Soil and Sediment Concentrations of Chromium, Copper, and Arsenic Adjacent to a Chromated Copper Arsenate–Treated Wetland Boardwalk

Stan Lebow
Daniel Foster

Abstract

Environmental accumulation of preservative adjacent to a chromated copper arsenate (type C)–treated wetland boardwalk was evaluated. The site is considered a realistic "worst case" because of the large volume of treated wood, low current speeds, high annual rainfall, and environmental sensitivity. Soil and sediment samples were collected before construction and 0.5, 2, 5.5, 11, 24, 60, and 131 months (11 y) after construction and analyzed for total chromium, copper, and arsenic concentrations. This article updates the findings after 11 years of exposure. Environmental concentrations varied with time, with proximity to the treated wood, and between riparian and aquatic locations. Concentrations of leached components in the soil developed slowly, were greatest at the 60-month sampling, and declined at the 131-month inspection. Soil samples with elevated levels of copper and chromium were confined to directly under the drip line of the boardwalk, and arsenic appeared to be limited to within 0.3 m (1 ft) of the structure. Concentrations of leached components in the sediments increased more quickly than those in the soil and tended to reach maximum or near maximum levels within the first year. However, concentrations of arsenic and copper in sediments directly under the walkway reached maximum levels after 60 months, before declining at the 131-month sampling. Elevated concentrations of copper, chromium, and arsenic were occasionally found in sediments as much as 3 m (10 ft) from the boardwalk.

Chromated copper arsenate (CCA)–treated wood has been widely used by the Forest Service and other government agencies for construction of boardwalks, bridges, and docks. Although use of CCA has been limited since 2004, many existing structures remain in service. Some of these applications placed the treated wood into wetlands or other sensitive environments, causing concern about possible environmental contamination from leached preservative. Because of the wide range of age of structures, types of structures, and site conditions, it has been difficult for researchers to evaluate concerns about environmental contamination. In one of the earliest studies, chromium, copper, and arsenic levels were measured adjacent to CCA-treated boardwalks of varying ages at several sites in southern Tasmania (Comfort 1993). Levels of copper and chromium adjacent to the boardwalk were significantly elevated compared with the control samples, but arsenic levels were not elevated. There did not appear to be any relationship between the age of the boardwalk and the levels detected; the highest copper levels were detected around a 1-year-old structure while the highest chromium levels were detected around the oldest structure (Comfort 1993). A more recent study evaluated metal concentrations under and adjacent to boardwalks constructed through saltwater marshes and reported highly elevated concentrations under the walkway and some elevation up to 10 m from the structure (Weis and Weis 2002). Concentrations were greatest, but least widely dispersed, under the newest walkway. Note that wood treated for use in seawater contains several times more CCA than that used in freshwater or soil, and the results of this study may not be representative of freshwater applications.

Two CCA-treated bridges in Florida were also evaluated, one over a saline bay and the other over a freshwater marsh (Brooks 2000a). The bridge over the bay was in the final stages of construction, whereas the bridge over the marsh

The authors are, respectively, Research Forest Products Technologist and Chemist, USDA Forest Serv., Forest Products Lab., Madison, Wisconsin (slebow@fs.fed.us, dofoster@fs.fed.us). This paper was received for publication in January 2010. Article no. 10719.
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had been built 2 years before. Some samples of sediments removed within 3 m (10 ft) of the newly constructed bridge contained elevated levels of copper, chromium, and arsenic. The high variability in concentrations detected and the observation of wood chips in the sediments led Brooks to conclude that at least a portion of the elevated samples contained treated wood sawdust.

Other studies have evaluated soil concentrations of preservative around a variety of CCA-treated structures, including residential decks, utility poles, sound walls, playground equipment, and wooden stakes (DeGroot et al. 1979, Cooper and Ung 1997, Stilwell and Gorny 1997, Stilwell and Graetz 2001, Chirenje et al. 2003, Lebow et al. 2004, Cookson 2005). These studies have reported varying degrees of soil accumulation and mobility for chromium, copper, and arsenic and differing impressions of the role of the age of the structure. The range of findings regarding soil and sediment concentrations adjacent to CCA-treated structures reflects the complexity of this issue.

