Identifying Effective Sealants for CCA-Treated Wood

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Introduction

The goal of this project is to attempt to identify the most effective sealants that can be applied to arsenic-treated wood to reduce user exposure to treatment chemicals, especially arsenic. The wood uses of most concern are those where human contact with the wood is the greatest: play structures, decks, benches, tables, railings, and, to a lesser degree, fences. In addition, we will seek to determine the most effective application methods and how often the products need to be reapplied.

The San Francisco Board of Supervisors Resolution No. 011-01-COE requires "all City Departments who maintain existing playground and park equipment made of preservative-treated wood containing arsenic where contact with human skin is likely to occur ensure proper sealing in accordance with California Health and Safety Code section 115775 until such time that all structures have been replaced with arsenic-free alternatives." (SFBS 2001) The referenced California Health and Safety Code section 115775 describes an appropriate sealer for arsenic-treated wood only as "a nontoxic and nonslippery sealer" (CalHSC 1995), the same description given by the California Department of Health Services (CDHS) when they first recommended sealing treated-wood play structures more than fifteen years ago (CDHS 1987). It is recognized in San Francisco's resolution that replacement is the goal and sealing the wood is only a temporary measure.

Despite the 1987 CDHS recommendation regarding treated-wood play structures, concerns about arsenic exposure remained relatively muted for about 15 years, during which period there was little interest in identifying effective sealants for arsenic-treated wood. After a group of academic studies on leaching and disposal issues (e.g. Stilwell and Gorny 1997; Solo-Gabrielle et al. 2000; Townsend et al. 2001a,b) and several highly publicized reports from the environmental community on human health risks (EWG 2001a; EWG/HBN 2001b; EWG 2002), EPA announced in 2002 that chromated copper arsenate (CCA)-treated wood was being phased out for most consumer use (USEPA 2002). These events have elevated the level of interest in sealants.

An appropriate product for temporarily sealing surface arsenic must provide an effective barrier and stand up to weathering and wear. The surface preparation and application process must not disperse contaminants or expose workers to unsafe conditions. There is no consensus yet on what products are best or how often surfaces need to be refinished to maintain protection against dislodgeable arsenic. Intervals from six months to two years have been recommended, and if a necessary re-treatment frequency proves impractical, then sealing may not be efficacious and removal of the wood should occur.

Unfortunately, there are as yet few studies that compare the ability of wood finishes to block arsenic. The United States Environmental Protection Agency is currently conducting a study that will shed more light on the subject, but this study is not scheduled for completion until 2005 (USEPA 2003b). David Stilwell (1998) measured good arsenic sealing ability for four types of finishes but warned that durability should be considered. That study did measure durability of the finishes. There is some literature on the durability of the different major types of wood finishes, but most of these studies neither measure arsenic sealing nor identify specific products by name. Consumers Union has conducted numerous durability tests of brand name products, and, on the basis of categories of finishes, their results are generally in accord with other published studies. These studies, then, predict with some degree of certainty how well various types of finishes will hold up to normal weathering. They do not generally subject the wood to mechanical wear, however, and so they may be less informative in predicting the durability of wood finishes subjected to extensive foot traffic or hand contact.

An additional problem cited by several authors is well articulated by Lebow et al. (2003), who state that “it is not practical to evaluate all finish formulations available to consumers because formulations often change and their composition is usually proprietary.” They argue that it is more productive to gain an understanding of how the various finish components work in protecting the wood so that reliable predictions can be made based on the general product description.

Types of Wood Finishes Available

Exterior wood finishes are generally classified as either penetrating or film forming, but there are now some products (such as tinted water-based finishes) that blur these distinctions to some degree. In addition, the distinction between water-based and solvent-based, while generally absolute, has also been bridged by some products (oil-modified water-borne stains) that combine both solvents and water in an attempt to get the best performance characteristics of each. A number of authors list the major types of wood finishes available. The list in Table 1 was compiled primarily from chapter 15 of the *Wood Handbook: Wood as an Engineering Material* (FPL 1999), with some additions from other sources. Products registered as wood preservatives (i.e. pesticidal compounds) are omitted.

