Prod. J. 47(5):42-45.

Stephan, I., Nimz, H.H. and Peek, R.D. 1993. Detoxification of salt-impregnated wood by organic acids in a pulping process. Document: IRG/WP 93-50012Orlando, Florida, USA.

Stephan, I. and Peek, R.D. 1992. Biological detoxification of wood treated with salt preservatives. Document No.: IRG/WP 3717, Harrogate, UK.

Stillwell, D.E. and K.D. Gorny. 1997. Contamination of soil with copper, chromium and arsenic under decks built from pressure treated wood. Bull. Environ. Contam. Toxicol. 58:22-29

Table 1: **Average concentration of copper in water drippage from naturally weathered fence and deck units (ppm)**

TREATMENT	Time in Service	[Cu] HT	[Cu] LT	[Cr] HT	[Cr] LT	[As] HT	[As] LT
FENCE							
CCA Only	0-4 m	5.00 a	4.91 a	1.11 ab	1.16 a	2.58 a	2.79 a
CCA + WRA	0-4 m	3.55 a	3.00 a	1.07 a	0.77 ab	2.67 a	1.82 ab
CCA + WRB	0-4 m	1.89 b	2.02 b	0.53 bc	0.70 b	1.08 b	1.36 b
CCA + TWS	0-4 m	0.91 c	1.46 b	0.37 c	0.58 ab	0.49 c	0.79 c
CCA Only	2 y	3.51a	3.74a	1.89 a	1.89 a	2.80 a	3.06 a
CCA + WRA	2 y	2.40a	2.50a	1.50 b	1.66 ab	2.02 b	2.17 ab
CCA + WRB	2 y	1.30b	1.12b	0.57 c	0.86 b	1.03 c	0.80 ab
CCA + TWS	2 y	0.62c	0.73b	0.34 c	0.37 c	0.40 d	0.57 b
DECK							
CCA Only	0-4 m	1.63 a	1.92 a	0.63 a	0.63 a	1.51 a	1.68 a
CCA + WRA	0-4 m	1.50 a	1.28 a	0.36 a	0.42 a	1.04 a	1.18 ab
CCA + WRB	0-4 m	1.58 a	1.28 a	0.59 a	0.70 a	1.03 a	1.10 b
CCA Only	2 y	0.38 a	0.81 a	0.20 a	0.47 a	0.17 a	1.66 a
CCA + WRA	2 y	0.33 a	0.37 a	0.22 a	0.19 a	0.81 a	0.36 a
CCA + WRB	2 y	0.35 a	0.24 a	0.20 a	0.19 a	0.32 a	0.41 a

Note: Values within a column for a given time in service that share the same letter are not statistically different.

Table 2: **Cumulative leaching losses after three - two week leaching cycles (% of initial loading)**

Surface Treatment/Coating (code-description)	Initial Moisture Condition	# Reps.	Average % Leached		
			Cu	Cr	As
Uncoated CCA controls	dry	5	7.9	0.9	8.5
	wet	5	6.8	1.0	7.5
Coal tar epoxy (no pigment)	dry	5	0.4	0.06	0.1
	wet	5	0.2	0.02	0.2
Coal tar epoxy with 5% titanium pigment	dry	3	0.2	0.05	0.45
	wet	3	0.2	0.00	0.8
Coal tar epoxy with 10% titanium pigment	dry	3	0.06	0.01	0.5
	wet	3	0.07	0.01	0.2
Ferric ammonium sulfate (saturated solution in water)	wet	2	Very high	17.4	1.55
Ferric ammonium sulfate solution with a secondary bath in a calcium carbonate water slurry	wet	2	Very high	12.9	0.4
Moisture cure polyurethane (Ashland " Isogrip")	dry	3	0.7	0.03	0.05
Moisture cure polyurethane (with furfural additive to improve wet surface adhesion)	wet	2	9.2	0.7	3.8
Tool coating compound "Plasti-Dip"	dry	3	0.1	0.03	0.08
Polyurethane sealant ("Sikaflex ICSL" Sika Chemicals)	dry	2	0.15	0.01	0.03
	wet	2	0.1	0.04	0.32
Calcium oxide ("quicklime") water slurry	dry	2	0.3	0.5	7.9
	wet	2	0.3	0.25	7.6
Calcium hydroxide (slaked lime Or hydrated lime), water slurry	dry	3	0.2	0.9	2.1
	wet	3	0.1	0.6	2.2
Concrete mix with vinyl additive, "Quikrete"	dry	2	0.3	0.7	1.35
	wet	2	0.3	1.1	1.4
Portland cement- water slurry 70 to 30 parts by wt., portland to water	dry	3	0.3	1.0	2.35
	wet	3	0.15	0.7	1.7
Portland cement- water slurry 50 to 50 parts by wt.	dry	3	0.15	0.6	4.2
	wet	3	0.1	0.5	3.0