In an effort to better characterize potential concerns associated with treated wood structures in environmentally sensitive areas, a cooperative study was initiated that included members of the wood-treating industry; the Western Wood Preservers Institute, the US Forest Service, and the Bureau of Land Management. The objectives of the study were to monitor preservative release, environmental accumulation, and biological impact from treated wood used in construction of an in-service wetland boardwalk (Lebow et al. 2000). The project was selected for evaluation because it involved use of large volumes of treated wood placed into a sensitive environment in a location with high annual rainfall. As such, it was expected to provide a realistic ''worst-case'' scenario that would be conservative for most other applications. In the present article, we discuss the leaching and environmental accumulation of copper, chromium, and arsenic from the section of boardwalk constructed of CCA (type C)–treated wood after 11 years of exposure. The findings reported for the first 5 years after construction are updated (Lebow and Foster 2005). A detailed discussion of the biological impacts during the first year after construction can be found in Brooks (2000b).

Materials and Methods

The study was incorporated into a large boardwalk construction project at a Bureau of Land Management recreation site (Wildwood) in Welches, Oregon, approximately 64 km (40 mi) southeast of Portland. The site was considered a severe leaching scenario because of high rainfall (Table 1), standing water, and the large volume of treated wood used in construction. This article presents only a summary of the methodology; for a more detailed description of site conditions, construction practices, scheduling, and sampling methodology, see Lebow et al. (2000).

Table 1.—Sampling schedule and rainfall amounts.

Sampling date	Months after construction	Rainfall since construction, mm (in.)
Jun 1996	0.5	20 (0.8)
Aug 1996	2	109 (4.3)
Nov 1996	5.5	668 (26.3)
May 1997	11	2,743 (108.0)
May 1998	24	4,658 (183.4)
Jun 2001	60	10,244 (403.3)
May 2008	131	23,467 (923.9)

Wood treatment

The lumber used for the CCA-C–treated boardwalk section was from the ''Hem-fir'' species group and appeared to be primarily western hemlock. It was pressure treated by Exterior Wood of Washougal, Washington, in September 1995. The lumber was treated for use in ground contact (target retention of 6.4 kg/m^3 [0.4 lb/ft^3]), as recommended by American Wood-Preservers' Association (now the American Wood Protection Association) Standards (AWPA 2000). To ensure adequate posttreatment conditioning, it was also specified that the treated material be handled in accordance with the Western Wood Preservers Institute's Best Management Practices (BMPs) for wood to be used in aquatic applications (WWPI 1996). Inspections of preservative retention, penetration, and BMP conformance were conducted by an independent inspection agency, which reported that the average retention in 20 cores removed from the charge was 11.7 kg/m^3 (0.73 lb/ft^3). To verify retention, an additional 55 samples were removed from the narrow faces of joists, joist headers, support columns, and railings after construction. Analysis of these samples revealed that the average CCA-C retention in the outer 15 mm (0.6 in.) varied from 7.7 kg/m^3 (0.48 lb/ft^3) in the joist headers to 16.3 kg/m^3 (1.02 lb/ft^3) in the support columns. The overall average CCA-C retention in the samples was 10.6 kg/m^3 (0.66 lb/ft^3). Although the use of retentions greater than that standardized for this application was unintended, it did contribute toward the objective of making this study a realistic worst case.

Design and construction of test section

The test section consisted of approximately 36.5 m (120 ft) of elevated walkway, 1.8 m (6 ft) wide, including an octagonal observation platform (Fig. 1). A large volume of wood was used in the construction of the test section, which included 140 by 292-mm (nominal 6 by 12-in.) columns, cross-bracing, and hand rails. To minimize field modifications during construction, a cooperating mill performed as much fabrication of the wood members as possible prior to pressure treatment. During boardwalk construction, most

Figure 1.—Test section of boardwalk 11 years after construction. Soil samples were removed from the area in the foreground of this picture, while sediment samples were removed adjacent to the elevated walkway in the background.

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sawing and drilling was conducted on tarps away from the test areas. However, in some cases, such as bolt connections to support columns and cutting the columns to height, fabrication within the test site was necessary. In these cases, a combination of trays, tarps, and a vacuum cleaner was used to collect the shavings and sawdust and minimize their contact with the water or soil at the test site. Field treatment of cuts or holes in the test sections was minimal; in cases in which treatment was judged necessary, a copper naphthenate solution (2% copper as metal) was brushed on the exposed surface.

