EVALUATION OF LEACHATE QUALITY

FROM

CCA PRESERVED WOOD PRODUCTS

Prepared for:

Environment Canada
Pacific and Yukon Region
North Vancouver, B.C.

and

B.C. Ministry of Environment, Lands and Parks
Lower Mainland Region
Surrey, B.C.

Prepared by:

Envirochem Special Projects Inc.
North Vancouver, B.C.

March, 1992

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January 5, 1993

Mr. Doug Wilson
Environment Canada
224 West Esplanade
North Vancouver, B.C.
V7M 3H7

Dear Doug:

Re: Evaluation of Leachate Quality from CCA Preserved Wood Products

Enclosed please find a copy of the final report on the above mentioned project.

Thank you for providing Envirochem the opportunity to assist with your environmental requirements. As always, we look forward to assisting you in future projects.

Yours truly,

ENVIROCHEM SPECIAL PROJECTS INC.

Dennis E. Konasewich, Ph.D.
Principal

DEK/gb

c: Mr. Ken F. Hack, Stella-Jones Inc. - (1 copy of report)

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EVALUATION OF LEACHATE QUALITY FROM CCA PRESERVED WOOD PRODUCTS

1.0 INTRODUCTION

Envirochem Special Projects Inc. has undertaken a joint B.C. Ministry of the Environment and Environment Canada study to evaluate the leachability characteristics of wood preservatives from stored wood products and their potential contribution to stormwater discharges.

Although controlled leachate tests of antisapstain treated wood have been conducted by Environment Canada, similar studies have not been conducted for wood treated with wood preservatives. Environmental quality data for stormwater releases from wood preservative operations are minimal and little is known about the leaching characteristics of wood preservation chemicals from treated products. The purpose of this study is to provide preliminary data for regulatory agencies to assess the potential and significance of any releases from wood preservative treated products.

There are numerous wood products treated with the four primary chemical preservation compounds used in the Lower Mainland ie. chromated copper arsenate (CCA), ammoniacal copper arsenate (ACA), pentachlorophenol in oil (PCP), and creosote. Following consultation with wood preservation industry representatives and with regulatory personnel, it was agreed that this study would provide an initial evaluation of leaching from products treated with CCA with an effort to evaluate products with similar dimensions and shapes to enable a relative assessment of leaching characteristics. CCA treatment is used for a variety of wood products including fence posts and boards, landscape ties, foundation plywood, playground lumber, patio lumber and marine pilings, and is used on a variety of species including Douglas fir, Western hemlock, red cedar and lodgepole pines.

The study was restricted to an evaluation of CCA treated wood for two major reasons:

- CCA represents the largest percentage of all the wood preservation facilities in the Lower Mainland. Of six wood preservation operations in the Lower Mainland, five treat wood products exclusively with CCA. The sixth operation also provides CCA treated products, in addition to products treated with ACA, creosote and PCP.

Therefore, the volume of treated wood in storage yards in the Lower Mainland is predominantly CCA.

- Only six leachate trays were available, and all were required in the study of CCA treated products to accommodate to following variables:

  - two different wood species are predominantly treated with CCA, and two control bundles of each species were necessary

  - in addition to the normal treatment process, two types of post-treatment processes are in growing use in the Lower Mainland; application of iron oxide based brown stain to dimension lumber; and, accelerated fixation of poles and some dimension lumber

The test wood products were provided with the kind cooperation of Taiga Forest Products Ltd. and Domtar Inc., Wood Preserving Division.

2.0 METHODOLOGY

The set of protocols that were followed in this study were based on protocols developed by Krahn (1990) for the study of leachates from antisapstain treated wood. The wood preservation leachate study was conducted in March, 1992 at space provided by Western Stevedoring/ Lynnterm in North Vancouver, B.C.

2.1 Wood Test Products

Six wood test product bundles were utilized for this study. Four wood bundles of coastal hemlock fir (hem-fir) dimension lumber were prepared by Taiga Forest Products Ltd. Each bundle consisted of 128 5 cm x 15.2 cm (2"x 6") 4.27 m (14 ft.) long pieces bound in three places with metal strapping.

Wood preservative chromated copper arsenate (CCA) was applied on 21 February to three of the four wood bundles supplied by Taiga. The chemical applied was CCA - Type C in the following formulation: Arsenic Pentoxide (As_2O_5) 33.5%, Chromic Acid (CrO_3) 47.50%, and Cupric Oxide (CuO) 19% on a dry oxide basis, at a rate of 0.4 lbs per cubic foot or 6.4 kg per cubic meter on an assay basis. The CCA was applied by a vacuum/pressure Bethel Process. The Taiga lumber bundles were kept under cover for seven days after the application of the CCA plus an application of an iron oxide based brown stain to one bundle, as per regular Taiga treatment protocols. However, one of the Taiga lumber bundles was shipped to Domtar to undergo their 'accelerated fixation' process immediately following treatment with CCA. All bundles were wrapped prior to shipment to the Lynnterm study area. The bundles were not subjected to precipitation en route to the study site. Delivery of all of the wood bundles occurred on February 28.

The remaining two bundles were western red cedar logs supplied by Domtar Inc., Wood Preserving Division; one untreated bundle consisted of four logs of an approximate diameter of 50-60 cm (20-24") and the other treated bundle consisted of 19 logs of approximately 20-25 cm (8-10"). The logs were also held together by metal strapping in three places. The cedar log bundles supplied by Domtar were treated with a similar CCA Type C formulation at an application rate of 0.6 lbs per cubic foot or 9.6 kg per cubic meter on an assay basis, again using the full cell process. The cedar logs were treated on February 21. Immediately following treatment with CCA the cedar logs and the bundle of dimension lumber supplied by Taiga Forest

Products underwent the standard Domtar 'accelerated fixation' process, which basically involved placing the wood in an insulated tunnel supplied with steam at 80-100°C for approximately 4-8 hours. The cedar logs and the dimension lumber were kept under cover until their delivery to the site on February 28.

2.2 Leachate Tray Set-up

Six metal trays owned by Environment Canada were used to support the wood test bundles and to provide a leachate collection surface. The lumber and logs were bundled and mounted on the trays with dimensions approximately 1.22 m (4 ft) wide and 1.68-4.57 m (14-15 ft) long. The lumber bundle was approximately 81 cm (32 in) high and the logs approximately 114-122 cm (45-48 in) high. Photographs showing the configuration of the bundles mounted on the trays are shown in Figure 1.

The wood bundles were supported on metal beams above a leachate collection surface constructed from a sheet of black polyethylene fastened to the perimeter of the metal frame with C clamps, which drained to a single hole in the centre into a leachate collection container. The 200 litre container, built of mild steel, was lined with black polyethylene. The leachate collection surface of each tray provided for a 6" margin around the perimeter of each wood bundle and is therefore approximately 5 x 15 ft (75 sq ft) or 7 m^2. The margin enabled collection of all leachate with minimal collection of precipitation which was not exposed to the wood bundles. As a result dilution of the leachate was minimized.

2.3 Sampling Schedule

It was originally intended that the wood test bundles would be exposed primarily to natural rainfall with moisture supplemented by artificial rainfall from sprinklers when necessary to maintain a reasonable project schedule and to minimize the influence of time on the amount of wood preservation chemicals leached. Meteorological records indicate that March is a month of frequent rainfall in the Lower Mainland. Based on previous calculations by P. Krahn of Environment Canada, the average worst case month has an accumulation of 238 mm of rain with an average number of 18 days of rain, ie. rain occurring approximately every other day for a month (Krahn, 1990). Therefore, the anticipated sampling schedule was to achieve at least 200 mm of rain spread over a one month period on a frequency of once every two days.

Top: 19 CCA treated cedar logs (on left) and 4 untreated cedar logs (on right)

Bottom: Clockwise from closest bundle: CCA treated with brown stain, CCA treated with accelerated fixation, CCA treated (no post-treatment), untreated

Figure 1. Photographs of the Wood Test Bundles on Leachate Trays on the Lynnterm Site.

During the course of the study, only 10 mm of natural rainfall fell and artificial rainfall was implemented. Artificial rain was produced by using an elevated reciprocating sprinkler head with flow volumes calibrated to produce an equivalent rainfall of approximately 3-4 mm/hr using a configuration as shown in Figure 2. Sample collection was directly correlated to the total amount of accumulated rainfall measured by a rain gauge positioned at the level of the top of the wood bundle. Samples were collected when the "benchmark rainfall accumulations" for the study of 15 mm, 30 mm, 45 mm, 70 mm, 90 mm, 120 mm, 160 mm, and 200 mm were achieved. Samples obtained at 30 mm and 70 mm were not analyzed.

For each rainfall event the sprinklers were turned on and adjusted to a flowrate of approximately 3-4 mm/hr for a period of 4-5 hours. All leachate generated from each rainfall event in each tray was collected and the amount recorded.

To correct for any differences in artificial rainfall applied to each test bundle, the volume of leachate collected in each tray was measured and used to derive an accumulated precipitation applied to each bundle. The actual amount of rainfall measured in the rain gauge was not used in the calculation because of possible error from wind and evaporation relative to the volume collected in each tray. If any rainfall was lost as a result of evaporation and/or retention in the wood, the error introduced by making this assumption would be consistent for each wood test bundle.

2.4 Collection and Analysis of Leachate Samples

At each sampling event, two samples were obtained. First, a 250 ml sample for chemical analysis was collected and filtered through a No. 1 Whatman paper filter into a plastic bottle and fixed with concentrated nitric acid. The sample was filtered to remove any wood debris from the leachate which could contribute significant levels of arsenic, chromium and copper when fixed with nitric acid. Previous studies of the behaviour of CCA in water indicated that arsenic, chromium and copper losses through the filter would be negligible (Gerencher, 1989). The second sample was collected in bioassay jugs (4 collapsible carboys each with 22 litre capacity) and used in a 96 hour static LC_{50} bioassay test with Rainbow trout. The pH of the sample was measured as a component of the 96 hr bioassay test. Chemical analyses were carried out by Quanta Trace Laboratories in Burnaby and the bioassay samples were sent to the B.C. Ministry of the Environment laboratory in North Vancouver. Samples were shipped immediately following collection or stored at 4°C in the dark until shipment the following day.

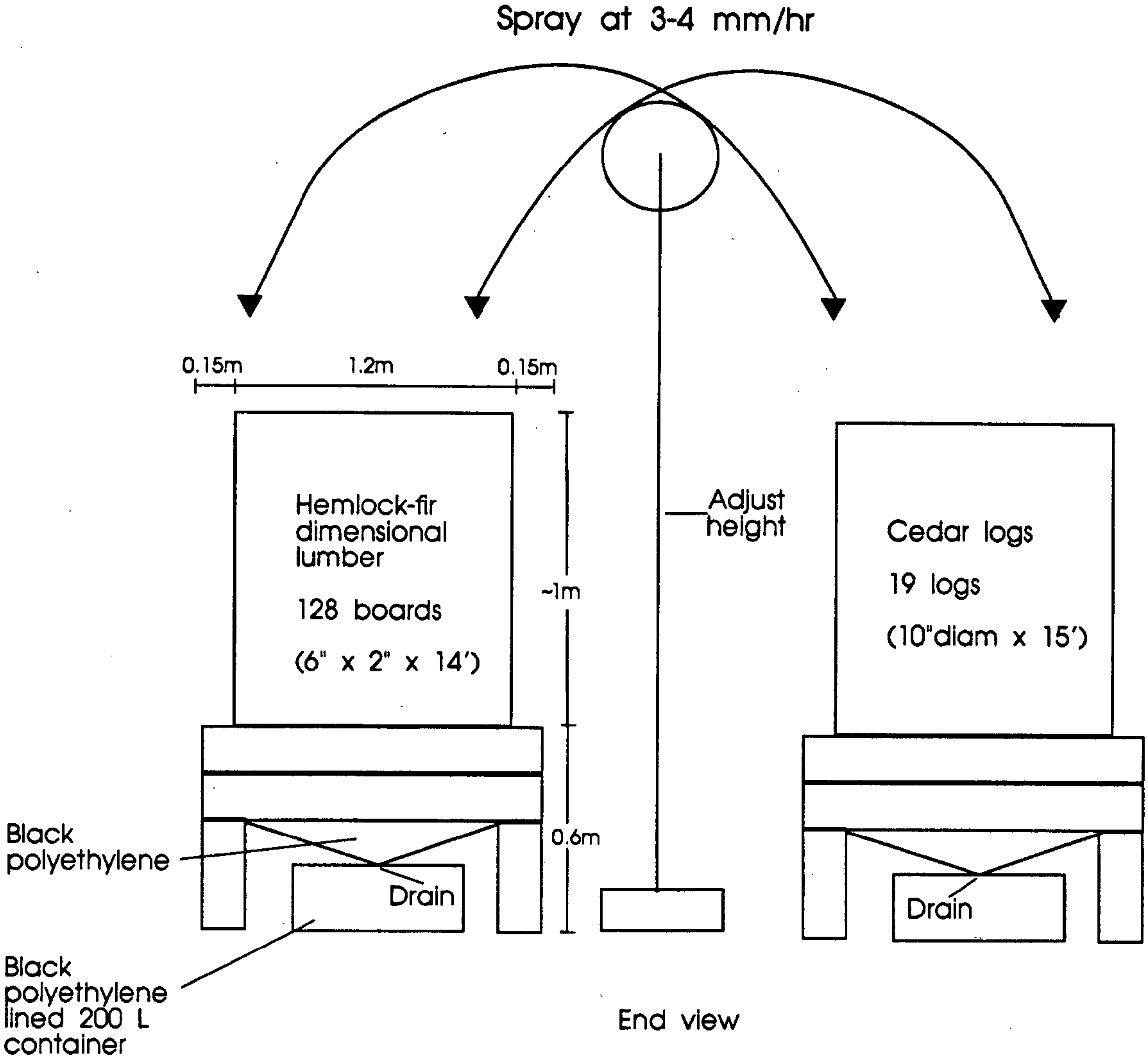


Figure 2. Schematic Diagram of Wood Test Bundles on Leachate Trays Subjected to Artificial Rainfall.