Table 1. Basic Types of Exterior Wood Coatings (excluding wood preservatives)

Product	film forming	penetrating	vehicle	color
Paint, oil-based	yes	no	solvent	opaque
Paint, latex	yes	no	water	opaque
Solid color stain, oil-based	yes	no	solvent	opaque
Solid color stain, latex	yes	no	water	opaque
Semi-transp. penetrating stain	no	yes	solvent	semi-trans
Water-borne stain	yes	no	water	semi-trans
Oil-modified water-borne stain	yes	yes	solv./water	semi-trans
Tinted penetrating finish	no	yes	solvent	tinted/toned
Tinted water-based finish	slight	yes	water	tinted/toned
Water repellent	no	yes	solvent	clear
Varnish	yes	no	either	clear
Natural oil finishes (e.g. tung)	yes	yes	solvent	clear

The EPA study that is currently in progress is evaluating the effectiveness of 12 different types of products, including most of those listed above (USEPA 2003b). They are in addition testing two products specifically designed to encapsulate CCA, one an “elastic vinyl” and the other described simply as a polymer. Such products are recent and no testing data for them was found in any of the studies described here.

Brief descriptions of each product type follow.

Paint

Paints are highly pigmented coatings that form a protective film but do not penetrate into the wood except to fill cut cells and vessels (FPL 1999). Because of their opacity, paints provide the highest level of protection to the wood underneath. Latex paints made with 100% acrylic resins are the most durable because the resin remains somewhat flexible. Oil based (alkyd resin) paints tend to become more brittle over time. Both kinds of paint can eventually peel away from the substrate, particularly if the surface is improperly prepared, if excessive water gets behind the paint, or if the surface receives heavy wear. When this occurs, considerable surface preparation is required before recoating.

Solid color stain

Available in either solvent-based or water-based formulations, solid color stains completely hide the wood grain but are usually tinted in wood-like colors. Like paints, they have a high degree of pigmentation and tend for form a film over the surface. They can peel or chip away when they fail.

Semi-transparent penetrating stain

These solvent-based stains are essentially water repellents with a moderate amount of pigmentation added. They penetrate the wood surface, do not form a surface film, and are relatively porous. The do not protect the wood as well as solid color stains (see details below in research findings), but will not blister or peel away if water gets underneath. They can be reapplied with minimal surface preparation.

Semi-transparent water-borne stain

These products are similar to the oil-based stains except that they do not penetrate the wood surface as much. They do tend to form a slight surface film.

Oil-modified water-borne stain

These water-borne stains that have some solvent incorporated in order to get better penetration of the wood. Their VOC content is intermediate between the oil-based and the water-based stains.

Tinted penetrating finish

These solvent-based finishes are similar to semi-transparent stains but with less pigment. Since they let more light into the wood, they don’t hold up as well as semi-transparent stains.

Tinted water-based finish

These are similar to the semi-transparent water-based finishes but with less pigment, hence less durability. They tend not to penetrate the wood and may form a slight surface film. Oil-modified tinted finishes are also available.

Water repellent
Water repellents are clear coatings that penetrate the wood and cause water to bead up on the surface but do not prevent the flow of water vapor. The repellency is usually provided by a small amount of wax, along with some resin or drying oil. Because they are clear, water repellents do not have good durability, but some can be painted over, providing a good combination of a moisture and ultraviolet barrier. Most water repellents are solvent-based, but some oil-modified products are available. (xxxCheck Weather Bos)

Varnish
Varnishes are clear, film-forming finishes. Varnishes tend to be brittle and will crack and flake off when used outdoors. Because they are clear, varnishes also don't provide much protection against sunlight. Spar varnishes are more flexible because they contain higher levels of solvent. They can be built up in multiple layers to give good protection against the elements, but the process is labor intensive. Polyurethane varnishes form a cross-linked film that is not soluble in the original solvent and is very strong. They are now available in both solvent-based and water-based formulations. Exterior polyurethanes contain a UV absorber, but are still less durable than in indoor applications and can eventually crack or flake.