Table 3: Cost and Characteristics of Trial Coatings and Surface Treatments for Wet and Dry CCA Treated Red Pine (For reducing/eliminating CCA leaching)

Coating	Cost/ Liter ($)	Cost/pole (Butt region only) ($)	Appl,n Method	Pot Life (hrs)	Initial Cure (contact time) (hrs)	Coating to Substrate Bond Quality		Organic Vapors
						Dry Surface	Wet Surface	
Coal Tar Epoxy (Laurentide)	8.00	5.00	Spray Roll Brush	24	4-8	Excellent	Excellent	Moderate to High
Urethane Sealant Sikaflex2csl (by Sika)	12.00	25.00	Roll Brush	3	7	Excellent	Fair	Moderate to High
Urethane, MDI type Isogrip 300 (Ashland)	7.00	5.00	Spray Roll Brush	Indefinite (one part)	8 on dry 12 on wet	Excellent	Fair	Low
"Plastic Dip" elastomer (PDI,Inc.)	7.30	20-30	Dip only	Indefinite (one part)	1	Poor	Very Poor	High
Portland Cement Mix no aggregate	<1	<1	Spray Dip Brush	1	no cure period necessary	Excellent	Excellent	N/A
Dry Lime white wash.	<1	<1	Spray Dip Brush	1	no cure period necessary	Excellent	Excellent	N/A

Table 4: CCA component concentrations in leachate from coated pole sections exposed to simulated rain exposure

Treatment	Species	CCA Component Concentration in Leachate (ppm)		
		Copper	Chromium	Arsenic
Control	Red Pine	4.2	1.2	2.3
	Southern Pine	2.4	0.7	2.5
Polyurethane	Red Pine	0.6	0.1	0.7
	Southern Pine	0.2	0.04	0.2
Coal tar epoxy	Red Pine	0.4	0.1	0.6
	Southern Pine	0.3	0.02	0.5
Polymer concrete	Red Pine	0.85	1.6	0.08
	Southern Pine	0.4	1.0	0.02

Table 5: Comparison of CCA component extraction of different deck washes compared to similar wash with equivalent amounts of water only

Component of Deck Wash	RATIO OF LEACHED ELEMENT COMPARED TO WATER		
	Cu	Cr	As
PHOSPHORIC ACID	37	10	0.3
OXALIC ACID	20	4.5	4
CITRIC ACID	14	2	1.2
BORATE	1	0.5	1
NaOH	5	15	1.1
NaOH/NaOCl	4	60	5
PERCARBONATE	4	50	4

Table 6: CCA component extraction during typical rain events in Fredericton, NB

LEACHING FROM NATURAL RAIN (AVERAGE OF 5 EVENTS), FREDERICTON, NB.						
AVERAGE WATER COLLECTED	AVG. CONC. IN LEACHATE (PPM)			mg LEACHED		
	Cu	Cr	As	Cu	Cr	As
21 L	3.8	0.9	2.8	81	19	59

Table 7: Comparison of CCA component extraction of different deck washes compared to average summer rain events in Fredericton, NB