Scheduling of construction and sampling

The CCA-C–treated boardwalk section was constructed in late May and early June 1996. Two weeks prior to the start of construction, 16 soil and 9 sediment samples were removed to determine background concentrations of copper, chromium, and arsenic. Background levels of copper varied from 20 to 43 mg/kg in the soil and 17 to 24 mg/kg in the sediment. Background levels of chromium varied from 6 to 8 mg/kg in soil and 7 to 14 mg/kg in sediment, while background levels of arsenic ranged from 1 to 3 mg/kg in soil and 1 to 4 mg/kg in sediment. The first postconstruction sampling was conducted June 21, 1996, after approximately 20 mm (0.8 in.) of rain had fallen on the boardwalk. Samples were also removed at 2, 5.5, 11, 24, and 131 months (11 y) after construction (Table 1).

Method of sampling

During the first 24 months of evaluation, soil samples were removed to a depth of 305 mm (12 in.) with a 32-mm (1.25-in.)–diameter stainless steel soil recovery probe. The cores were removed from the sampler in sections corresponding to depths of 0 to 150 mm (0 to 6 in.) and 150 to 300 mm (6 to 12 in.) from the soil surface. Sediment samples were collected in 406-mm (16-in.)–long and 19-mm (0.75-in.)–diameter acetate tubes to a depth of 102 mm (4 in.). The filled tubes were kept upright and frozen for shipment and handling. The sediment cores were subsequently divided into two assay zones representing depths of 0 to 25 mm (0 to 1 in.) and 25 to 102 mm (1 to 4 in.) from the sediment surface. Concentrations of copper, chromium, and arsenic in the lower assay zones of soil and sediment samples were consistently less elevated than those in the upper assay zones, and at the 60-month and 11-year inspections, only the upper 0 to 150 mm (0 to 6 in.) of soil and upper 0 to 25 mm (0 to 1 in.) of sediment were collected. The data presented in this article are limited to those upper zones.

Soil and sediment sampling locations

At each sampling following construction, soil samples were removed in transects starting directly under the edge of the viewing platform and extending to distances of 0.15, 0.3, and 0.6 m (6, 12, and 24 in.) away from the platform (Lebow and Foster 2005). These transects were replicated seven times. The same transects were used at each inspection but were shifted slightly to avoid sampling soil disturbed in previous inspections. Transects were selected to minimize slope and other features that might direct rainfall runoff away from the sampling zones. In addition, four control samples were taken from a distance of at least 3 m (10 ft) from the boardwalk.

Postconstruction sediment samples were removed in transects starting directly under the edge of the boardwalk and extending downstream to distances of 0.3, 0.6, 1.5, and 3.0 m (1, 3, 5, and 10 ft) away from the boardwalk. These transects were replicated six times. Another set of six samples was removed from directly under the walkway. A minimum of four control samples were also removed at a minimum distance of 10 m (33 ft) upstream from the boardwalk.

Determining copper, chromium, and arsenic in samples

The air-dried samples were passed through a 2-mm (0.08-in.) screen and the larger material (primarily small stones) was discarded. The remaining sample was ground using a ceramic mortar and pestle. Ground soil and sediment samples were extracted using a microwave-assisted version of EPA Method 3050B, which is intended for determination of total arsenic, chromium, and copper in sediments and soils (US Environmental Protection Agency 1995). For samples collected during the first 24 months after construction, copper and chromium concentrations in the resulting extract were determined by flame atomization atomic absorption spectroscopy, while arsenic was analyzed using furnace atomization. Samples collected at 60 months and 11 years were analyzed using inductively coupled plasma emission spectrometry. For a more detailed description of sample processing and analysis, see Lebow et al. (2000).

The levels of preservative components in the soil and sediments varied greatly, even at equivalent distances from the treated wood. While the levels of most samples remained relatively low, a few samples had much higher levels of preservative components. This type of lognormal distribution is common in environmental sampling. Because of the lognormal distribution, the average value of preservative levels was higher than most of the actual values. To overcome this problem, this report uses the geometric mean of the values at any given distance from the treated wood. The geometric mean is the estimated median of a population with a lognormal distribution.