Natural oil finishes
Finishes made from natural oils penetrate into the wood. They can be divided into those that cure (typically boiled or processed tung or linseed oils) and those that do not (e.g. mineral oil or raw linseed oil). Curing oils can be built up to form a surface, but not as thick or hard as varnish. Oils are not generally considered to be good outdoor finishes, especially on highly exposed surfaces. The oils themselves can be food for mildew.

Special Products for CCA Encapsulation
One product located on the Internet is an "elastomeric acrylic encapsulment coating" that reportedly provides a layer five times thicker than paint and is much more flexible. The recommended application method is a base coat of the company's epoxy sealer and then two coats of the flexible outer coating. According to the company's website, this material can also be used to seal lead-based paint and asbestos.

It would not be surprising at all if products specifically designed to encapsulate CCA (or other toxic chemicals) would prove to me the most effective products for that purpose. It will be important, however, to weigh the time and labor involved in applying a multi-coating system against its potentially better durability.

Historical Recommendations on Sealants for Treated Wood

California Department of Health Services
In 1987, the California Department of Health Services evaluated the hazards of wood preservatives used on playground equipment. Their report recommended that all chemically treated wood (except Niedox-10, a borate-treated wood), whether new or existing, be treated “with a nontoxic and nonslippery sealant” and that the sealants “be applied every two years to playground and recreational equipment.” (CDHS 1987)

Environmental Working Group
In a 2002 study finding no statistical difference in surface arsenic levels on CCA wood sealed six months prior as compared to unsealed wood, EWG issued a recommendation that CCA-treated wood be sealed at least every six months (EWG 2002). This is the highest re-coating frequency found.

CPSC
The Consumer Product Safety Commission has not yet issued specific recommendations for sealing arsenic-treated wood, preferring to wait until the joint EPA/CPSC studies are completed. In the interim, they have suggested “that parents and caregivers thoroughly wash children’s hands with soap and water immediately after playing on CCA pressure-treated wood playground equipment. In addition, the staff recommends that children not eat while on CCA-treated wood playground equipment.” (CPSC 2003)

U.S. EPA
The current EPA recommendation regarding sealing of CCA-treated wood states:
“* While available data are very limited, some studies suggest that applying certain penetrating coatings (e.g., oil-based semi-transparent stains) on a regular basis (one re-application per year or every other year depending upon wear and weathering) may reduce the migration of wood preservatives from CCA-treated wood.
* In selecting a coating, consumers should be aware that, in some cases, "film-forming" or non-penetrating stains (latex semitransparent, latex opaque, and oil-based opaque stains) on outdoor surfaces such as decks and fences are not recommended, as subsequent peeling and flaking may ultimately have an impact on durability as well as exposure to the preservatives in the wood.” (USEPA 2003a)

In this recommendation, EPA raises the concern that finishes which peel or flake off as they wear may more hazardous than penetrating finishes, either because they suddenly expose large areas of the wood underneath to skin contact or because children may receive a large arsenic exposure by ingesting the chips. EPA’s recommendation presents a dilemma because, as we will see, studies show that the film-forming coatings are most effective at protecting the wood from weathering. EPA seems to hold open the possibility that some film-forming or non-penetrating stains may not flake or peel, but does not indicate that those can be identified at this time. Instead, they recommend using oil-based semi-transparent stains, which studies show offer moderately good durability, do not flake or peel, and can easily be recoated. EPA’s current study may lead to better supported and more specific recommendations.

Many other recommendations published on the Internet or in popular media appear to be taken from one of the above original sources.