Following collection and preservation by nitric acid, leachates from CCA products were analyzed for copper, chromium and arsenic by Inductively Coupled Plasma (ICP) emission spectroscopy and arsenic by hydride generation with detection limits of 0.001 ppm. A quality assurance program was conducted including: a minimum of two method blanks, unfiltered and another filtered through No. 1 Whatman paper; analysis of one of every six samples submitted in duplicate; analysis of a minimum of two standard reference materials; and the recovery of spikes of relevant compounds. The laboratory reports are included as Appendix A and a QA/QC Data Assessment is included as Appendix B.

2.5 Variables in Methodology Affecting Leachability

2.5.1 Fixation of Wood

The test bundles received favourable fixation conditions of warm temperatures and no rainfall in the three weeks following treatment and prior to leaching. After the preparation of each leachate tray was complete late February, the wood test product bundles were lifted in place on the trays and the wrappings were removed. Although the weather forecasts for the following two weeks consistently predicted rain, artificial rain had to be commenced on March 13. This unusually extended dry period provided three full weeks of fixation (500 hrs) for each of the wood test bundles prior to exposure to the outside elements. In addition, the weather throughout the fixation period was warm (12-18°C) and sunny during the daytime with low humidity. Therefore, although CCA fixation may have been slightly inhibited by low humidity, the time and temperature of the fixation period in this study is considered better than normal conditions experienced during winter months in the Lower Mainland.

2.5.2 Precipitation - Intensity, Duration and Frequency

As mentioned above, virtually no natural rainfall occurred during the study period. Although the program attempted to simulate natural March weather conditions by supplementing rainfall with sprinkler water, the actual patterns and intensity of natural rainfall are likely different than that produced by the sprinklers. During natural precipitation, more equal coverage of the wood bundle will occur. Constant observation and regular adjustment of the sprinkler system was required to compensate for the wind and distribution pattern produced by the sprinklers. The sprinklers create a cone of pulsing mist which decreases in intensity with increasing distance from the sprinkler.

The water quality of natural rainfall may differ from the artificial rainfall applied in this study. The artificial rainfall was supplied from a domestic water supply fire hydrant at the Lynnterm study site. During this period, waters from the Greater Vancouver Regional District had a pH in the range of 5.5-6.0. Typically, the waters have low alkalinity in the range of 1 to 3 mg/l $CaCO_3$.

Although in principle the amount of leachate collected in each tray depends on the amount of rainfall applied, the initial moisture content of the wood will affect the actual amount produced. Wood with a high moisture content will not absorb significant amounts of water. In this test, it is likely that minimal water was absorbed after the initial cycle because the time between cycles was not sufficient to significantly dry the wood.

2.5.3 Wood Species

The species of the wood may have an effect on the leachability of preservation chemicals. In this study, the wood species were western red cedar and coastal hem-fir which are both softwoods. However, the permeability of each of the wood species is different and this affects the penetration of CCA into the wood. CCA in lower permeability wood tends to concentrate near the surface which is more susceptible to being leached or dislodged. (Cooper, 1991).

2.5.4 Test Product Packaging and Handling

The configuration of the leachate trays and the wood test bundles were setup to simulate, to the closest degree possible, an actual wood preservation storage yard. However, there were still differences in the test product packaging and handling that differ from actual practice. Dimension lumber bundles are normally stacked on the storage yard to conserve storage space. The surface area exposure/bundle on an actual yard would therefore be less than the single bundle per tray as used in this study. The dimension lumber subjected to the accelerated fixation process at Domtar was bundled with wooden slats separating each layer of lumber to expose more surface area during treatment, and hence more surface area was exposed during this study. This is ordinarily not done to the dimension lumber product packages but is required for the accelerated fixation process to be effective. The cedar logs handled at Domtar are not usually covered for any period after treatment and accelerated fixation; they are immediately transferred to the storage yard. In this study they were covered for two weeks after treatment and not subjected to rainfall, natural or otherwise, for three weeks.

3.0 RESULTS AND DISCUSSION

3.1 Leachate Preservative Concentration

The chemical analyses results have been plotted for each test bundle against accumulated precipitation. See Figures 3a through 3c below. The y-axis represents the concentration of the relevant compound; arsenic, chromium or copper detected in the leachate measured in parts per million (ppm) (equivalent to milligrams per litre (mg/l)). The x-axis represents the accumulated precipitation. This parameter was chosen as the x-axis as it was thought to be more intuitively meaningful than the volume of leachate collected.

Accumulated precipitation has been used as a variable in an effort to relate the amount of chemical loss in the trays to the rainfall that a bundle of wood would be exposed to during storage in the yard. Each tray had a collection area of 7 m^2 in which the base benchmark volume of 15 mm of rainfall would produce 105 litres. This is a nominal collection rate of 7 litres of leachate per millimetre of rain. To relate the volume of leachate collected in each tray to rainfall, accumulated rainfall has been calculated by dividing the volume of leachate collected in each tray by the nominal collection rate of 7 litres per millimetre of rain. This is also equivalent to dividing the accumulated volume by the surface area of the tray. The values reported represent the total accumulated rainfall, natural or otherwise, from commencement of the leachate test.

The arsenic concentration from each leachate tray is plotted against millimetres of accumulated rainfall in Figure 3a. An exponential best fit line calculated by the graphics software package GRAPHER™ has been drawn through the data points to highlight the trend of decreasing concentrations with increased accumulated rainfall.

In general, the following trends (higher to lower) of arsenic concentrations are observed: CCA treated dimension lumber (no post treatment) ranging from 2.39 mg/l to 1.6 mg/l; CCA treated dimension lumber with brown stain with ranges from 2.12 mg/l to 1.07 mg/l; CCA treated dimension lumber with accelerated fixation with ranges from 1.18 mg/l to 0.792 mg/l; and, CCA treated cedar logs ranging from 1.33 mg/l to 0.395 mg/l. The untreated wood bundles had arsenic concentrations lower than the detection level of 0.04 mg/l.

FIGURE 3a. ARSENIC CONCENTRATION vs. PRECIPITATION

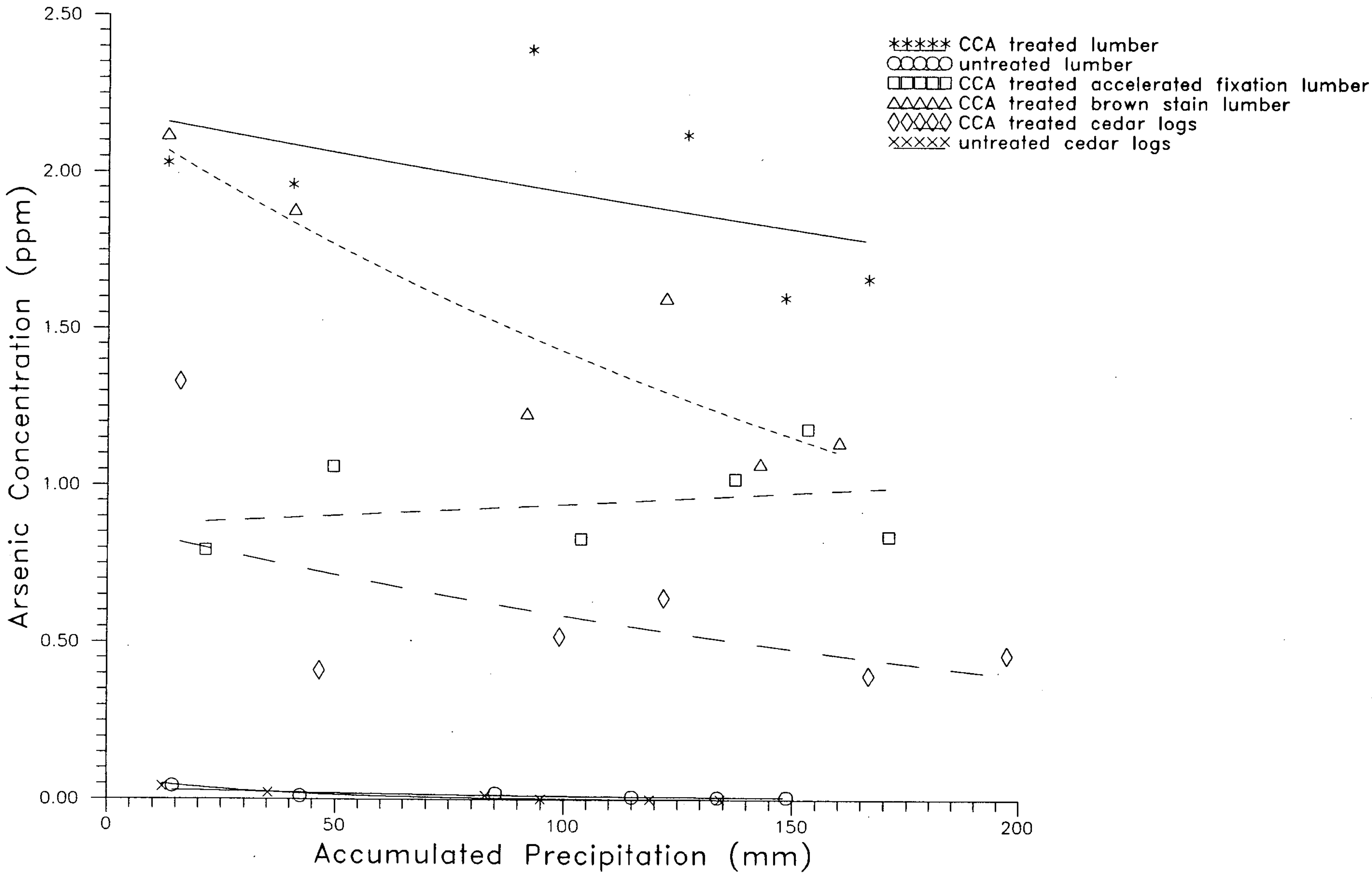


FIGURE 3b. CHROMIUM CONCENTRATION vs. PRECIPITATION

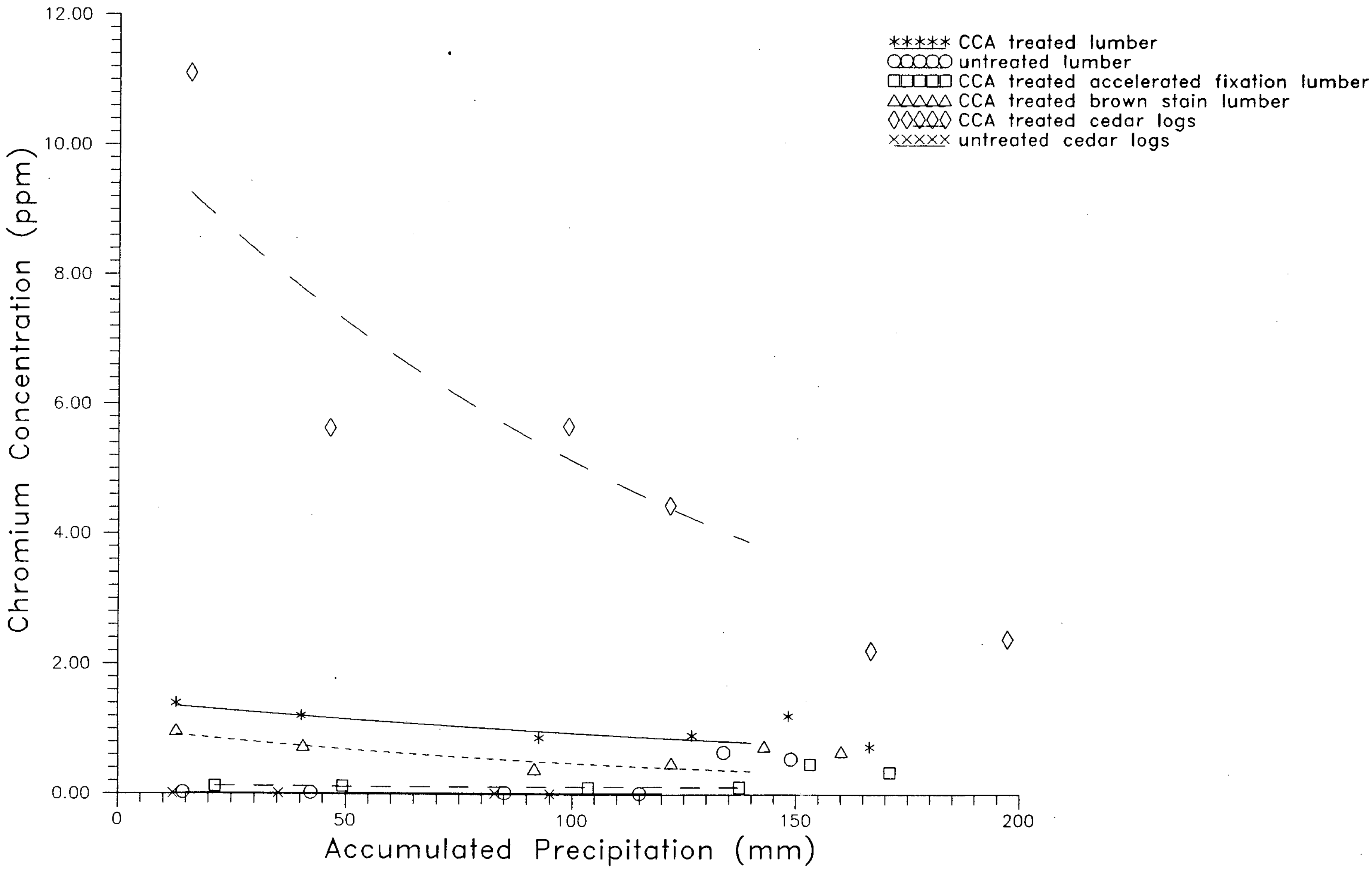
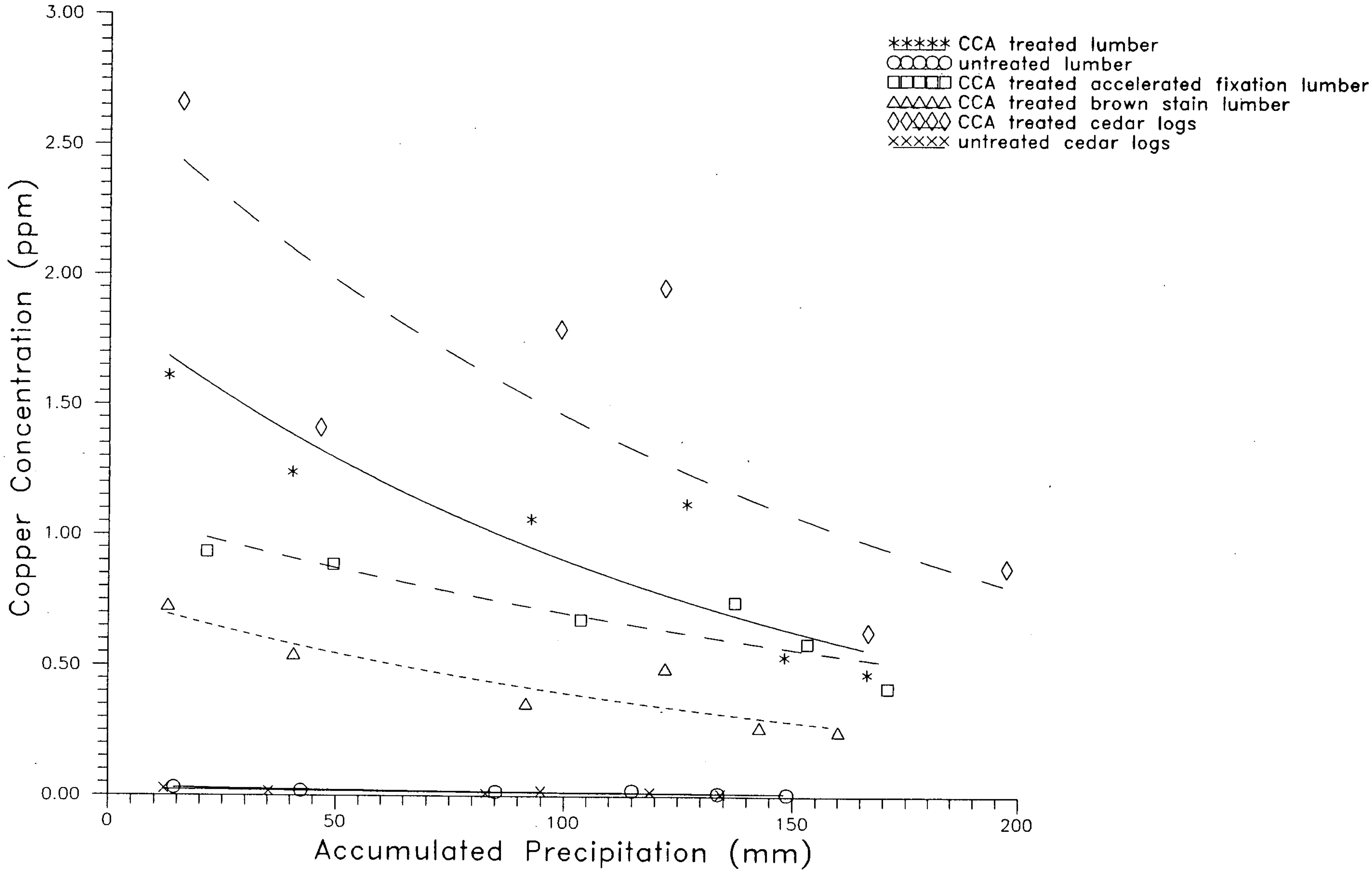