Results and Discussion

Soil and sediment concentrations of all three CCA components generally declined during the 60- to 131-month time period. The decline was most noticeable for locations beneath the walkway or under the drip line, where the highest concentrations had occurred previously. Occasional samples were more elevated than in previous inspections, but the sample digestion process used in this study does not differentiate CCA derived from leaching from that derived from small wood particles. The walkways are heavily used by the public and subject to abrasion of wood particles into the areas immediately below the walkway. This distinction is noteworthy because CCA components in abraded particles would likely be less bioavailable than those leached in a soluble form.

Soil concentrations

Although chromium, copper, and arsenic concentrations in the soil fluctuated, there was a trend of gradual increase for the first 60 months of the study, followed by a plateau or decline at the 131-month sampling (Table 2). Geometric mean copper concentrations directly under the drip line of

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Table 2.—Total copper, chromium, and arsenic concentrations (mg/kg) in the upper 150 mm of soil samples removed from adjacent to the viewing platform (geometric mean and maximum).[a]

Months after construction	Distance from walkway (m): 0 (drip line) Mean	Max	0.15 Mean	Max	0.3 Mean	Max	0.6 Mean	Max	≥3 (controls) Mean	Max
Copper										
0.5	22	23	22	25	19	27	21	24	23	24
2	26	32	22	24	23	27	23	25	22	24
5.5	26	34	21	25	21	22	20	23	19	22
11	31	56	25	38	23	29	21	24	20	22
24	37	73	29	33	22	26	24	27	22	24
60	52	72	28	37	24	29	26	28	30	32
131	41	189	23	28	23	31	19	20	17	19
Chromium										
0.5	7	8	8	9	8	9	7	8	8	10
2	9	9	8	8	9	10	9	10	8	9
5.5	9	11	8	10	10	13	8	10	8	9
11	10	13	8	12	13	20	10	12	8	10
24	13	17	14	16	13	17	12	13	13	15
60	20	23	16	21	14	18	15	17	14	15
131	14	16	12	14	11	15	11	12	10	12
Arsenic										
0.5	4	6	1	2	1	2	1	1	1	1
2	2	6	2	5	2	4	1	2	1	1
5.5	7	36	2	7	2	3	1	3	1	3
11	12	29	7	14	4	7	3	5	3	2
24	2	24	3	10	1	1	1	2	1	2
60	48	117	10	32	5	13	4	5	2	4
131	30	114	6	39	5	9	2	5	1	2

[a] Based on seven replicate transects adjacent to the boardwalk and four replicate control samples.

the viewing platform reached a maximum of 52 mg/kg 60 months after construction but declined to 41 mg/kg after 131 months. However, the maximum copper concentration (189 mg/kg) was detected at 131 months. Movement of copper away from the viewing platform through the soil appeared to be quite limited. With the exception of one 37-mg/kg sample removed 0.15 m (6 in.) away from the platform at the 60-month sampling, elevated copper concentrations were not detected except in the drip line area.

Chromium levels in the soil remained low throughout the course of the study (Table 2). The highest chromium concentration detected was 23 mg/kg in a sample removed from under the drip line of the viewing platform 60 months after construction. Chromium release from CCA-C–treated wood is generally lower than that of copper or arsenic (Lebow 1996), and the rate of release from the platform was apparently not great enough to allow more substantial accumulation in the soil.

Arsenic soil concentrations showed little change until 5.5 months after construction (Fig. 2), when a maximum of 36 mg/kg was detected under the drip line of the viewing platform (Table 2). However, geometric mean concentrations in that area did not appear to increase until 11 months after construction, at which time geometric mean concentration was 12 mg/kg. Arsenic levels in the drip line area then declined to a geometric mean of 2 mg/kg 24 months after construction, before increasing to 48 mg/kg 60 months after construction. The reason for the low arsenic concentrations detected at 24 months is unclear. Because leached CCA components are not uniformly distributed in the soil, it is possible that the levels detected were a sampling anomaly. At the 60-month sampling, five of the seven samples collected from the drip line area contained more arsenic than any previous soil sample (Table 2). Geometric mean arsenic concentrations in the soil directly under the drip line had declined slightly, to 30 mg/kg, by the 131-month sampling.