Research Findings

A. Wood Finish Durability Studies

Durability of wood finishes is a factor in how long they can act as a sealant against arsenic, but the nature of the relationship between durability and arsenic-sealing capability has not been well established experimentally. The tests discussed in this section evaluated how well the products protect the wood from the elements, one measure of their durability. Lebow et al. (2003) showed that exposures simulating rain and solar UV radiation decreased the ability of a water repellent to seal in arsenic. They postulate that weather damage increases arsenic leaching from the wood by allowing more water into the wood via surface checking and by roughening the wood surface, thus increasing its area. They further suggest the mechanisms by which the various finish components may act to reduce arsenic leaching from the surface, lending credence to the idea that rain and UV radiation will eventually break down the finish and the wood fibers themselves, causing leaching to increase. Unfortunately, none of the studies we found subjected the wood to mechanical wear, an important durability factor for decking, furniture, and play structures that would be expected to hasten the surface breakdown.

Forest Products Laboratory, Chapter 15 of the *Wood Handbook*

This reference work lists the service life expected for various exterior wood finishes (FPL 1999). The results were compiled from the observations of many researchers and are predictions for an average location in the continental United States. Service life is for vertical exposure, such as on a fence. Service life in horizontal exposure would be two to three times less because of greater sunlight intensity and the pooling of water on the wood surface (Lebow et al. 2003). The results are shown below in Table 2.

Table 2. Service life and application process for exterior wood finishes (FPL 1999)

Finish	service life	application process
Water-repellent preservative	1-3 years	brushing
Water-borne preservative	none*	pressure (factory applied)
Organic solvent preservative	2-3 years	pressure, steeping, dipping or brushing
Water repellent	1-3 years	1-2 brush coats, dipping preferred
Semi-transparent stain	3-6 years	1-2 brush coats
Clear varnish	2 years	3 coats minimum
Solid color stain	3-7 years	brush: water repellent, prime, + 2 top coats
Paint	7-10 years	brush: water repellent, prime, + 2 top coats

*note: unless stained or painted

This source also summarizes the suitability and life of wood finishes in different exterior applications (FPL 1999). For decking materials, the results are shown in Table 3.

Table 3. Suitability and expected service life for wood finishes on decking

Type of surface	semi-transparent stain		solid-color stain		paint	
	suitability	life (yrs)	suitability	life	suitability	life
Decking, new	mod	2-3	low	1-2	low	2-3
Decking, weathered	high	3-6	low	1-2	low	2-3

The service life for solid-color stain and paint on decking in Table 3 are much lower than indicated in the Table 2. This difference is partly due to the horizontal exposure and may also include (though it is not explicitly stated) some allowance for foot traffic. Ross et al. (1992) state that paints and solid color stains are unsuitable on decks because of both weathering and foot traffic. The higher suitability of semi-transparent stain on weathered decking than on new decking stems from the product's ability to bind better to the roughened surface.

Kropf et al. 1994

A number of other studies on durability were found. Kropf et al. (1994) noted that a literature search of studies of weathering behavior was difficult to distill into conclusions and useful recommendations because of the rapid pace of change in product formulations, driven in large part by environmental considerations. Nevertheless, they concluded that color, coating thickness, and pigmentation were more important than climatic differences in determining the long-term behavior and durability of various coatings.

In their own tests, these researchers exposed panels of western red cedar, Douglas-fir plywood, European beech, and European spruce in south-facing arrays oriented at 45 and 90 degrees to horizontal at locations in Wisconsin and Switzerland. They found that in terms of performance the coatings ranked in the following order (from best to worst):
1. water-borne film-forming systems (white), [in other words latex paint]
2. solvent-borne or mixed systems (white)
3. solid-color stains
4. film-forming semi-transparent stains
5. solvent-borne penetrating stains, and
6. water-borne penetrating stains.