FIGURE 3c. COPPER CONCENTRATION vs. PRECIPITATION



The plot of chromium concentration against the amount of rainfall is shown in Figure 3b. The chromium concentrations in the leachate from the CCA treated cedar logs are significantly higher than all other wood bundles ranging from 11.1 mg/l to 2.21 mg/l. Progressively lower chromium concentrations resulted from the CCA treated lumber (no post treatment) ranging from 1.4 mg/l to 0.738 mg/l, followed by CCA treated lumber with brown stain ranging from 0.98 mg/l to 0.4 mg/l and the CCA treated lumber with accelerated fixation ranging from 0.467 mg/l to 0.11 mg/l. The untreated wood bundles are consistently in the order of 0.02 mg/l until the last two sampling events where the concentrations range from 0.36 mg/l to 0.654 mg/l which actually exceeds the concentration in some of the treated samples. A laboratory error is suspected in the last two chromium results and therefore they are not used in the data interpretation.

Copper concentration is plotted against the amount of rainfall in Figure 3c. Copper concentrations are again are at the highest levels from the CCA treated cedar logs and range from 2.66 mg/l to 0.629 mg/l. The CCA treated lumber (no post treatment) concentrations ranged from 1.61 mg/l to 0.469 mg/l. Copper concentrations from the CCA treated lumber with accelerated fixation ranged from 0.934 mg/l to 0.416 mg/l compared to the lowest levels which were found in the CCA treated lumber with brown stain ranging from 0.729 mg/l to 0.251 mg/l. Concentrations in the untreated wood bundles were less than 0.03 mg/l.

The laboratory analytical results for arsenic, chromium, and copper as well as the 96 hr LC_{50} toxicity test results after each sampling event are summarized in Table 1.

For the purpose of more complete information, the concentration of metals other than arsenic, chromium and copper in all leachates during the third sampling event are provided in Table 2. Comparable concentrations of iron are present in the leachates from each wood test bundle including the brown stained CCA treated lumber. The brown stain is iron oxide based.

3.2 Loss of Preservative Constituents

The accumulated loss (grams) of the wood preservative constituents arsenic, chromium, and copper are plotted against the accumulated amount of leachate collected from each wood test bundle in Figures 4a to 4c. The concentration in the leachate collected was multiplied by the total volume collected to calculate the mass of chemical lost per leaching cycle. A summation of losses gives the total amount of chemical lost over the duration of the leachate study.

Sample Description	Sample Date	Sample pH	Total Rainfall (mm)	Arsenic Conc. (ppm)	Chromium Conc. (ppm)	Copper Conc. (ppm)	Fish 96HR LC50 (%)
CCA treated dimensional hemlock-fir	13/03/92	6.6	12.9	2.03	1.4	1.61	7
	20/03/92	6.4	40.3	1.96	1.21	1.24	4.3
	24/03/92	6.6	92.6	2.39	0.873	1.06	10.3
	26/03/92	6.5	126.7	2.12	0.905	1.12	20.8
	30/03/92	6.7	148.1	1.6	1.21	0.534	9.9
	31/03/92	6.3	166.4	1.66	0.738	0.469	33.2
untreated dimensional hemlock-fir	13/03/92	6.6	14.3	0.042	0.025	0.03	non-toxic
	20/03/92	6.5	42.4	0.011	0.027	0.02	non-toxic
	24/03/92	6.4	85.1	0.02	0.027	0.017	non-toxic
	26/03/92	6.3	115	0.009	0.021	0.022	non-toxic
	30/03/92	6.4	133.7	0.007	0.654	0.011	non-toxic
	31/03/92	6.2	148.7	0.008	0.549	0.008	non-toxic
CCA treated dimensional hemlock-fir w/ accelerated fixation	13/03/92	6.15	21.4	0.792	0.123	0.934	6.4
	20/03/92	6.2	49.4	1.06	0.129	0.886	5.7
	24/03/92	6.3	103.6	0.83	0.11	0.675	16
	26/03/92	6.4	137.3	1.02	0.113	0.742	14.6
	30/03/92	6.3	153.1	1.18	0.467	0.584	13.2
	31/03/92	6.2	170.9	0.838	0.344	0.416	23.6
CCA treated dimensional hemlock-fir w/ brown stain	13/03/92	7.0	12.9	2.12	0.98	0.729	14.5
	20/03/92	6.7	40.7	1.88	0.749	0.544	73.7
	24/03/92	6.9	91.6	1.23	0.4	0.356	40% mort. @ 100%
	26/03/92	6.7	122.1	1.6	0.485	0.49	40% mort. @ 100%
	30/03/92	6.8	142.7	1.07	0.75	0.265	41.2
	31/03/92	6.4	160	1.14	0.67	0.251	undetermined
CCA treated western red cedar logs	13/03/92	6.3	15.7	1.33	11.1	2.66	4
	20/03/92	6.7	46.4	0.41	5.63	1.41	7.6
	24/03/92	6.8	98.9	0.518	5.65	1.79	3.7
	26/03/92	6.9	121.7	0.641	4.43	1.95	5.2
	30/03/92	6.3	166.6	0.395	2.21	0.629	19.1
	31/03/92	6.3	197.3	0.46	2.38	0.875	13.2
untreated western red cedar logs	13/03/92	6.1	12.1	0.04	0.008	0.026	non-toxic
	20/03/92	6.0	35.3	0.021	0.016	0.018	non-toxic
	24/03/92	5.6	82.9	0.013	0.016	0.010	non-toxic
	26/03/92	5.8	95	0.003	0.014	0.02	non-toxic
	30/03/92	5.9	118.9	0.001	0.36	0.016	non-toxic
	31/03/92	5.3	134.3	0.001	0.406	0.009	non-toxic

Table 1. Summary of Laboratory Results: As,Cr, and Cu; 96 hr LC50

TABLE 2. RESULTS OF COMPLETE METAL ANALYSIS FOR THIRD SAMPLING EVENT (mg/l)

Parameter	CCA-treated lumber	Untreated lumber	CCA-treated lumber with acc. fixation	CCA-treated lumber with brown stain	CCA-treated cedar logs	Untreated cedar logs
Aluminum	0.042	0.082	0.067	0.066	0.093	0.1
Antimony	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Arsenic	2.39	0.02	0.83	1.23	0.518	0.013
Barium	<0.001	0.004	<0.001	0.006	<0.001	0.006
Beryllium	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002
Bismuth	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Cadmium	<0.0003	<0.0003	<0.0003	<0.0003	<0.0003	<0.0003
Calcium	1.34	2.15	1.24	2.06	4.43	2.25
Chromium	0.873	0.027	0.11	0.4	5.63	0.016
Cobalt	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Copper	1.06	0.017	0.675	0.356	1.79	0.01
Iron	0.135	0.189	0.209	0.206	0.251	0.246
Lead	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004
Lithium	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Magnesium	0.33	0.43	0.25	1.31	1.37	0.28
Manganese	0.036	0.276	0.08	0.026	0.03	0.024
Molybdenum	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003
Nickel	<0.001	<0.001	0.002	<0.001	0.006	0.002
Phosphorus	0.42	2.75	0.17	0.19	0.05	2.27
Potassium	12.6	12	4.32	8.75	3.94	6.93
Selenium	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Silicon	1.9	2.02	1.94	1.94	2.19	2.2
Sodium	2.43	1.93	1.18	2.19	3.3	1.71
Strontium	0.003	0.004	0.002	0.009	0.009	0.01
Thorium	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Titanium	<0.001	<0.001	<0.001	0.002	0.003	0.003
Uranium	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Vanadium	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Zinc	0.021	0.029	0.02	0.02	0.025	0.031
Zirconium	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001