COMPOUND	RATIO OF CONTAMINANTS LEACHED COMPARED TO AN AVERAGE RAIN FALL		
	Cu	Cr	As
PHOSPHORIC ACID	1.11	0.23	0.02
OXALIC ACID	0.44	0.39	0.14
CITRIC ACID	0.63	0.26	0.07
BORATE	0.04	0.03	0.03
NaOH	0.15	0.74	0.03
NaOH/NaOCl	0.11	2.26	0.22
PERCARBONATE	0.04	1.53	0.14

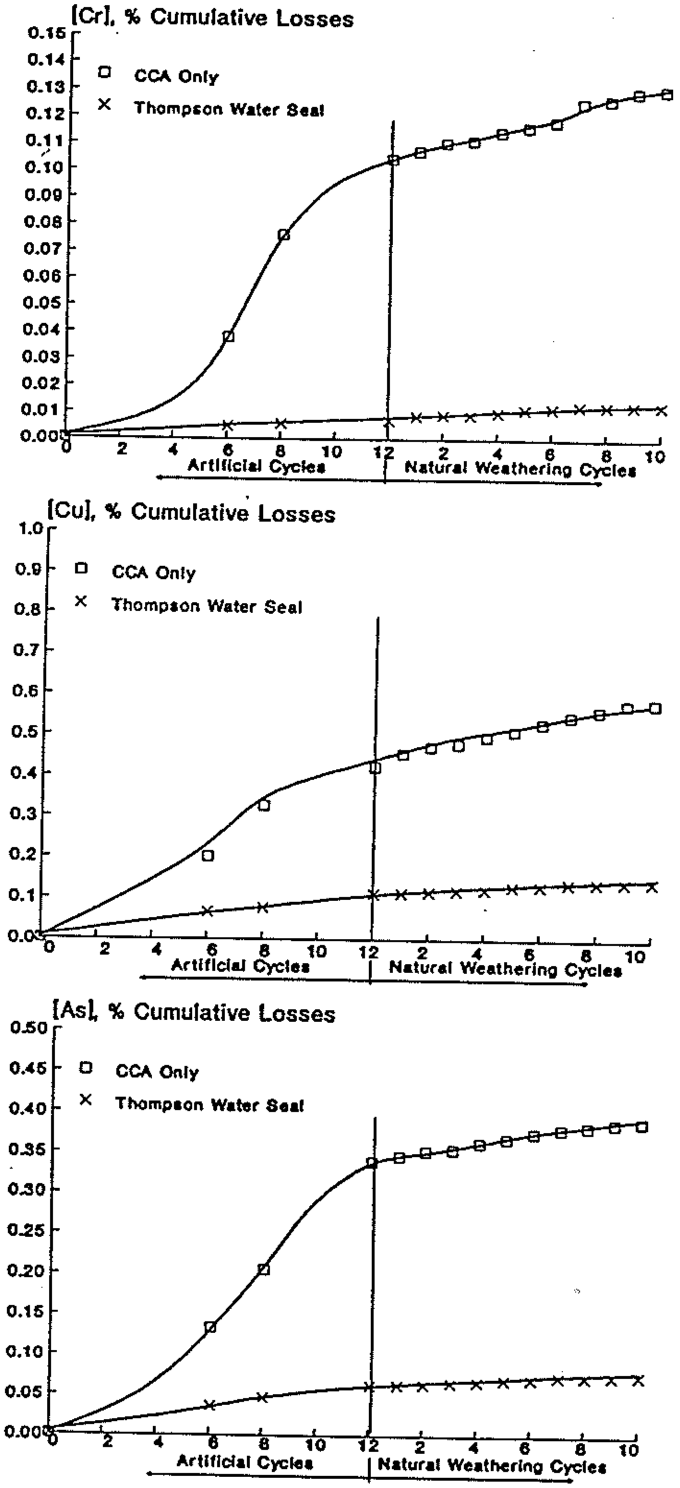

Figure 1: Effect of Brush-on Water Repellent on Leaching of CCA Components from Treated SPF Fence Units – Samples Fixed at 21 C