Loss of arsenic from the walkway into the soil was probably much lower during the second year because leaching from CCA-treated wood is typically highest initially and then declines to a lower plateau with time

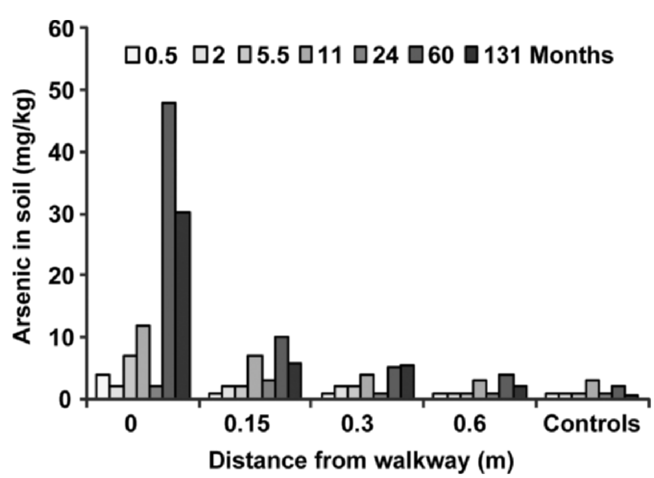

Figure 2.—Geometric mean of arsenic concentrations (mg/kg) detected in soil samples removed adjacent to CCA-treated viewing platform.

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(Lebow 1996). The increase at 60 months may be partially attributable to the addition of an interpretive display on the railing directly above the sampling area shortly after the 24-month sample collection. The presence of the display probably increased foot traffic and subsequent abrasion of particles into the sampling zone. However, none of these rationales would explain the similar 24-month decline and subsequent 60-month increase noted in the sediment samples.

Studies of the movement of CCA constituents in soils generally agree that the constituents are not highly mobile, although some movement of arsenic may occur in sandy soils (De Groot et al. 1979, Bergman 1983, Brown 1986, Bergholm and Dryler 1989, Bergholm 1990, Murphy and Dickinson 1990, Lund and Fobian 1991, Holland and Orsler 1995). Movement of both copper and chromium in soil is limited by their strong reactivity with organic soil components (Bergholm 1990, Lund and Fobian 1991), while arsenic retention in soil is more influenced by the presence of iron, aluminum, and clay (Fordham and Norrish 1974, Frost and Griffin 1977). The plateau or slight decline in soil concentrations observed at 131 months indicates that the rate of CCA release from the boardwalk had slowed in comparison to earlier in the study, and may also indicate that some downward migration of leached components was occurring in the soil. In subsequent inspections the lower 150- to 300-mm (6- to 12-in.) soil assay zone will be analyzed to evaluate this latter possibility.

Although elevated concentrations of copper, chromium, and arsenic were detected in the soil, there is little evidence to suggest that these concentrations will cause significant harm to the environment. The geometric mean copper and chromium soil concentrations remained relatively low compared with control concentrations and are unlikely to be of concern. However, the geometric mean arsenic concentration immediately under the drip line of the viewing platform exceeded control concentrations by more than a factor of 10. Soil clean-up standards have been developed for arsenic, but they vary widely and are based on potential effects on human health rather than effects on local ecosystems (Provoost et al. 2006). Although the effects of various arsenic concentrations on soil organisms are not well known, soil microorganisms are generally thought to be capable of tolerating relatively high levels of arsenic (Eisler 1988). A screening benchmark concentration for the toxicity of arsenic to earthworms of 60 mg/kg has been proposed by Efroymson et al. (1997), while a slightly higher screening benchmark (100 mg/kg) has been proposed for toxicity to soil microorganisms and microbial processes (Efroymson et al. 1997). Only two samples removed during the course of the study exceeded these benchmarks, and the geometric mean concentrations of arsenic remained below both benchmarks, even under the drip line of the viewing platform. The localized nature of the elevated arsenic concentrations would also be expected to minimize potential impacts.

Sediment concentrations

Increased copper concentrations were detected in wetland sediment samples 0.5 month after construction, and geometric mean concentrations under the walkway and in the drip line area were elevated to 75 and 43 mg/kg, respectively, 2 months after construction (Fig. 3; Table 3). Concentrations directly under the walkway peaked at 60 months before declining at 131 months, while concentrations at greater distances from the walkway peaked at 24 months and then declined or remained relatively constant. Geometric mean concentrations appear slightly elevated at 0.3 and 0.6 m (1 and 2 ft) from the walkway after 131 months. Occasional elevated samples were found at distances of up to 1.5 m (5 ft) and 3 m (10 ft) from the walkway (Table 3), but geometric mean concentrations appear similar to controls at 60 and 131 months after construction.