FIGURE 4a. ACCUMULATED ARSENIC LOSS vs. LEACHATE COLLECTED

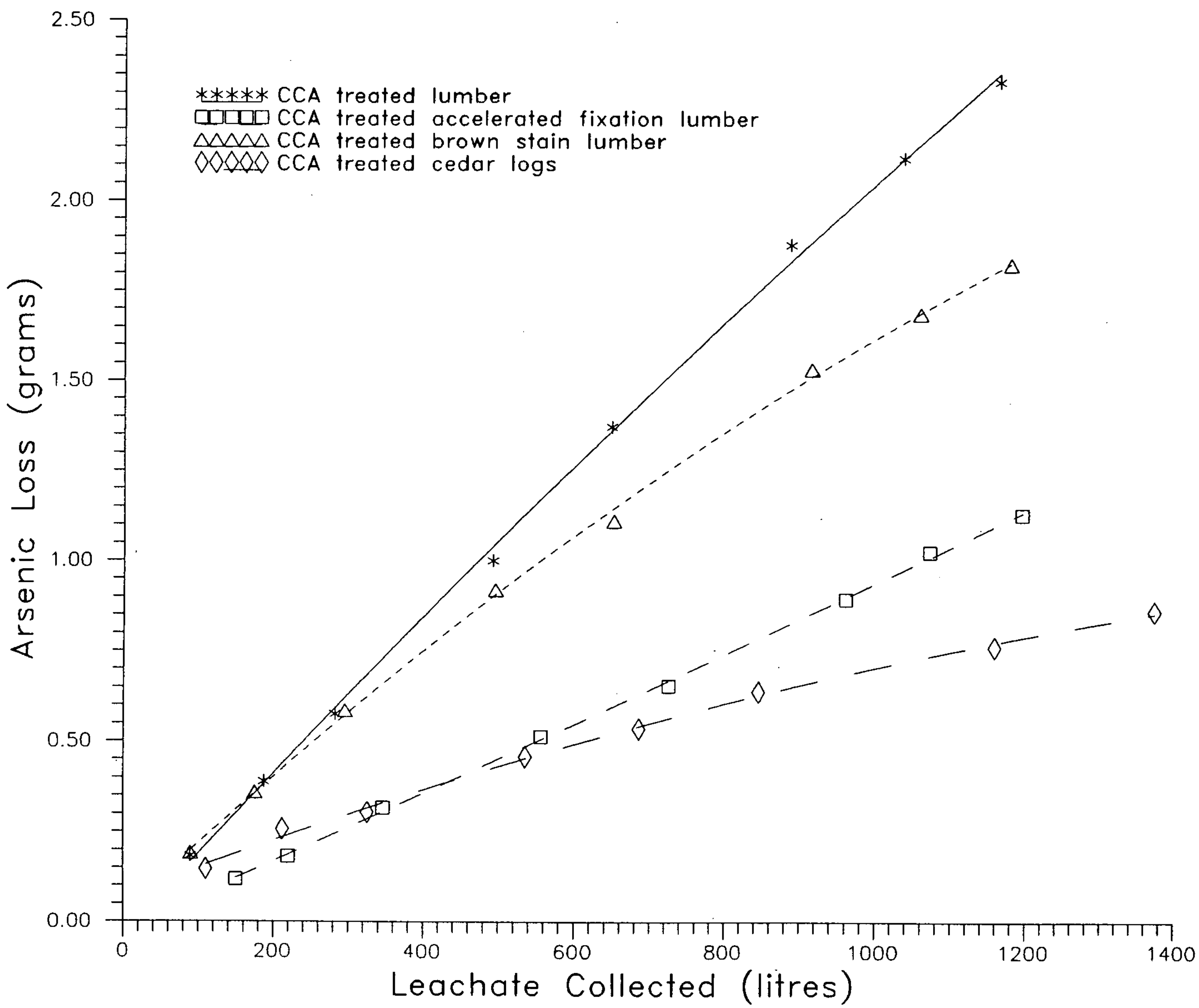


FIGURE 4b. ACCUMULATED CHROMIUM LOSS vs. LEACHATE COLLECTED

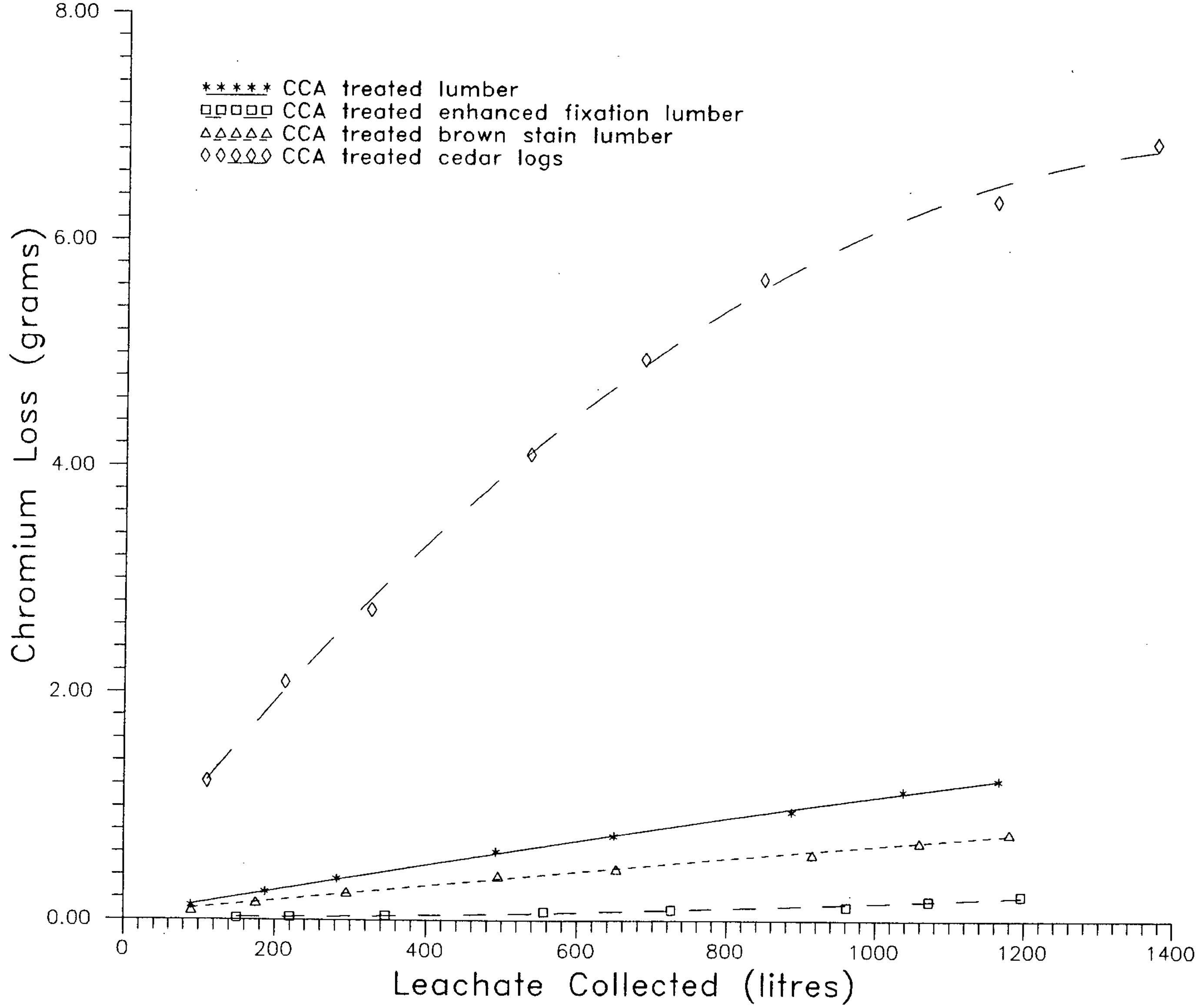
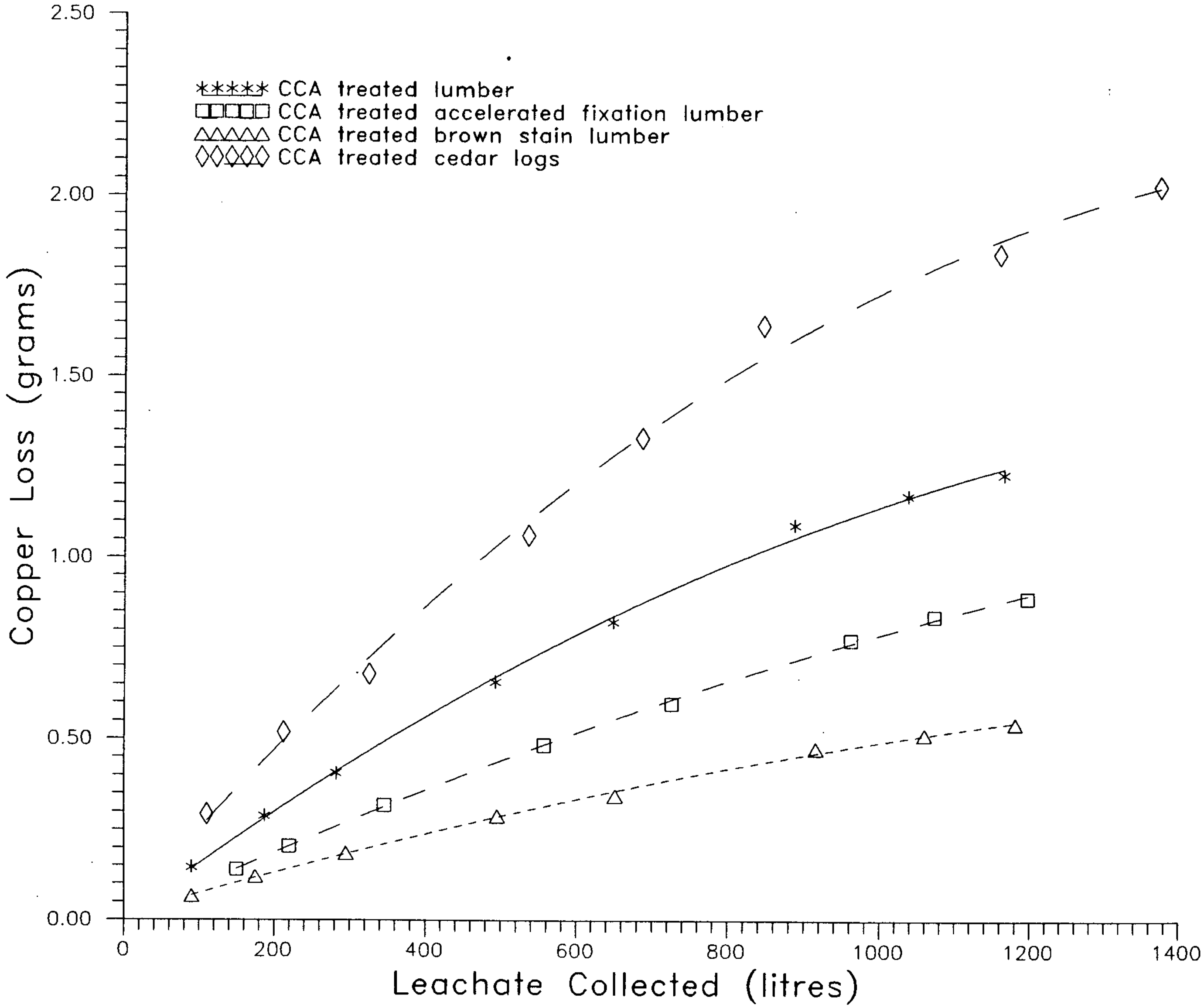


FIGURE 4c. ACCUMULATED COPPER LOSS vs. LEACHATE COLLECTED



Leachate collected from two intermediate leachate cycles were not analyzed in the laboratory and therefore their respective concentrations were interpolated from the plots of concentration vs. accumulated precipitation.

The plot of accumulated arsenic loss vs. accumulated leachate collected is shown in Figure 4a. Best fit lines (polynomial as calculated by GRAPHER™) are drawn through each set of data from each wood test bundle. From the limited data set the best fit lines suggest there is a slight curvature in the plot indicating that as more and more leachate is collected a smaller amount of arsenic is leaching from the wood bundles with brown stained CCA lumber and with the CCA treated logs. The rate of arsenic depletion for the CCA treated lumber with no post treatment remained constant. The total amount of arsenic lost for the first 1000 litres of leachate collected is greatest for the CCA lumber (no post treatment) at 2.0 g, then the CCA lumber with brown stain at 1.6 g, followed by CCA treated lumber with accelerated fixation at 0.9 g and the CCA treated cedar logs at 0.7 g.

The plot of accumulated chromium loss vs. accumulated volume of leachate collected is shown in Figure 4b. The total loss of chromium at 1000 litres of leachate collected is significantly greater for the CCA cedar logs at 6.0 g compared to 1.0 g for CCA treated lumber, 0.6 g for CCA treated lumber with brown stain, and 0.1 g for CCA treated lumber with accelerated fixation. A rapid loss is initially observed with the CCA treated cedar logs; a rate of loss of approximately 6 mg Cr per litre of leachate produced for the first 1000 litres was observed, with a decrease to approximately 3 mg lost per litre of leachate for the remaining 400 litres. The total rate of loss of chromium for CCA treated lumber is low and relatively constant at approximately 1 mg lost per litre of leachate, 0.5 mg per litre of leachate for CCA treated lumber with brown stain, and 0.1 mg per litre of leachate for CCA treated accelerated fixation lumber.

The plot of accumulated loss of copper vs. leachate collected is shown in Figure 4c. CCA treated cedar logs have the highest total loss of copper at 1000 litres of leachate collected at 1.7 g compared to 1.1 g for the CCA treated lumber, and 0.8 g for CCA treated lumber with accelerated fixation. The lowest total loss of copper was from CCA treated lumber with brown stain at 0.5 g. The initial rate of loss of copper from the CCA treated cedar logs is approximately 2 mg per litre and then decreases to 0.9 mg per litre of leachate for the remaining 400 litres. The other wood bundles deplete at progressively slower rates as follows: CCA treated lumber from 1.4 mg per litre of leachate to 0.7 mg per litre of leachate, CCA treated lumber with accelerated fixation from 0.8 mg to 0.6 mg per litre of leachate and CCA treated lumber with brown stain from 0.5 mg to 0.4 mg per litre of leachate.

The rate at which chromium and copper deplete from the CCA treated cedar logs is significantly higher than for the CCA treated dimension lumber bundles. This may be due to the increased amount of accessible surface area of the logs, or may reflect a lower penetration of CCA into the cedar logs producing a higher concentration of wood preservatives at the surface layer which are more readily solubilized and extracted into the leachate compared to the dimension lumber. However, the concentrations quickly decrease to near comparable levels produced in the dimension lumber leachate.

Table 3 lists the total estimated loss of each wood preservative for the entire study period. This estimated loss is expressed as a percentage (%) of the total preservative applied. This was calculated by multiplying the application rate of the dry oxide formula (assay basis) by the volume of wood treated based on the standard depth of penetration of 10 cm (0.4) in for the lumber and 15 cm (0.6 in) for the logs.

For example, estimate of amount of CCA applied in kg per bundle of lumber is:

	CCA applied to lumber on assay basis:	6.4 kg/m^3
	Standard Depth of Penetration:	0.01 m
	Total Volume of Treated wood/Bundle:	1.75 m^3
therefore,	**Total Amount CCA applied:**	**11.2 kg**

The total loss for the lumber bundles is also expressed per wood volume basis or per 1000 board feet, where one board foot equals one twelfth of a cubic foot (calculated on the nominal lumber dimensions 2" x 6" x 14'). In addition, the estimated loss is expressed per 1000 sq. ft. of total surface area of all wood surfaces. Only a fraction of the total surface area is exposed to precipitation and is a function of bundle configuration, and rainfall intensity and duration.

The percentages of CCA wood preservative constituents lost to the total amounts applied to the dimension lumber bundles ranged from 0.003% to 0.06%. The most significant difference observed was for CCA treated lumber with accelerated fixation with which chromium losses were an order of magnitude lower than for the CCA treated lumber with no post treatment and the CCA treated lumber with brown stain. Accelerated fixation also resulted in lower releases of arsenic and copper for CCA treated wood. The percentage of chromium and copper lost from the CCA treated cedar logs is an order of magnitude higher than from the dimension lumber bundles.

3.3 Proportion of Preservative Constituents in Leachate

Figures 5a to 5d. show stacked-bar graphs for each of the treated wood bundles plotting the comparative concentrations of each preservative constituent vs. amount of rainfall. The plots enable a comparison of the constituent concentrations leaching from the wood. The graphs also show the differences in leaching of particular constituents compared to the original CCA Type C proportions of 1.4:1.6:1 (As:Cr:Cu).