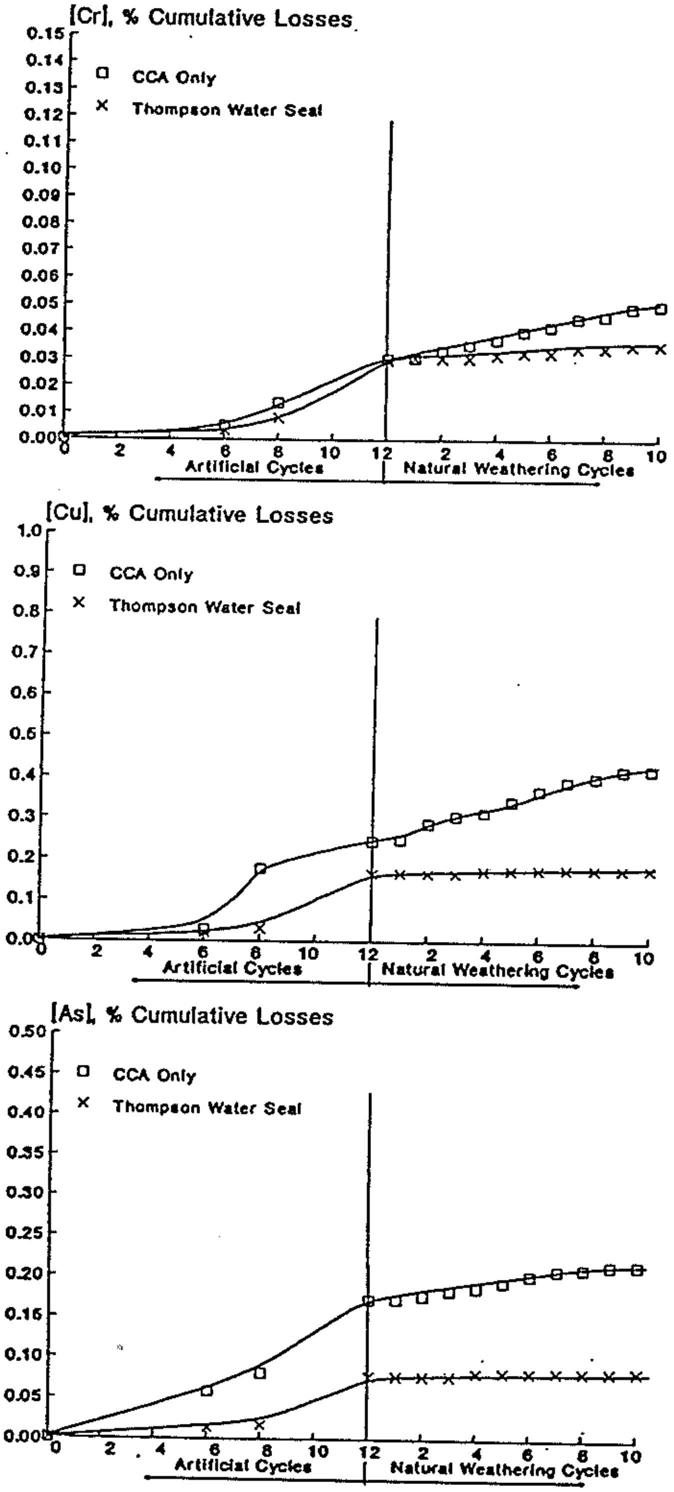

Figure 2: **Effect of Brush-on Water Repellent on Leaching of CCA Components from Treated SPF Fence Units – Samples Fixed at 60 C**