They also noted that vertically oriented samples lasted 1.5 to 2 times longer than the inclined samples. An important conclusion of this study is that opaque pigments are necessary in a coating to protect well against visible light and ultraviolet radiation. Moisture protection, on the other hand, is enhanced by a thicker coating. They found that for comparable coating thickness, the acrylic paints offered somewhat better long-term performance than alkyd paints. They also concluded that higher resin content seemed to enhance performance, partially because it forms a thicker film. Unfortunately, as in the other studies reviewed here, no mechanical abrasion other than normal weathering was applied to the surfaces. Although this study was not done on pressure-treated wood, the results are consistent with studies done on treated wood, at least in terms of the relative durability of the finishes.

Feist and Ross 1995

Feist and Ross (1995) studied the performance and durability of finishes on previously coated CCA-treated wood. Existing surfaces were cleaned with a commercial wood cleaner containing sodium peroxydicarbonate, rinsed, and allowed to dry before refinishing. The boards were oriented at 45 degrees, facing the sun, at locations in Wisconsin and Mississippi. Their results clearly showed that the degree of pigmentation was important in the overall performance of the coating, with results from best to worst as shown below:

1. fully pigmented, film-forming paints and stains
2. lightly pigmented (semi-transparent) stains
3. unpigmented (transparent water repellents)

This study does provide some additional information on particular aspects of finish wear, since each finish was scored on a series of criteria, including discoloration, flaking/cracking, water repellency, finish erosion, and general appearance. One general conclusion from this study is that finishes held up better on CCA-treated wood than on untreated samples of the same wood in the same exposure conditions. This fact should be kept in mind when looking at durability data measured on untreated wood.

For the solid-color stain and paint products, the authors prefer the flaking-and-cracking evaluation as the best measure of performance. Although they admit that film-forming surfaces tend to fail by cracking, blistering, and peeling, the researchers found in their tests that even after 24 months of exposure, the flaking-and-cracking ratings of the two acrylic latex flat house paints were still very good, generally better than their overall appearance scores. The 24-month results of the flaking/cracking tests for film-forming coatings are shown in Table 4. The tabulated results are for preservative retentions of 0.25 and 0.40 pounds per cubic foot (pcf). An average of the eight results for each finish is also displayed. A score of 10 is perfect, and a score of 5 indicates a need for recoating but without substantial surface preparation to do so.

Table 4. Flaking and cracking scores for film-forming coatings on CCA (Feist & Roos 1995)

Type of finish	type of wood	location	results	
			.25 pcf	.40 pcf
Oil-based translucent varnish stain	Southern pine	Wisc.	5.7	7.0
	Southern pine	Miss.	4.0	6.0
	Hem-fir	Wisc.	7.0	7.3
	Hem-fir	Miss.	5.7	6.0
			Average	6.09
Solid color acrylic stain	Southern pine	Wisc.	5.0	5.0
	Southern pine	Miss.	5.0	6.3
	Hem-fir	Wisc.	5.0	5.7
	Hem-fir	Miss.	6.3	6.7
			Average	5.63
Acrylic latex flat house paint	Southern pine	Wisc.	9.0	8.7
	Southern pine	Miss.	9.0	8.3
	Hem-fir	Wisc.	9.0	9.0
	Hem-fir	Miss.	8.7	8.7
			Average	8.80
Acrylic latex flat house paint	Southern pine	Wisc.	9.0	8.7
	Southern pine	Miss.	8.0	8.3
	Hem-fir	Wisc.	8.3	9.0
	Hem-fir	Miss.	8.3	8.3

Average	8.49

These scores indicate that acrylic house paint may be a good choice for non-horizontal, low-traffic surfaces where a solid color is acceptable.

The results for semi-transparent stains are shown in Table 5. The authors did not express a preference for any single performance characteristic for this types of product but state that the general (visual) appearance rating of the finish is often a good overall indicator of overall finish durability. That is the rating that is reported here. The article does report specific results for both substrate checking/cracking and finish erosion, but we do not know which of these parameters correlates better to arsenic sealing ability. Results are given at both 6 and 18 months because these products deteriorate more quickly than the film-forming products in Table 4. One product that contained a wood preservative itself is omitted.