Estimated Losses*	CCA treated lumber	CCA treated lumber accel. fix'tn	CCA treated lumber brown stain	CCA treated cedar logs
Accumulated Arsenic Lost (g)	2.3	1.1	1.8	0.9
% of As lost (% of amount applied)	0.06	0.03	0.05	0.04
As (g) Lost per 1000 board feet (nominal) ++	1.28	0.61	1.00	-
As (g) Lost per 1000 sq. ft. surface area	1.09	0.52	0.85	1.17
Accumulated Chromium Lost (g)	1.2	0.2	0.8	6.9
% of Cr lost (% of amount applied)	0.023	0.003	0.015	0.22
Cr (g) Lost per 1000 board feet (nominal) ++	0.67	0.11	0.45	-
Cr (g) Lost per 1000 sq. ft. surface area	0.57	0.09	0.38	9.0
Accumulated Copper Lost (g)	1.2	0.9	0.5	2.0
% of Cu lost (% of amount applied)	0.056	0.04	0.02	0.16
Cu (g) Lost per 1000 board feet (nominal) ++	0.67	0.50	0.28	-
Cu (g) Lost per 1000 sq. ft. surface area	0.57	0.43	0.24	2.6

* after 8 leachate cycles, with approximately 1400 litres (in total) of precipitation per test bundle
++ no value calculated for cedar logs as board feet has no meaning for round material

Table 3. Estimated Losses of Wood Preservative Constituents

As:Cr:Cu vs. Accumulated Rainfall

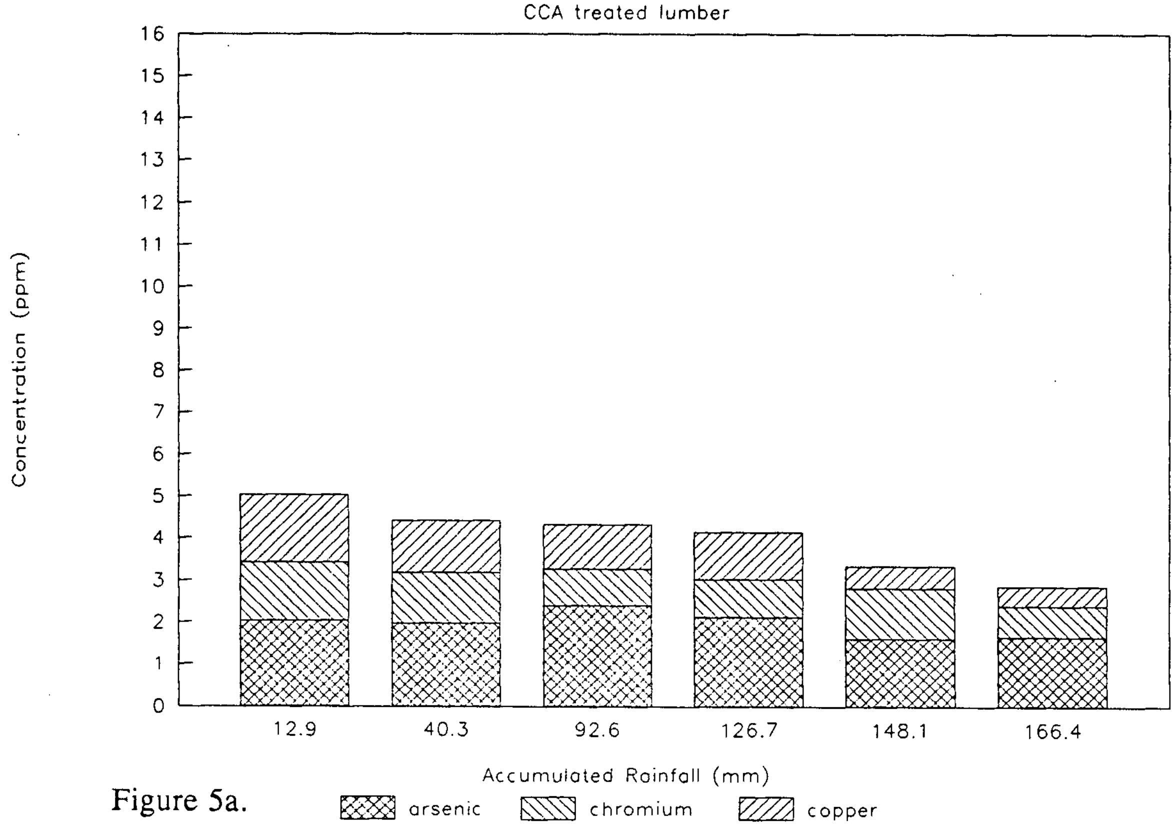


Figure 5a.

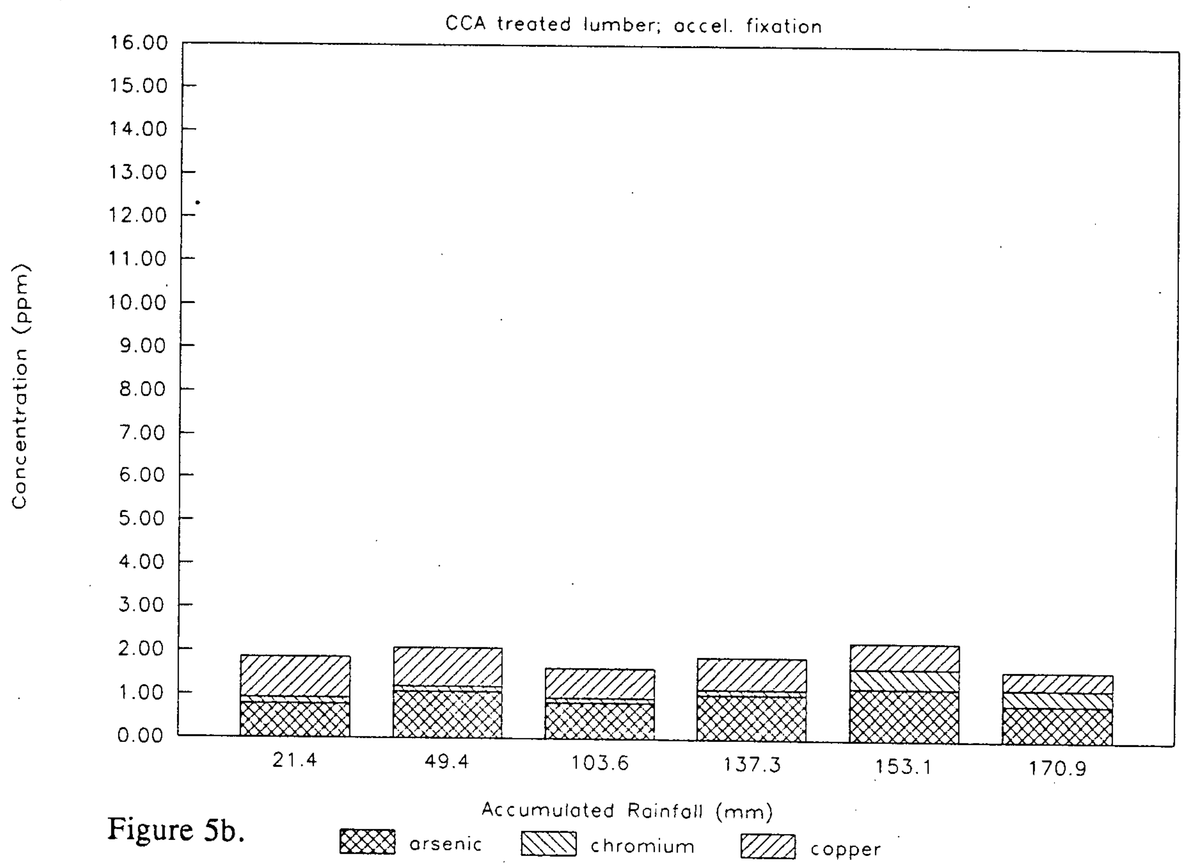


Figure 5b.

As:Cr:Cu vs. Accumulated Rainfall

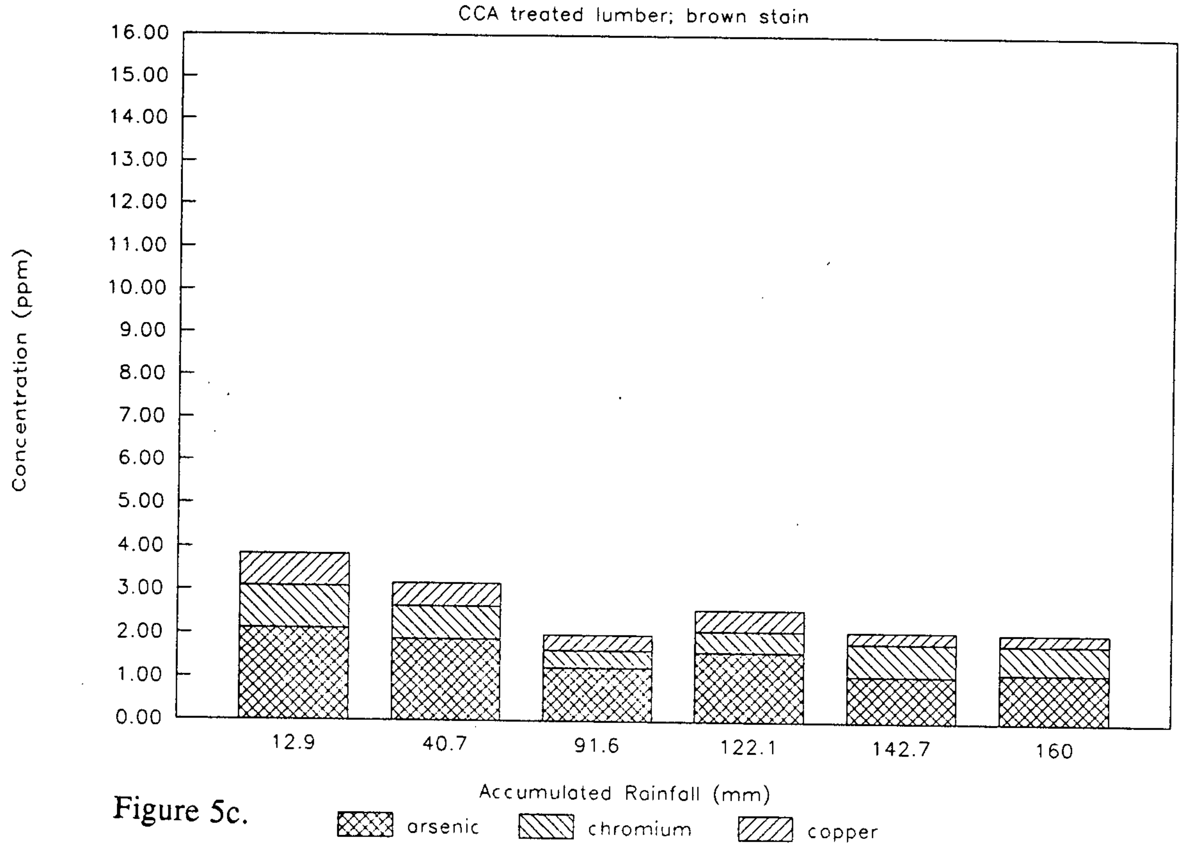


Figure 5c.

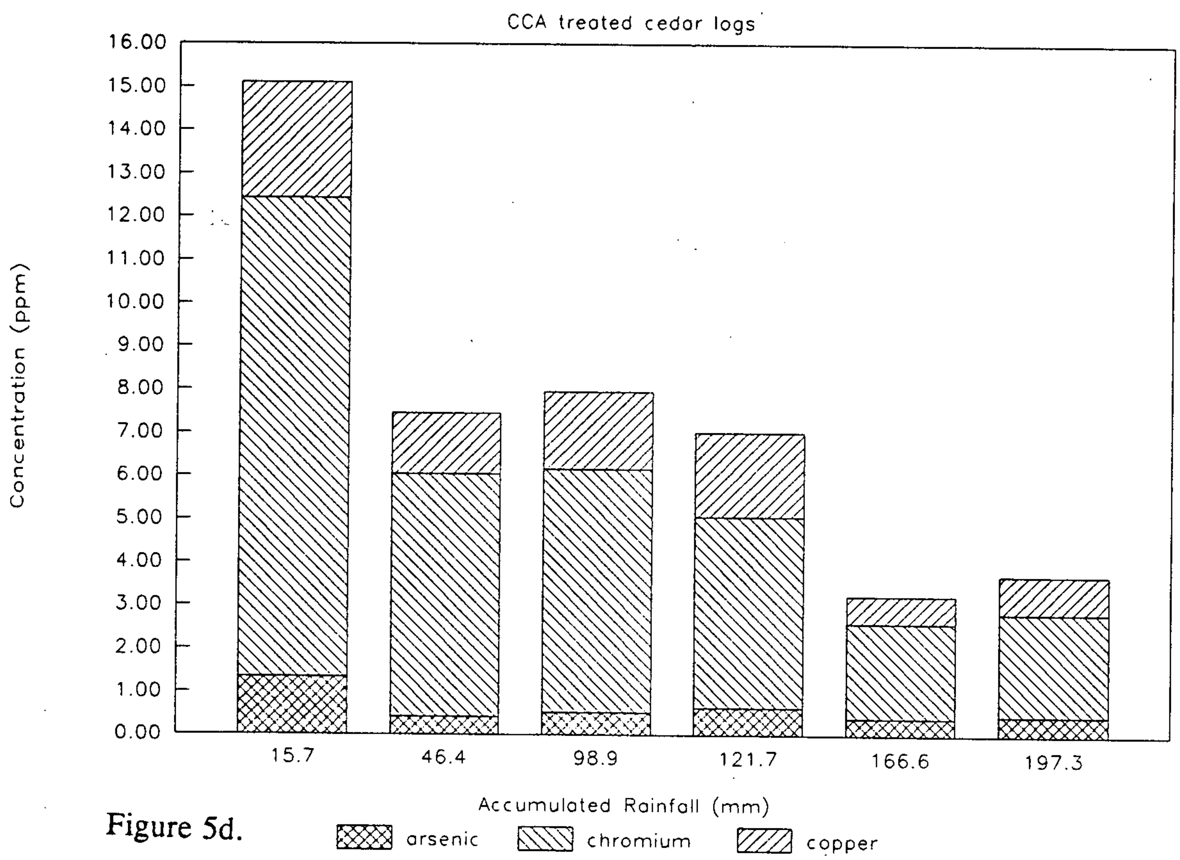


Figure 5d.