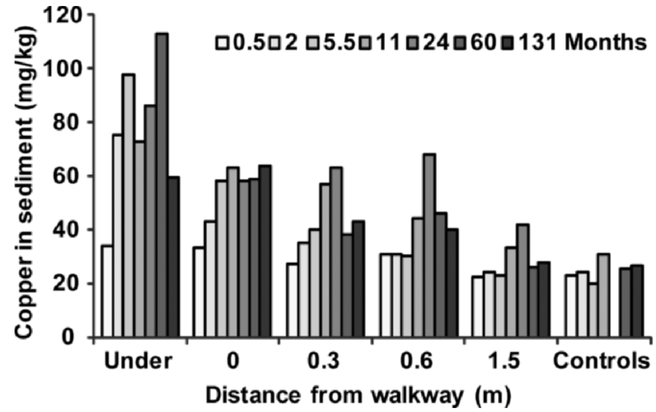

Figure 3.—Geometric mean of copper concentrations (mg/kg) detected in sediment samples removed adjacent to CCA-treated walkway.

Elevated chromium concentrations were detected under the walkway 2 months after construction, when a maximum concentration of 104 mg/kg was detected (Table 3). Concentrations under the walkway then declined for several samplings, peaked again at 60 months, and then declined at 131 months. Occasional elevated samples were also detected in the drip line sampling zone and 0.3 and 0.6 m (1 and 2 ft) away from the walkway. As in the soil samples, chromium concentrations in the wetland were generally lower than those for copper and arsenic.

Arsenic concentrations in sediments under the walkway also noticeably increased within 2 months after construction, with a maximum of 130 mg/kg detected (Table 3). Elevated concentrations were also detected in samples removed at all tested distances away from the walkway except control locations. During the remainder of the first year, arsenic concentrations appeared to remain relatively stable under the walkway, while they gradually increased in samples removed at greater distances from the walkway. This trend was reversed at the 24-month sampling, when geometric mean arsenic concentrations decreased for all sampling locations. As noted for the soil samples, the cause of the steep drop in arsenic concentration at the 24-month sampling is unclear, although the occurrence of this decrease in both the sediment and soil samples may indicate an aberration in arsenic determination for the 24-month samples. At the 60-month inspection, arsenic concentrations were again elevated to levels similar to those found at the 11-month inspection. Arsenic concentrations then dropped substantially at the 131-month inspection.

Arsenic concentrations were elevated in one or more sediment samples removed 3 m (10 ft) downstream from the walkway at several of the inspections. Geometric mean arsenic levels at the 3-m (10-ft) locations were generally at least as great as those at the 1.5-m (5-ft) locations,

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Table 3.—Total copper, chromium, and arsenic concentrations (mg/kg) in the upper 25 mm of sediment samples removed from adjacent to the elevated walkway (geometric mean and maximum).[a]

Months after construction	Distance from walkway (m)													
	Under		0 (drip line)		0.3		0.6		1.5		3		≥10 (controls)	
	Mean	Max	Mean	Max	Mean	Max	Mean	Max	Mean	Max	Mean	Max	Mean	Max
Copper														
0.5	34	49	33	48	27	43	31	48	22	34	28	28	23	29
2	75	201	43	55	35	54	31	48	24	32	28	35	24	26
5.5	98	219	58	138	40	64	30	59	23	28	25	27	20	23
11	73	115	63	95	57	83	44	61	33	51	30	38	31	60
24	86	174	58	77	63	82	68	90	42	66	41	67	–	–
60	113	205	59	132	38	63	46	79	26	39	24	36	25	32
131	59	96	64	166	43	67	40	75	28	70	20	36	27	29
Chromium														
0.5	14	23	18	37	13	21	16	27	10	17	12	12	10	12
2	33	104	21	33	17	38	15	29	13	17	13	14	10	11
5.5	27	55	19	38	16	30	13	23	10	13	12	15	9	12
11	21	37	17	32	18	40	14	24	11	14	14	18	9	11
24	20	25	22	57	19	32	22	30	13	22	14	19	–	–
60	32	45	21	47	15	23	20	60	11	13	14	22	9	9
131	22	29	23	45	15	22	15	24	13	40	7	11	7	9
Arsenic														
0.5	10	16	11	32	6	18	10	24	5	10	12	12	3	4
2	41	130	19	34	14	28	10	24	7	13	16	22	4	6
5.5	39	82	17	88	12	35	8	39	5	9	8	15	2	4
11	38	65	33	58	36	78	25	42	14	24	13	18	6	10
24	8	24	4	33	7	23	9	31	4	24	8	33	–	–
60	49	165	36	167	10	47	21	51	4	6	9	74	2	3
131	10	23	17	56	13	47	10	25	4	15	4	8	3	4