Table 5. General appearance scores for semi-transparent coatings (Feist & Ross 1995)

Type of finish	type of wood	location	results			
			6 months		18 months	
Semi-transp. oil-based natural stain	Southern pine	Wisc.	8.0	8.0	7.3	6.3
	Southern pine	Miss.	8.0	7.3	6.3	5.3
	Hem-fir	Wisc.	9.0	8.3	7.0	6.7
	Hem-fir	Miss.	5.0	6.0	3.3	4.3
		Average	7.45		5.81	
Waterborne deck stain for treated wood	Southern pine	Wisc.	7.7	7.3	5.0	5.0
	Southern pine	Miss.	8.3	7.0	7.0	5.3
	Hem-fir	Wisc.	6.0	7.0	4.3	5.0
	Hem-fir	Miss.	5.7	6.3	4.7	4.7
		Average	6.91		5.13	
Semi-transp. alkyd resin stain for pressure treated wood	Southern pine	Wisc.	5.3	5.7	3.3	4.0
	Southern pine	Miss.	8.0	7.3	3.3	5.0
	Hem-fir	Wisc.	7.3	7.0	4.0	3.7
	Hem-fir	Miss.	7.3	7.0	5.3	5.3
		Average	6.86		4.24	
Semi-transp. waterborne wood stain for pressure treated wood	Southern pine	Wisc.	7.0	7.7	5.0	5.7
	Southern pine	Miss.	5.3	6.7	3.7	4.3
	Hem-fir	Wisc.	7.7	8.0	4.0	6.0
	Hem-fir	Miss.	7.0	7.0	4.3	4.7
		Average	7.05		4.71	
Semi-transp. waterborne deck stain for treated wood	Southern pine	Wisc.	7.3	6.3	5.3	4.7
	Southern pine	Miss.	8.0	8.3	6.7	6.3
	Hem-fir	Wisc.	4.0	4.7	2.7	3.7
	Hem-fir	Miss.	6.7	7.3	5.0	6.0
		Average	6.58		5.05	

These results show rather small differences in performance between the five types of products. One is reluctant to choose a "best" product here because the fluctuations in the individual results are large compared to the differences in the averages. The first product, the semitransparent, oil-based natural stain had slightly better numbers than the others. However, three of the five products were still above a “5” rating at 18 months, and the other two were not far below. It is not apparent that the oil-based products did better as a group than the water-based products. Although this study does not measure arsenic mobility, if sealing ability against arsenic is well correlated to general surface durability, the 6- and 18-month comparisons suggest that on average two years is probably too long for a retreatment interval. Periodic inspection would be necessary to assess the condition of wood surfaces in different exposures and uses to determine re-treatment needs on a case by case basis.

Consumers Union
The non-profit consumers’ organization Consumers Union has had a continually running test of deck finishes underway since 1996. The purpose of these tests is to rate various brand name products for durability and resistance to dirt, fading, and mildew. The results have been reported in a series of articles in *Consumer Reports* magazine (CU 1997; CU 1998; CU 2001a,b; CU 2002). CU tests are done on pressure-treated pine, but they do not measure sealing ability against arsenic. Some of the products CU tested are actually wood preservatives themselves and thus not candidates for treating pressure-treated wood for our purposes. Those products are not reported here. However, many of the products are deck stains, water repellants, or penetrating oil finishes, all of which would be candidate products. Ross et al. (1992) report that pressure-treated pine absorbs more water than fir and tends to crack or check more, so the products might have scored better had they been tested on treated fir instead.

Methodology
In CU’s tests, identical three-foot-long pieces of pressure-treated pine deck lumber were attached horizontally to a frame placed close to the ground in a sunny spot. The tests took place in Yonkers, New York. Each board was given one coat of treatment with a different product; more coats were used if the manufacturer specifically recommended it. The position of the boards on the deck structure was randomly determined. The poorest-performing products were removed from the test at various intervals and replaced with new products. Although the tests are described as evaluating durability, no description is given of any mechanical abrasion or other wear applied to the wood during the tests. Thus it is not clear to what extent these results should apply to play equipment or other structures with heavy wear. In addition, the surfaces were not recoated periodically, so to get an idea of durability over the one to two year period recommended by most sources, one should look only at the first one or two years of the test results.