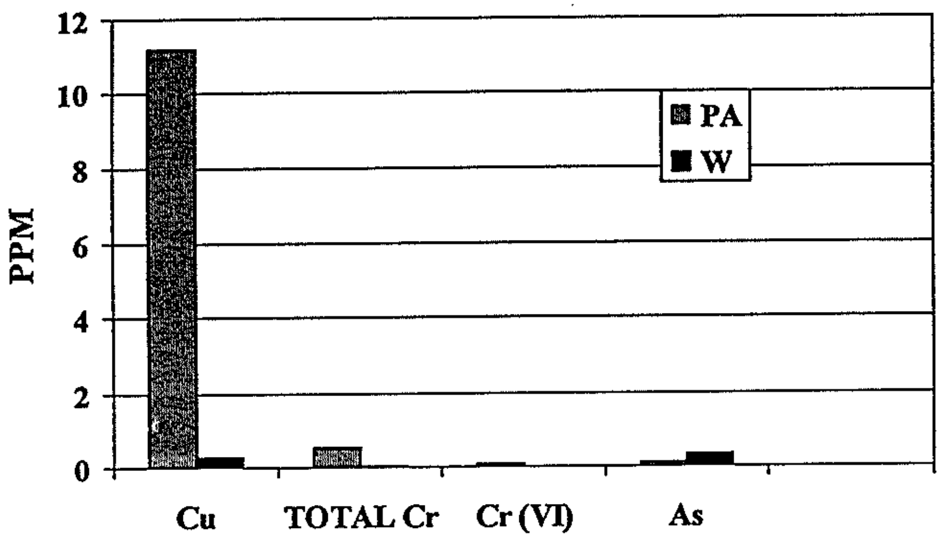

Figure 3. Leaching of CCA components from test decks after application of a deck treatment containing phosphoric acid (PA) in comparison with water only treatment (W). -Average of two decks.

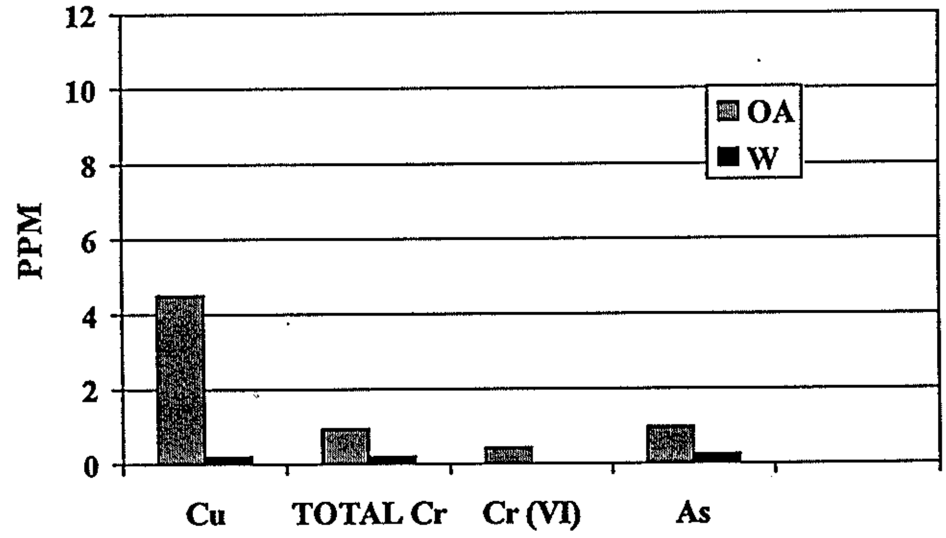

Figure 4. Leaching of CCA components from test decks after application of a deck treatment containing oxalic acid (OA) in comparison with water only treatment (W). -Average of two decks.