Based on Figures 5a to 5d and Table 4, it is observed that:

- post-treatment (accelerated fixation or brown staining) of CCA dimensional hem-fir lumber results in decreased releases of copper, chromium and arsenic. Accelerated fixation resulted in an appreciable reduction in releases of chromium; and

- the copper to arsenic ratio increased during the duration of the study for all CCA dimensional hem-fir lumber. This information suggests that a measure of chromium fixation does not infer that similar copper or arsenic fixation has occurred; and

- accelerated fixation of CCA treated cedar logs did not reduce chromium releases to the extent observed with the hem-fir dimensional lumber however, this may be due to the different product shape, surface area, wood species, etc.. However, arsenic releases from CCA treated cedar logs were relatively less than copper and chromium releases, indicating a higher degree of arsenic fixation than observed with the hem-fir dimensional lumber.

3.4 Leachate Toxicity

Leachate toxicity was evaluated by the standard 96 hr LC_{50} bioassay using rainbow trout (*Oncorhynchus mykiss*) as per Environment Canada protocols. Essentially, the 96 hr LC_{50} bioassay test determines the concentration of leachate which will cause death to 50% of the test fish population over 96 hours. As an example, a 5% 96 hr LC_{50} implies that a 20 fold dilution of the runoff with clean water would be required to ensure that no more than 50% fish die over 96 hours exposure. The reported LC_{50} value is inversely related to toxicity - i.e. the higher the LC_{50} concentration, the less the toxicity.

The bioassay results are shown in Figure 6 which shows the 96 hr LC_{50} toxicity test results vs accumulated mm of rainfall. The leachates from both untreated wood bundles (cedar and hem-fir) were found to be consistently non-toxic. Of the treated wood bundles, the CCA treated lumber with brown stain consistently had the highest 96hr LC_{50} indicating the lowest toxicity. The leachate from this wood bundle contained the second highest levels of arsenic, but low levels of chromium and copper. The CCA treated cedar logs had the lowest 96hr LC_{50} (or the highest toxicity). Generally, the leachate had the highest concentrations of chromium and copper and the lowest concentration of arsenic.

Table 4. Comparison of As: Cr: Cu Releases

Solution		*Leachate Cycle*	*Relative Ratio As: Cr: Cu*	*Conc. Relative to CCA-treated Wood w/ no post treatment As:Cr:Cu*
Type C Treatment Solution		n/a	1.4: 1.6: 1	n/a
Leachate Dimensional Lumber (Hemlock-fir)				
•	CCA (no post treatment)	1	1.3: 0.9: 1	1: 1: 1
		4	1.9: 0.8: 1	1: 1: 1
		6	3.5: *: 1	1: *: 1
•	CCA (accelerated fixation)	1	0.85: 0.13: 1	0.4: 0.1: 0.6
		4	1.4: 0.15: 1	0.5: 0.1: 0.7
		6	2.0: *: 1	0.5: *: 0.9
•	CCA (brown stained)	1	2.9: 1.3: 1	1: 0.7: 0.5
		4	3.3: 1.0: 1	0.8: 0.5: 0.4
		6	4.5: *: 1	0.7: *: 0.5
Leachate - Cedar Poles				
•	CCA (accelerated fixation)	1	0.5: 4.2: 1	0.6: 8: 1.7
		4	0.3: 2.3: 1	0.3: 5: 1.7
		6	0.5: 2.7: 1	0.3: *: 1.9

* *indicates analytical results for chromium suspect.*

FIGURE 6. 96HR LC50 TOXICITY vs. PRECIPITATION

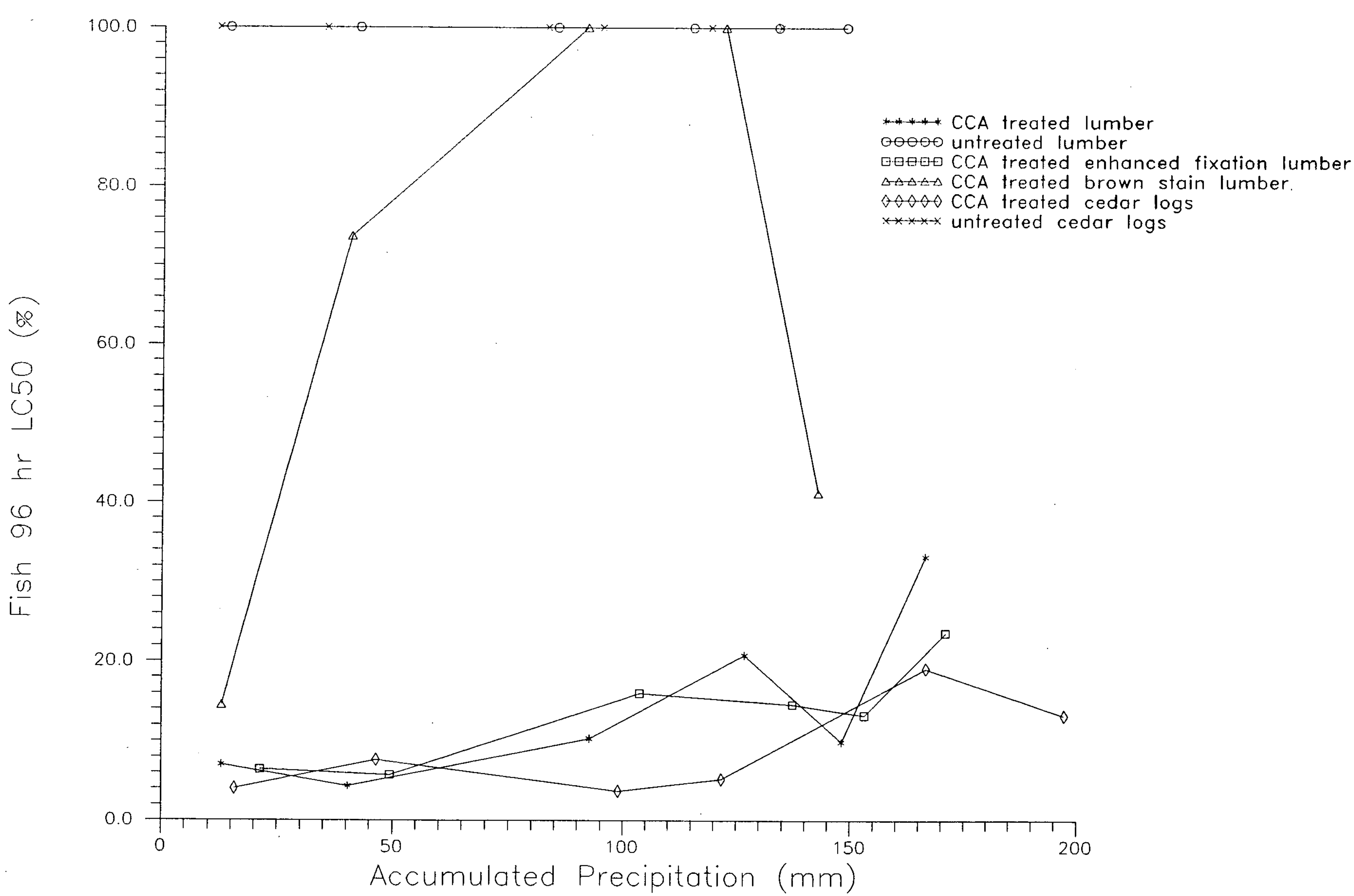


Table 5 compares the maximum concentrations in the leachates with reported LC_{50} aquatic toxicities, i.e. concentrations at which 50% of the test fish die (Konasewich and Henning, 1988). Concentrations of arsenic and chromium in all leachate samples did not exceed reported LC_{50} values. The concentrations of copper in leachates consistently exceeded the aquatic toxicity LC_{50} except for the leachate obtained from the CCA treated lumber with brown stain. This bundle had consistently the least toxic leachate and consistently the lowest concentration of copper.

It would be difficult to derive a correlation between the concentration and proportions of preservative constituents in the leachate to an 96hr LC_{50} toxicity for several reasons. Speciation of the metals will affect toxicity. CCA treated wood is considered properly fixed when the Cr (VI) has been reduced to Cr(III) which is less toxic. However, Cr(VI) is highly water soluble and mobile, therefore, any unreacted chromium leached from the wood is probable in this much more toxic state. Another factor is that combinations of elements may result in additive, synergistic or antagonistic toxicity effects.

3.5 Study Variables

This study recognizes that there are differences between the experimental design and actual facility conditions. The differences are summarized in Table 6 and include:

<u>Storage Practices</u>

The use of a single dimensional lumber bundle versus vertically stacked bundles (eg. six bundles) as used in many facilities. Overall the area of surface exposure of bundles at a CCA treatment facility is less per bundle than used in this study. In addition, many operations are now packaging bundles with synthetic wrap. Therefore, on a per board foot basis, data from this study may overestimate releases from dimensional lumber operations.

CCA-treated cedar logs may be stored under varying conditions ranging from loose piles to single rows of poles. This practice negates extrapolation of results from this study to actual field conditions.

Table 5. Maximum Concentration Compared to Current Criteria

Parameter	Maximum Concentration				Current Criteria	
	CCA Treated Lumber (hemlock-fir)	CCA Treated Lumber (acc. fixation)	CCA Treated Lumber (brown stain)	CCA Treated Cedar Logs	Reported Aquatic Toxicity LC_{50}	CCME Interim Remediation Criteria Freshwater Aquatic Life
Arsenic (ppm)	2.39	1.18	2.12	1.33	10.8	0.05
Chromium (ppm)	1.44	0.47	0.98	11.1	69	0.02-0.2
Copper (ppm)	1.61	0.93	0.73	2.66	0.02-0.89	0.002-0.004

Table 6

Uncertainty Table for Assessment of Releases from CCA Treated Wood (Experimental vs. Actual Occurences)

Variables	Potential Effect on Actual Releases		
	Over-estimation	Under-estimation	Over or Under-estimation
Storage Practices			
The use of a single bundle dimension lumber to evaluate losses/board foot in an actual yard.	Moderate	--	--
Use of bundle of cedar logs.	--	--	Moderate
Fixation Time			
Test wood fixed for seven days at temperature of 18°C.	--	High	--
Treatment Conditions			
Seven day storage under cover.	--	Moderate to High	--
Precipitation Conditions			
Use of sprinkler system.	--	--	Moderate
Use of city water vs. rain.	--	Moderate	--
Environmental Impact			
Use of LC_{50} and chemical data to evaluate potential impact of sites.	Moderate to High	--	--

Fixation Time

Due to delays and weather conditions which existed during this study, i.e. dry and moderately warm temperatures to 18°C, favourable conditions existed for fixation of CCA in the test bundles. Based on the logarithmic relationship between fixation time and temperature (Cooper, 1991), it is assumed that the losses observed during this study would underestimate the losses which would actually occur during winter months in the Lower Mainland of British Columbia for facilities without fixation chambers.

Treatment Conditions

Dimensional lumber and cedar logs were stored for seven days under cover subsequent to treatment with CCA. Some CCA facilities in British Columbia do not have such covered storage capabilities. Results from this study, if applied to these facilities, would underestimate potential releases from freshly treated wood.

Precipitation Conditions

Artificial rainfall may have significant effects on the quality of leachate produced relative to the leachate quality produced from actual rain. The wetting efficiency which dictates the extent of solubilization of the preservative constituents is influenced by the intensity, duration and frequency of the rainfall. The artificial rainfall pulses over the wood rather than falls in a steady stream and falls in more of a mist than actual vertical droplets. With actual rain, coverage over the wood bundle is more even, whereas with the artificial rainfall, the coverage may be affected by the wind speed and direction.

The artificial rainfall was applied every other day or so for a period of 4 to 5 hours. This allowed the wood to dry out somewhat between leaching cycles which may allow wicking of mobile species to the surface where they would come out faster on the next wetting. Drying between wettings may not necessarily occur under natural conditions when extended periods of rain are encountered. It is also possible that constituents may leach out slightly faster in the latter case as the water does not have to re-wet and re-penetrate the wood to solubilize the constituents. The dry day also adds another day of fixation to the wood.

Intensity of rainfall application could affect the leachate quality. Greater penetration of the bundle is likely achieved during a downpour as the small channels between the lumber become filled with water and the water is forced laterally between the boards. At a lower rate of application, the water is more likely to flow through the vertical channels between the boards and drain out the bottom with less lateral movement of water through the bundle.

Each of these precipitation conditions has the potential to affect the preservative concentrations in the leachate. However, the net effect of these conditions occurring during this test is not considered to have significantly affected the results.

The quality of the artificial rain is different from that of actual rain predominantly in the pH. The water used in the artificial rain had a pH ranging from 5.8 to 6.0. Rainwater is slightly more acidic at pH of approximately 5 and may more efficiently extract the wood preservative constituents than the hydrant water. Based on data by Cooper (1989), a pH less than four would have significant impact on leaching rates. For this study, a moderate underestimate of CCA releases is suggested by the use of GVRD water rather than rainwater.

Environmental Impact

The fish bioassay and chemical analyses results obtained during this study do not directly reflect the environmental impact of surface runoff from a wood preservation facility. The results from this study overestimate the potential environmental impact of surface runoff. Many factors will contribute to reduce the concentrations and impact relative to the leachate study results, including dilution with uncontaminated rainwater and surface runoff and infiltration and adsorption of wood preservation chemicals in the soil of unpaved yards. In order to relate the leachate study results to actual site runoff, these site specific factors would have to be determined and a dilution factors for each site calculated.

Releases of CCA from a site would be retarded by unpaved storage yard surfaces. For example, Gerencher (1989) reported that the iron and aluminum amorphous and crystalline hydrous oxide component of soils was highly correlated with arsenic absorption. The percentage organic carbon was significantly correlated with chromium and copper retention in the soils. On paved surfaces, it is likely that absorption does not occur under normal conditions.

3.6 Impact on Stormwater Discharges

Since this study was undertaken concurrently with a study of surface runoff quality from wood preservation facilities in the Lower Mainland (Whiticar and Konasewich, 1992), it has been possible to examine the leachate results relative to the actual stormwater quality data from one of the wood preservation facility sites.