[a] Based on six replicate transects adjacent to the boardwalk and a minimum of four replicate control samples.

suggesting that this area may have been contaminated during construction activities. By the 131-month inspections, arsenic geometric mean arsenic concentrations at 3 m (10 ft) from the walkway were similar to the controls. Geometric mean arsenic concentrations at 1.5 m (5 ft) downstream from the walkway appeared to be elevated at only the 11-month inspection. Geometric mean arsenic concentrations 0.6 m (2 ft) from the walkway appeared to be somewhat elevated at each inspection.

Arsenic reactivity in sediments is most strongly related to inorganic constituents; iron oxide, aluminum, calcium, and clay minerals are important in binding arsenic (Fordham and Norrish 1974, Frost and Griffin 1977). Conversely, copper and chromium deposits in sediments are usually complexed with organic compounds (Giesking 1975, Tan 1993), and the quantity of fine sediments at the site, as well as the localized pattern of copper and chromium distribution, suggests that the majority of these metals released from the wood rapidly become associated with sedimentary material. Further mobility is likely to occur primarily when the sediments themselves are dislodged by high water or other types of disturbances.

Impact on aquatic organisms

It is notable that sediment concentrations of all three CCA components reached maximum or near maximum levels within the first year after construction, because it was during this time span that aquatic invertebrate populations in the vegetation and sediments were monitored (Brooks 2000b). A comparison of the invertebrate community present during baseline sampling with that observed during postconstruction spring and summer sampling indicated that no taxa were excluded or significantly reduced in number by the boardwalk construction. Because of its aquatic toxicity, copper was considered to be the element of primary concern, but there appeared to be little if any correlation between sediment copper levels and the number or diversity of aquatic invertebrates. Brooks hypothesized that the lack of impact in those cases was related to type of invertebrates present. He noted that invertebrates that live in sediments associated with slow, stagnant water tend to be more robust and less sensitive to pollutants than those living in areas with rapidly moving water (Brooks 2000b). Because leached preservative components generally only reached elevated levels in the sediments of slow-moving water, if at all, it appears unlikely that elevated preservative levels and highly pollutant-sensitive invertebrates would be found in the same location. It is also worth noting that the digestion procedure used in this study was intended to quantify total metal concentrations rather than bioavailable concentrations. Because they are typically bound to organic or inorganic components within sediments, the bioavailable concentrations of metals are typically much lower than total concentrations (Tessier and Campbell 1987, An and Kampbell 2003).

Conclusions

The results of this study demonstrate that when used in an area of high rainfall, CCA-C–treated wood structures can cause measurable increases in environmental concentrations of total copper, chromium, and arsenic in close proximity to the treated wood. The environmental concentrations varied with time, distance from the treated wood, and placement of

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the structure (soil or standing water). Concentrations of leached components in the soil developed slowly, were generally greatest at the 5-year sampling event, and have subsequently declined. Concentrations of leached components in the sediments increased more quickly than in the soil, reaching maximum or near maximum levels within the first year. As discussed in an earlier report (Brooks 2000b), sediment concentrations detected within the first year did not have a measurable impact on aquatic invertebrate populations. As expected, the movement of leached CCA components was much lower in soil than in the sediments. Soil samples with elevated levels of copper and chromium were confined to directly under the drip line of the viewing platform, and arsenic appeared to be limited to within 0.3 m (1 ft) of the structure. In contrast, elevated concentrations of copper, chromium, and arsenic were occasionally found in sediments as much as 3 m (10 ft) from the elevated walkway. In both soil and sediment samples, copper and arsenic concentrations were consistently more elevated than chromium concentrations.

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