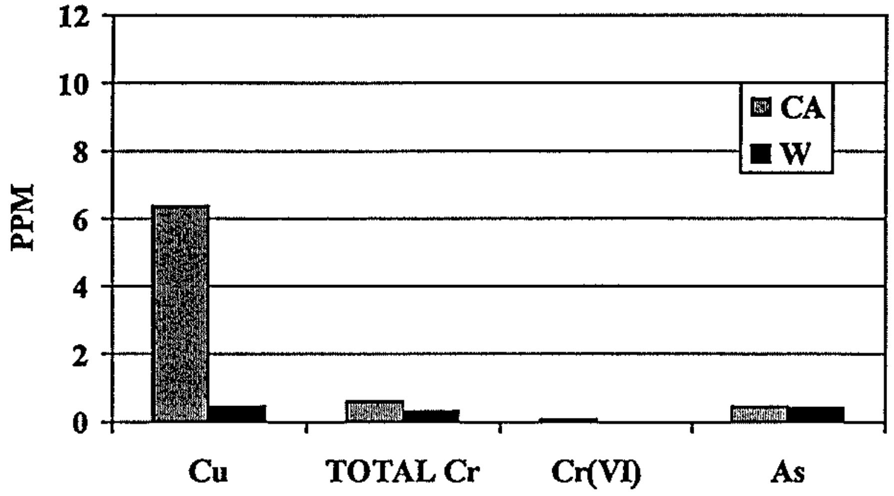

Figure 5. Leaching of CCA components from test decks after application of a deck treatment containing citric acid (CA) in comparison with water only treatment (W). -Average of two decks.

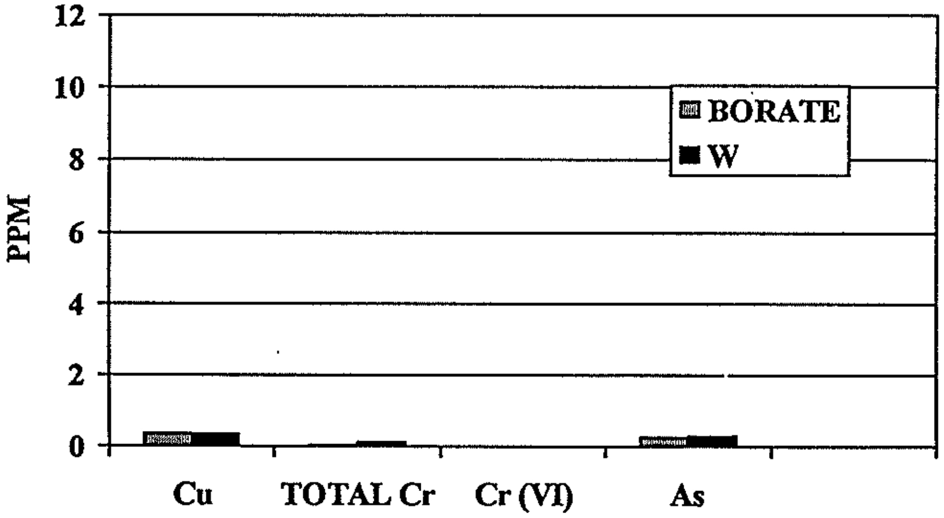

Figure 6. Leaching of CCA components from test decks after application of a deck treatment containing borate (B) in comparison with water only treatment (W). -Average of two decks.

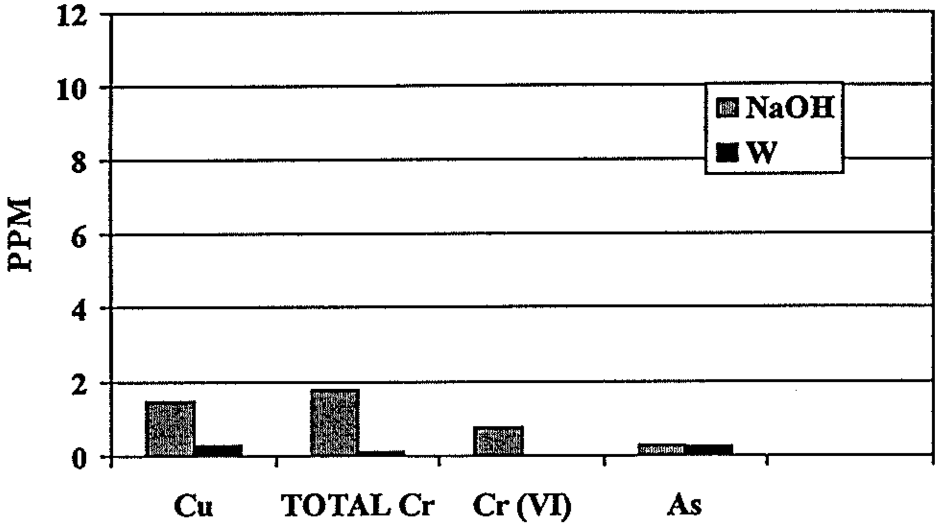

Figure 7. Leaching of CCA components from test decks after application of a deck treatment containing NaOH in comparison with water only treatment (W). -Average of two decks.