The surface runoff study found that the range of concentrations of wood preservation chemicals in the surface runoff was very large. Arsenic concentrations ranged from 0.076 to 84.2 ppm (mean of 11.2, standard deviation of 27.5), chromium concentrations ranged from 0.091 to 82.7 ppm (mean 12.8, s.d. of 26.7) and copper concentrations ranged from 0.082 to 87.8 ppm (mean of 11.4, s.d. of 28.7). The runoff results from the facility providing the treated wood products for the leachate study, were at the low end of the range. Low flows during the runoff testing and the potential for suspended particulate in the runoff may have caused this large range. It is felt that in future, use of dissolved metals analyses would produce a smaller range in the results and likely a lower concentrations of metals.

In order to evaluate the leachate study results to the surface runoff results, a calculation for a hypothetical CCA wood preservation facility utilizing typical product handling techniques and of average size has been developed. Assuming a total paved property surface area of 28,000 m^2 and a nominal rainfall of 15 mm, the volume of runoff that would be produced on the site would be 420 m^3. Assuming an inventory of treated dimension lumber of 500,000 board feet with the bundles stacked three high, the amount of leachate in the stormwater would be approximately 14 m^3.

Based on the leachate study results for the initial leaching cycle, the amount of wood preservative chemicals lost from each CCA treated lumber bundle were approximately arsenic 0.2 g, chromium 0.1 g, and copper 0.15 g. Therefore, if these amounts of wood preservative chemicals are lost from each bundle on the hypothetical storage yard, the concentration of arsenic, chromium and copper in the stormwater would be 0.13 ppm, 0.07 ppm, and 0.10 ppm.

The actual stormwater runoff results, particularly at the low end of the range, are in the same order of magnitude as those predicted from the concentrations of wood preservative constituents found in the leachate study. Although only a preliminary evaluation, it appears that the leachate study may be able to predict leachate concentrations produced in the storage yard if the actual site specific factors can be adequately determined.

4.0 CONCLUSIONS AND RECOMMENDATIONS

A study has been conducted to evaluate the leachability characteristics of the wood preservative CCA from stored wood products. Four CCA treated wood test product bundles were used in this study including coastal hem-fir dimension lumber, coastal hem-fir dimension lumber with a post-treatment application of an iron oxide based stain, coastal hem-fir dimension lumber which had undergone an accelerated fixation process, and western red cedar logs to which accelerated fixation was also applied. In addition to the four treated test bundles, the study incorporated two untreated control bundles; coastal hem-fir dimension lumber and western red cedar logs.

The study utilized six metal trays and the testing protocols developed by Environment Canada. One bundle was placed on each tray and subjected to artificial rainfall. Leachate samples were collected after predetermined amounts of rainfall had fallen. Samples collected were analyzed for arsenic, chromium, and copper. In addition, each leachate was evaluated for toxicity to fish on the basis of the 96 hr LC_{50} tests.

Arsenic was found in the leachates from treated wood bundles in concentrations ranging from 0.4 to 2.4 ppm with the highest concentrations produced from the CCA treated dimension lumber and the lowest from the CCA treated cedar logs. Chromium was found in the leachates from treated wood bundles in concentrations ranging from 0.1 ppm produced from the CCA treated lumber with accelerated fixation and 11 ppm produced from the CCA treated cedar logs. Copper was found in concentrations ranging from 0.25 ppm in the leachate from CCA treated lumber with brown stain to 2.6 ppm in the leachate from the CCA treated cedar logs. The untreated dimension lumber and untreated cedar logs consistently had concentrations of each constituent lower than 0.1 ppm and much lower in most cases.

The results illustrate the potential beneficial impact of post-treatment processes for dimensional lumber, and also illustrate differences in release rates between cedar logs and hem-fir dimensional lumber. Accelerated fixation overall reduced releases, in particular chromium. Releases of arsenic and copper were however, not proportionally reduced. In this study, the chromium and copper losses from the treated cedar logs were an order of magnitude higher than the losses from the treated hem-fir dimension lumber. It is unknown how much of this difference is attributable to the differing wood species, to the differing shape and dimension of the test bundles, or to the presence of cambium in the logs. Differences in copper concentrations provide an explanation for the variances in toxicity.

With the exception of leachates from CCA treated lumber with brown stain, all leachates from treated wood failed the 96 hr LC_{50} fish toxicity test. Leachates from untreated wood bundles were consistently non-toxic.

This study was originally intended to be conducted during colder conditions. Due to unexpected climatic conditions, the study was conducted with favourable fixation conditions. Nonetheless, the data suggests that procedures such as accelerated fixation may be able to minimize losses of CCA from freshly treated wood. The data also show the importance of influences such as wood species, shape and treatment processes on the variability of the amount of leachate produced.

There is a need to further evaluate stormwater discharges from individual CCA operations on a regular basis to determine if CCA releases are of potential concern to the environment. While this study has quantified the potential for chemical losses from a wood preservation facility site, actual environmental risk requires further study. Additional on-site leachate studies could be conducted to determine if losses can be reduced by varying operational practice. On-site studies would eliminate the influence of the site-specific factors relative to other facilities.

Additional leachate testing is necessary to evaluate the factors that affect leaching, particularly during a broader range of environmental conditions, including temperature, humidity and rainfall. Clearly, this study has provided insight to the potential to reduce preservative losses from wood products using post-treatment techniques. Additional leachate tests for each of the other wood preservative chemicals presently in use in the Lower Mainland, namely ACA, PCP in oil, and creosote should also be carried out. Other tests could include variables such as wood species and different wood products such as poles-logs, landscape ties, and dimension lumber.

5.0 REFERENCES

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APPENDIX A

Laboratory Results

quanta trace laboratories inc.
#401-3700 Gilmore Way, Burnaby, B.C., V5G 4M1 Tel:(604)438-5226 Fax:436-0565

ANALYSIS OF ENVIRONMENTAL SAMPLES

To: Envirochem Services
310 East Esplanade
North Vancouver, B.C.
V7L 1A4

Workorder: 18231
Received : 16-Mar-92
Completed: 20-Mar-92

Attn: Linda Eastcott

Re: PO# 62847 - CCA Leachate Study

Sample type / Identification / Lab Reference #	WATER TRAY 1A 18231-001	WATER TRAY 2A 18231-002	WATER TRAY 3A 18231-003	WATER TRAY 4A 18231-004A	WATER TRAY 4A 18231-004B
Method used	microwave RAR soluble TOTAL	microwave RAR soluble TOTAL	microwave RAR soluble TOTAL	microwave RAR soluble TOTAL	microwave RAR soluble TOTAL
ICP - Hydride Generation					
Arsenic As	2.03	0.042	0.792	2.12	2.19
Results in	mg/l	mg/l	mg/l	mg/l	mg/l
ICP - Ultrasonic Nebulization					
Chromium Cr	1.40	0.025	0.123	0.980	0.972
Copper Cu	1.61	0.030	0.934	0.729	0.719
Results in	mg/l	mg/l	mg/l	mg/l	mg/l

Sample type / Identification / Lab Reference #	WATER TRAY 5A 18231-005	WATER TRAY 6A 18231-006	CHECK SAMP BC-4-4 18231-007	CHECK SAMP BC-4-4 18231-007A	EPA SRM WP1085 CONC 1 18231-008
Method used	microwave RAR soluble TOTAL	microwave RAR soluble TOTAL	microwave RAR soluble TOTAL	MEAN VALUE	microwave RAR soluble TOTAL
ICP - Hydride Generation					
Arsenic As	1.33	0.040	0.071	-	0.024
Results in	mg/l	mg/l	mg/l		mg/l
ICP - Ultrasonic Nebulization					
Chromium Cr	11.1	0.008	0.536	-	4.98
Copper Cu	2.66	0.026	0.456	0.459	< 0.001
Results in	mg/l	mg/l	mg/l	mg/l	mg/l

/2...

quanta trace laboratories inc.
#401-3700 Gilmore Way, Burnaby, B.C., V5G 4M1 Tel:(604)438-5226 Fax:436-0[illegible]65

To: Envirochem Services

W/O: 18231 Page 2

Sample type Identification	EPA SRM WP1085 CONC 1	EPA SRM WP1085 CONC 2	EPA SRM WP1085 CONC 2	SPIKE TRAY 4A + 1 ppm	BLANK FIELD
Lab Reference #	18231-008A	18231-009	18231-009A	18231-010	18231-011
Method used	EPA RANGE 95% CI	microwave RAR soluble TOTAL	EPA RANGE 95% CI	microwave RAR soluble TOTAL	microwave RAR soluble TOTAL
ICP - Hydride Generation					
Arsenic As	-	4.67	3.51-6.43	3.16	0.08
Results in		mg/l	mg/l	mg/l	mg/l
ICP - Ultrasonic Nebulization					
Chromium Cr	4.18-5.94	0.002	-	2.00	0.006
Copper Cu	-	< 0.001	-	1.71	1.00
Results in	mg/l	mg/l		mg/l	mg/l

 Analyst:

RECEIVED APR 13 1992

quanta trace laboratories inc.
#401-3700 Gilmore Way, Burnaby, B.C., V5G 4K1 Tel:(604)438-5226 Fax:436-0565

ANALYSIS OF ENVIRONMENTAL SAMPLES

To: Envirochem Services
310 East Esplanade
North Vancouver, B.C.
V7L 1A4

Workorder: 18274
Received : 20-Mar-92
Completed: 07-Apr-92

Attn: Linda Eastcott

Re: PO# 62705 - CCA Leachate Study

Identification	REAGENT BLK	TRAY 1B	TRAY 2B	TRAY 3B	TRAY 3B
Lab Reference #	18274-001	18274-002	18274-003	18274-004A	18274-004B
Method used	microwave RAR soluble TOTAL	microwave RAR soluble TOTAL	microwave RAR soluble TOTAL	microwave RAR soluble TOTAL	microwave RAR soluble TOTAL
ICP - Hydride Generation					
Arsenic As	< 0.001	1.96	0.011	1.06	1.06
ICP - Ultrasonic Nebulization					
Chromium Cr	0.010	1.21	0.027	0.129	0.129
Copper Cu	0.009	1.24	0.020	0.886	0.890
Results in	mg/l	mg/l	mg/l	mg/l	mg/l

Identification	TRAY 4B	TRAY 5B	TRAY 6B	EC BC-4-4	EC BC-4-4
Lab Reference #	18274-005	18274-006	18274-007	18274-008	18274-008A
Method used	microwave RAR soluble TOTAL	microwave RAR soluble TOTAL	microwave RAR soluble TOTAL	microwave RAR soluble TOTAL	MEAN VALUE
ICP - Hydride Generation					
Arsenic As	1.88	0.410	0.0209	-	-
ICP - Ultrasonic Nebulization					
Chromium Cr	0.749	5.63	0.016	-	-
Copper Cu	0.544	1.41	0.018	0.454	0.459
Results in	mg/l	mg/l	mg/l	mg/l	mg/l

Identification	EPA WP1085 CONC 1	EPA WP1085 CONC 1	EPA WP1085 CONC 2	EPA WP1085 CONC 2	TRAY 3B +1ppm SPIKE
Lab Reference #	18274-009	18274-009A	18274-010	18274-010A	18274-011
Method used	microwave RAR soluble TOTAL	EPA RANGE 95% CI	microwave RAR soluble TOTAL	EPA RANGE 95% CI	microwave RAR soluble TOTAL
ICP - Hydride Generation					
Arsenic As	-	-	4.78	3.51-6.43	2.18
ICP - Ultrasonic Nebulization					
Chromium Cr	5.36	4.18-5.94	-	-	1.27
Copper Cu	-	-	-	-	1.93
Results in	mg/l	mg/l	mg/l	mg/l	mg/l

 Analyst:

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quanta trace laboratories inc.
#401 3700 Gilmore Way, Burnaby, B.C., V5G 4M1 Tel:(604)438-5226 Fax:436-0565

ANALYSIS OF ENVIRONMENTAL SAMPLES

To: Envirochem Services
310 East Esplanade
North Vancouver, B.C.
V7L 1A4

Workorder: 18306
Received : 25-Mar-92
Completed: 07-Apr-92

Attn: Linda Eastcott

Re: PO# 62847 - CCA Leachate Study

Identification	TRAY 1C	TRAY 2C	TRAY 3C	TRAY 4C	TRAY 4C
Lab Reference #	18306-001	18306-002	18306-003	18306-004A	18306-004
Method used	microwave RAR soluble TOTAL	microwave RAR soluble TOTAL	microwave RAR soluble TOTAL	microwave RAR soluble TOTAL	microwave RAR soluble TOTAL
ICP - Hydride Generation					
Arsenic As	2.39	0.020	0.830	1.23	1.31
ICP - Ultrasonic Nebulization					
Chromium Cr	0.873	0.027	0.11	0.400	0.388
Copper Cu	1.06	0.017	0.675	0.356	0.335
Results in	mg/l	mg/l	mg/l	mg/l	mg/l

Identification	TRAY 5C	TRAY 6C	EC BC-4-4	EC BC-4-4	EPA WP1085 CONC 1
Lab Reference #	18306-005	18306-006	18306-007	18306-007A	18306-008
Method used	microwave RAR soluble TOTAL	microwave RAR soluble TOTAL	microwave RAR soluble TOTAL	MEAN VALUE	microwave RAR soluble TOTAL
ICP - Hydride Generation					
Arsenic As	0.518	0.013	-	-	-
ICP - Ultrasonic Nebulization					
Chromium Cr	5.65	0.016	-	-	5.47
Copper Cu	1.79	0.010	0.459	0.459	-
Results in	mg/l	mg/l	mg/l	mg/l	mg/l

Identification	EPA WP1085 CONC 1	EPA WP1085 CONC 2	EPA WP1085 CONC 2	TRAY 4C +1ppm SPIKE
Lab Reference #	18306-008A	18306-009	18306-009A	18306-010
Method used	EPA RANGE 95% CI	microwave RAR soluble TOTAL	EPA RANGE 95% CI	microwave RAR soluble TOTAL
ICP - Hydride Generation				
Arsenic As	-	4.60	3.51-6.43	2.39
ICP - Ultrasonic Nebulization				
Chromium Cr	4.18-5.94	-	-	1.50
Copper Cu	-	-	-	1.42
Results in	mg/l	mg/l	mg/l	mg/l