Results
When interpreting the CU results and or seeking to recommend particular products, it is important to keep in mind that the product formulations change frequently. In CU’s June 1998 ratings, for example, 11 products were listed as reformulated or discontinued since the testing began. That represents about a 30% turnover rate in two years. If such a turnover rate continues to the present time, one can expect that perhaps one-third of the products reported in the most recent tests may have changed by now, and many products evaluated in the earliest reports are unlikely to be available in the formula tested.

CU's basic conclusions about the durability of deck treatments have not changed since shortly after the tests began and in general terms are consistent with those of other studies. Essentially, the more opaque the finish, the higher it scored. Clear finishes scored worst, while opaque or semitransparent products scored best. Toned or tinted products received intermediate scores. Interestingly, solvent-based products reportedly did better initially, but after two years had lost their advantage over water-based products. If the intention is to recoat after one to two years, then apparently solvent-based products would have an advantage.

After the first two years, the products listed in Table 4 rated good (G), very good (VG), or excellent (E) in overall score (CU 1998).

Table 6. Ratings of exterior wood finishes after two years (CU 1998)

Product name	type	base	score
Akzo Nobel Sikkens Cetol DEK	toned	solvent	E
Cabot Decking Stain	semi-trans	solvent	E
Cabot PTW Stain	semi-trans	solvent	VG/E
Glidden Endurance Deck &Siding Oil Stain	semi-trans	solvent	VG
Olympic Water Repellent Deck Stain	semi-trans	solvent	VG
Wolman Deck Stain with Water Repellent	semi-trans	water	G/VG
Behr Plus 10 Deck & Siding Stain	semi-trans	water	G
Olympic Natural Look Protector Plus	toned	solvent	G
Tru-Test Woodsman Deck Stain	semi-trans	solvent	G
Pratt & Lambert Stainshield Oil Deck Stain	semi-trans	solvent	G
Wolman Rain Coat with Natural Wood Toner	semi-trans	water	G
Benjamin Moore Moorwood Clear Finish	toned	solvent	G

In 2002, some of the products above were rated again after a longer exposure period.

Table 7. Results of better scoring products in 3-4 year exposure tests (CU 2002)

Product name	type	results
Cabot Decking Stain	op	lasted 4 yrs, needs reapplication
Glidden Endurance Deck & Siding	op	lasted 4 yrs, needs reapplication
Wolman Deck Stain w Water Repellent	semi	lasted 3 yrs, needs reapplication
Olympic Water Repellent Deck Stain	semi	lasted 3 yrs, needs reapplication
Olympic Natural Look Protector Plus	toned	lasted 3 yrs, needs reapplication
True Value Woodsman Deck Stain	semi	lasted 3 yrs, needs reapplication
Pratt & Lambert Stainshield Oil Deck Stain	semi	lasted 3 yrs, needs reapplication
Wolman rain Coat with Natural Wood Toner	semi	lasted 3 yrs, needs reapplication

Key: op=opaque; semi=semi-transparent

In addition, some new products added to the test were doing reasonably well:

Table 8. Additional results for products added to tests (CU 2002)