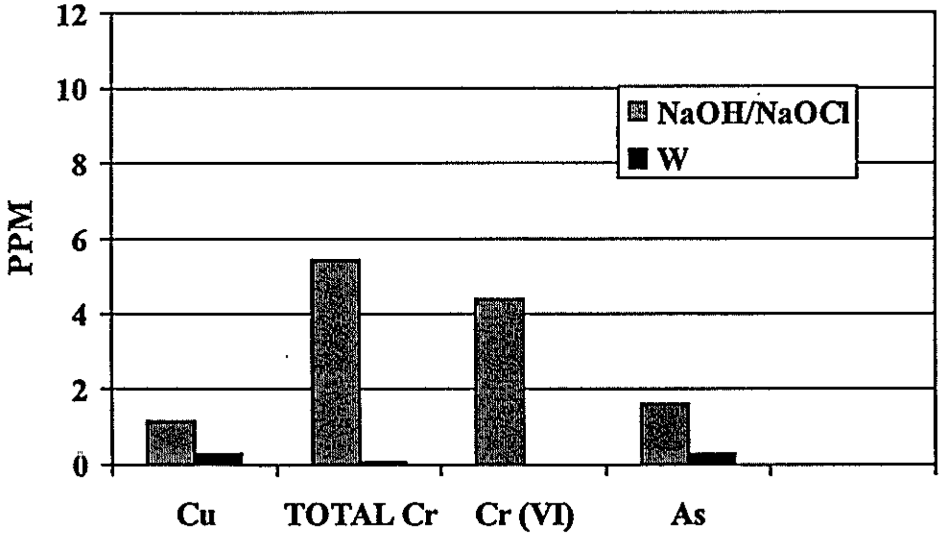

Figure 8. Leaching of CCA components from test decks after application of a deck treatment containing NaOH/NaOCl in comparison with water only treatment (W). -Average of two decks.

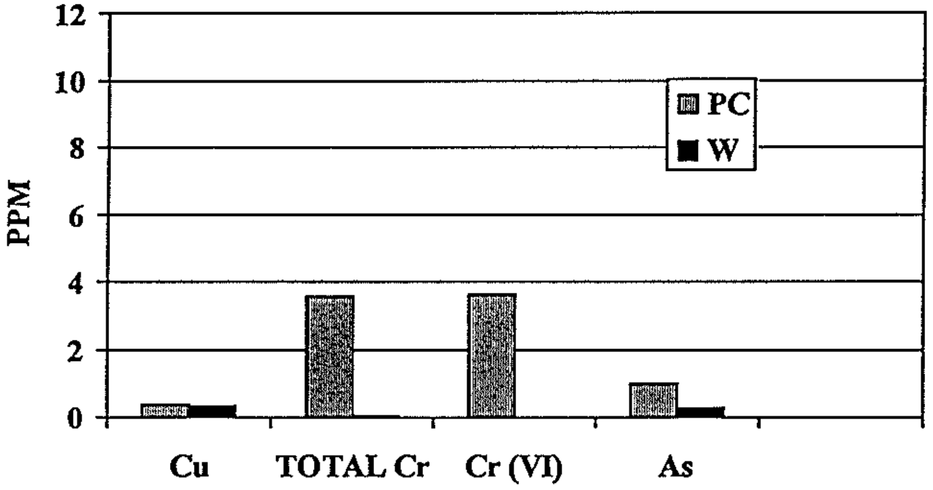

Figure 9. Leaching of CCA components from test decks after application of a deck treatment containing percarbonate (PC) in comparison with water only treatment (W). -Average of two decks.