Analyst: [signature]

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ANALYSIS OF ENVIRONMENTAL SAMPLES

To: Envirochem Services
310 East Esplanade
North Vancouver, B.C.
V7L 1A4

Workorder: 18328
Received : 27-Mar-92
Completed: 08-Apr-92

Attn: Linda Endicott

Re: PO# 62847 - CCA Leachate Study

Identification		TRAY 1D	TRAY 2D	TRAY 3D	TRAY 4D	TRAY 4D
Lab Reference #		18328-001	18328-002	18328-003	18328-004A	18328-004B
Method used		microwave RAR soluble TOTAL	microwave RAR soluble TOTAL	microwave RAR soluble TOTAL	microwave RAR soluble TOTAL	microwave RAR soluble TOTAL
ICP - Hydride Generation						
Arsenic	As	2.12	0.009	1.02	1.60	1.61
ICP - Ultrasonic Nebulization						
Chromium	Cr	0.905	0.021	0.113	0.485	0.490
Copper	Cu	1.12	0.022	0.742	0.490	0.486
Results in		mg/l	mg/l	mg/l	mg/l	mg/l

Identification		TRAY 5D	TRAY 6D	BLANK UNFILTERED	BLANK FILTERED	EC BC-4-4
Lab Reference #		18328-005	18328-006	18328-007	18328-008	18328-009
Method used		microwave RAR soluble TOTAL	microwave RAR soluble TOTAL	microwave RAR soluble TOTAL	microwave RAR soluble TOTAL	microwave RAR soluble TOTAL
ICP - Hydride Generation						
Arsenic	As	0.641	0.003	< 0.001	< 0.001	-
ICP - Ultrasonic Nebulization						
Chromium	Cr	4.43	0.014	0.010	0.009	-
Copper	Cu	1.95	0.020	0.022	0.040	0.447
Results in		mg/l	mg/l	mg/l	mg/l	mg/l

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To: Envirochem Services W/O: 18328 Page 2

Identification	EC BC-4-4	EPA WP1085 CONC 1	EPA WP1085 CONC 1	EPA WP1085 CONC 2	EPA WP1085 CONC 2
Lab Reference #	18328-009A	18328-010	18328-010A	18328-011	18328-011
Method used	MEAN VALUE	microwave RAR soluble TOTAL	EPA RANGE 95% CI	microwave RAR soluble TOTAL	EPA RANGE 95% CI
ICP - Hydride Generation					
Arsenic As	-	-	-	4.80	3.51-6.43
ICP - Ultrasonic Nebulization					
Chromium Cr	-	5.02	4.18-5.94	-	-
Copper Cu	0.459	-	-	-	-
Results in	mg/l	mg/l	mg/l	mg/l	mg/l

Identification	TRAY 40 1ppm SPIKE
Lab Reference #	18328-012
Method used	microwave RAR soluble TOTAL
ICP - Hydride Generation	
Arsenic As	2.57
ICP - Ultrasonic Nebulization	
Chromium Cr	1.57
Copper Cu	1.53
Results in	mg/l

 Analyst: ______

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ANALYSIS OF ENVIRONMENTAL SAMPLES

To: Envirochem Services
310 East Esplanade
North Vancouver, B.C.
V7L 1A4

Workorder: 18353
Received : 31-Mar-92
Completed: 20-Apr-92

Attn: Linda Eastcott

Re: PO# 62847 - CCA Leachate Study

Identification	TRAY 1E	TRAY 2E	TRAY 3E	TRAY 4E	TRAY 4E
Lab Reference #	18353-001	18353-002	18353-003	18353-004A	18353-004B
Method used	microwave RAR soluble TOTAL	microwave RAR soluble TOTAL	microwave RAR soluble TOTAL	microwave RAR soluble TOTAL	microwave RAR soluble TOTAL
ICP - Hydride Generation					
Arsenic As	1.60	0.007	1.18	1.07	1.09
ICP - Ultrasonic Nebulization					
Chromium Cr	1.21	0.654	0.467	0.750	0.741
Copper Cu	0.534	0.011	0.584	0.265	0.268
Results in	mg/l	mg/l	mg/l	mg/l	mg/l

Identification	TRAY 5E	TRAY 6E	BLANK	EC BC-4-4	EC BC-4-4
Lab Reference #	18353-005	18353-006	18353-007	18353-008	18353-008A
Method used	microwave RAR soluble TOTAL	microwave RAR soluble TOTAL	microwave RAR soluble TOTAL	microwave RAR soluble TOTAL	MEAN VALUE
ICP - Hydride Generation					
Arsenic As	0.395	< 0.001	< 0.001	-	-
ICP - Ultrasonic Nebulization					
Chromium Cr	2.21	0.360	0.056	-	-
Copper Cu	0.629	0.016	0.020	0.461	0.459
Results in	mg/l	mg/l	mg/l	mg/l	mg/l

Identification	EPA WP1085 CONC 1	EPA WP1085 CONC 1	EPA WP1085 CONC 2	EPA WP1085 CONC 2	TRAY 4E +1ppm SPIKE
Lab Reference #	18353-009	18353-009A	18353-010	18353-010A	18353-011
Method used	microwave RAR soluble TOTAL	EPA RANGE 95% CI	microwave RAR soluble TOTAL	EPA RANGE 95% CI	microwave RAR soluble TOTAL
ICP - Hydride Generation					
Arsenic As	-	-	4.99	3.51-6.43	2.10
ICP - Ultrasonic Nebulization					
Chromium Cr	4.93	4.18-5.94	-	-	1.72
Copper Cu	-	-	-	-	1.29
Results in	mg/l	mg/l	mg/l	mg/l	mg/l

Test results are for internal use only. Quanta Trace liability is limited to the testing fee paid. Analyst: ______

Envirochem

quanta trace laboratories inc.
#401-3700 Gilmore Way, Burnaby, B.C., V5G 4M1 Tel:(604)438-5226 Fax:436-0545

ANALYSIS OF ENVIRONMENTAL SAMPLES

To: Envirochem Services
310 East Esplanade
North Vancouver, B.C.
V7L 1A4

Workorder: 18353
Received : 31-Mar-92
Completed: 20-Apr-92

Attn: Linda Eastcott

Re: PO# 62847 - CCA Leachate Study

Identification	TRAY 1E	TRAY 2E	TRAY 3E	TRAY 4E	TRAY 4E
Lab Reference #	18353-001	18353-002	18353-003	18353-004A	18353-004
Method used	microwave RAR soluble TOTAL	microwave RAR soluble TOTAL	microwave RAR soluble TOTAL	microwave RAR soluble TOTAL	microwave RAR soluble TOTAL
ICP - Hydride Generation					
Arsenic As	1.60	0.007	1.18	1.07	1.09
ICP - Ultrasonic Nebulization					
Chromium Cr	1.21	0.654	0.467	0.750	0.741
Copper Cu	0.534	0.011	0.584	0.265	0.268
Results in	mg/l	mg/l	mg/l	mg/l	mg/l

Identification	TRAY 5E	TRAY 6E	BLANK	EC BC-4-4	EC BC-4-4
Lab Reference #	18353-005	18353-006	18353-007	18353-008	18353-008A
Method used	microwave RAR soluble TOTAL	microwave RAR soluble TOTAL	microwave RAR soluble TOTAL	microwave RAR soluble TOTAL	MEAN VALUE
ICP - Hydride Generation					
Arsenic As	0.395	< 0.001	< 0.001	-	-
ICP - Ultrasonic Nebulization					
Chromium Cr	2.21	0.360	0.056	-	-
Copper Cu	0.629	0.016	0.020	0.461	0.459
Results in	mg/l	mg/l	mg/l	mg/l	mg/l

Identification	EPA WP1085 CONC 1	EPA WP1085 CONC 1	EPA WP1085 CONC 2	EPA WP1085 CONC 2	TRAY 4E +1ppm SPIK
Lab Reference #	18353-009	18353-009A	18353-010	18353-010A	18353-011
Method used	microwave RAR soluble TOTAL	EPA RANGE 95% CI	microwave RAR soluble TOTAL	EPA RANGE 95% CI	microwave RAR soluble TOTAL
ICP - Hydride Generation					
Arsenic As	-	-	4.99	3.51-6.43	2.10
ICP - Ultrasonic Nebulization					
Chromium Cr	4.93	4.18-5.94	-	-	1.72
Copper Cu	-	-	-	-	1.29
Results in	mg/l	mg/l	mg/l	mg/l	mg/l

 Analyst: ____

Envirochem

quanta trace laboratories inc.
#401-3700 Gilmore Way, Burnaby, B.C., V5G 4M1 Tel:(604)438-5226 Fax:436-0565

ANALYSIS OF ENVIRONMENTAL SAMPLES

To: Envirochem Services
310 East Esplanade
North Vancouver, B.C.
V7L 1A4

Workorder: 18354
Received : 31-Mar-92
Completed: 21-Apr-92

Attn: Linda Eastcott

Re: PO# 62847 - CCA Leachate Study

Identification	TRAY 1F	TRAY 2F	TRAY 3F	TRAY 4F	TRAY 4F
Lab Reference #	18354-001	18354-002	18354-003	18354-004A	18354-004B
Method used	microwave RAR soluble TOTAL	microwave RAR soluble TOTAL	microwave RAR soluble TOTAL	microwave RAR soluble TOTAL	microwave RAR soluble TOTAL
ICP - Hydride Generation					
Arsenic As	1.66	0.008	0.838	1.14	1.23
ICP - Ultrasonic Nebulization					
Chromium Cr	0.738	0.549	0.344	0.670	0.679
Copper Cu	0.469	0.008	0.416	0.251	0.260
Results in	mg/l	mg/l	mg/l	mg/l	mg/l

Identification	TRAY 5F	TRAY 6F	BLANK	EC BC-4-4	EC BC-4-4
Lab Reference #	18354-005	18354-006	18354-007	18354-008	18354-008A
Method used	microwave RAR soluble TOTAL	microwave RAR soluble TOTAL	microwave RAR soluble TOTAL	microwave RAR soluble TOTAL	MEAN VALUE
ICP - Hydride Generation					
Arsenic As	0.460	0.001	< 0.001	-	-
ICP - Ultrasonic Nebulization					
Chromium Cr	2.38	0.406	0.057	-	-
Copper Cu	0.875	0.009	< 0.001	0.463	0.459
Results in	mg/l	mg/l	mg/l	mg/l	mg/l

Identification	EPA WP1085 CONC 1	EPA WP1085 CONC 1	EPA WP1085 CONC 2	EPA WP1085 CONC 2	TRAY 4F +1ppm SPIKE
Lab Reference #	18354-009	18354-009A	18354-010	18354-010A	18354-011
Method used	microwave RAR soluble TOTAL	EPA RANGE 95% CI	microwave RAR soluble TOTAL	EPA RANGE 95% CI	microwave RAR soluble TOTAL
ICP - Hydride Generation					
Arsenic As	-	-	4.89	3.51-6.43	2.19
ICP - Ultrasonic Nebulization					
Chromium Cr	5.03	4.18-5.94	-	-	1.67
Copper Cu	-	-	-	-	1.31
Results in	mg/l	mg/l	mg/l	mg/l	mg/l

 Analyst: ________

LYNTERM LEACHING STUDY 1992 - FISH RESULTS

SAMPLE ID	FISH 96HRLC50	DATE RECEIVED
TRAY 1A	7.0%	16/03/92
1B	4.3%	20/03/92
1C	10.3%	25/03/92
1D	20.8%	27/03/92
1E	9.9%	31/03/92
1F	33.2%	03/04/92
TRAY 2A	NON-TOXIC	16/03/92
2B	NON-TOXIC	20/03/92
2C	NON-TOXIC	25/03/92
2D	NON-TOXIC	27/03/92
2E	NON-TOXIC	31/03/92
2F	NON-TOXIC	03/04/92
TRAY 3A	6.4%	16/03/92
3B	5.7%	20/03/92
3C	16.0%	25/03/92
3D	14.6%	27/03/92
3E	13.2%	31/03/92
3F	23.6%	03/04/92
TRAY 4A	14.5%	16/03/92
4B	73.7%	20/03/92
4C	40% mortality @ 100%	25/03/92
4D	40% mortality @ 100%	27/03/92
4E	41.2%	31/03/92
4F	undetermined	03/04/92
TRAY 5A	4.0%	16/03/92
5B	7.6%	20/03/92
5C	3.7%	25/03/92
5D	5.2%	27/03/92
5E	19.1%	31/03/92
5F	13.2%	03/04/92
TRAY 6A	NON-TOXIC	16/03/92
6B	NON-TOXIC	20/03/92
6C	NON-TOXIC	25/03/92
6D	NON-TOXIC	27/03/92
6E	NON-TOXIC	31/03/92
6F	NON-TOXIC	03/04/92

APPENDIX B

QA/QC Data Assessment

Assessment of Arsenic, Chromium and Copper QA/QC Data

- six sets of analyses of EPA Standard Reference Materials for chromium and arsenic and a BC Standard for copper were conducted by Quanta Trace as part of the required QA/QC

- the chromium and arsenic EPA standards had a true value of 5.0 mg/l and the copper B.C. Standard had a true value of 0.459

- the standard deviations for each set of 6 analyses are:

  As: 0.14 mg/l
  Cr: 0.22 mg/l
  Cu: 0.006 mg/l

- the 95 % confidence interval of the mean (using standard methods) is:

  As: 4.79 +/- 0.16
  Cr: 5.13 +/- 0.25
  Cu: 0.457 +/- 0.007

- a measure of analytical accuracy is given by the mean error which is equivalent to the mean minus the true value or:

As:	0.21 mg/l	> one standard deviation of 0.14 mg/l
Cr:	0.13 mg/l	< one standard deviation of 0.22 mg/l
Cu:	0.002 mg/l	< one standard deviation of 0.006 mg/l

Therefore, the analytical results of chromium and copper are good, but the arsenic results could be statistically improved.