Product name	type	results
Benjamin Moore Moorwood Alkyd Transparent Deck and Siding Stain	toned	lasted 3 yrs, needs reapplication
Rhinoguard Wood Defense	toned	lasted 3 yrs, needs reapplication
True Value Woodsman UV Wood Sealer & Protector	toned	lasted 3 yrs, needs reapplication
Akzo Nobel Sikkens Cetol SRD	toned	lasted 3 yrs, needs reapplication
Penofin Penetrating Oil Finish 350 VOC	toned	lasted 3 yrs, needs reapplication
Sherwin-Williams UV Sunblock Deck & Wood Seal	semi	lasted 3 yrs, needs reapplication
Sherwin Williams Clear Deck & Siding Wood Finish	toned	lasted 2 yrs, needs reapplication
Glidden Endurance Deck Sealer for Pressure Treated Wood	clear	lasted 2 yrs, needs reapplication
Cabot Solid Color	op	holding up well after 1 year
Pittsburgh Rez Solid Color	op	holding up well after 1 year
Wolman Extreme	semi	holding up well after 1 year

The Connecticut Department of Public Health mentions that both these tests and others from the Connecticut Agricultural Experiment Station suggest that oil-based stains can be effective sealants (CDPH 2001). However, the tables above do also list some water-based products that held up well. CU also has published extensive tests of paints, but those are not reviewed here since most experts do not recommend paints for decking or other heavy use applications. Paints are suitable for some less demanding applications, but there seems to be less difference in performance between different paints than other wood finishes because paints are all opaque coatings.

B. Arsenic Containment Studies

The studies reviewed in this section actually measured the ability of coatings to block the release of arsenic, but the methodologies differ widely. Most used wipe sampling to measure dislodgeable arsenic on the wood surface before and after coating. One compared leaching of arsenic and other CCA components from finished and unfinished wood. Most of the studies have limitations for our purposes, but taken together they show that for some period of time any coating is better than none. They do not shed much light on which kinds of products are likely to be most effective and how long they might last.

California Department of Health Services

The CDHS report to the legislature issued in February 1987 reported measurements of arsenic surface residue reductions after surface treatments at two locations. Monterey pier samples which initially showed a mean surface arsenic level of 1131 $\mu g/100cm^2$ measured less than 10 $\mu g/100cm^2$ immediately after sealing with polyurethane. Two years later, arsenic levels increased to 12-65 $\mu g/100cm^2$. At Cedar Rose Park in Berkeley, CDHS reported that surface arsenic residues collected on gauze-wipe samples decreased from 31-314 $\mu g/100cm^2$ to 1-13 $\mu g/100cm^2$ after coating with an oil-based stain. These results apparently led to the CDHS recommendation that playground equipment be sealed every two years. No comparative testing of different kinds of sealants was reported, nor did the recommendation specify a preferred sealant beyond “nontoxic and nonslippery.”

Table 9. Dislodgeable arsenic levels before and after sealing (CDHS 1987)

Site	before sealing (µg/100cm2)	immediately after (µg/100cm2)	two years after (µg/100cm2)	treatment
Monterey pier	1131	<10	12-65	polyurethane
Cedar Rose Park	31-314	1-13	ND	oil-based stain

Connecticut Agricultural Experiment Station

Stilwell (1998) reported that four different coatings applied to CCA-treated wood coupons significantly reduced the amount of arsenic that could be removed by wipe samples. The reductions were more than 95% for polyurethane deck and porch enamel, a latex acrylic solid color stain, and a spar varnish. A reduction of 80-97% (average 90%) was found for a semi-transparent oil stain containing alkyd resins. The finishes were not subjected to any kind of weathering, and the author directs readers to the Consumer Reports tests and also suggests consulting paint dealers for advice on which coatings are most appropriate in high foot traffic areas.

USDA Forest Service

Lebow et al. (2003) studied the effects of simulated rainfall and ultraviolet (UV) radiation on leaching of arsenic and other preservative elements from CCA-treated wood. This study is particularly interesting because it attempts to understand the mechanism whereby water repellents act to reduce leaching. The researchers compared the effectiveness of three different concentrations of water repellents to each other and to unfinished wood. The tests simulated one-year's worth of weathering and also investigated separately the effects of the water and the UV radiation. The water repellent coatings were not commercial products but rather mixtures of different amounts of wax with mineral spirits and urethane varnish, all formulated by the research team.

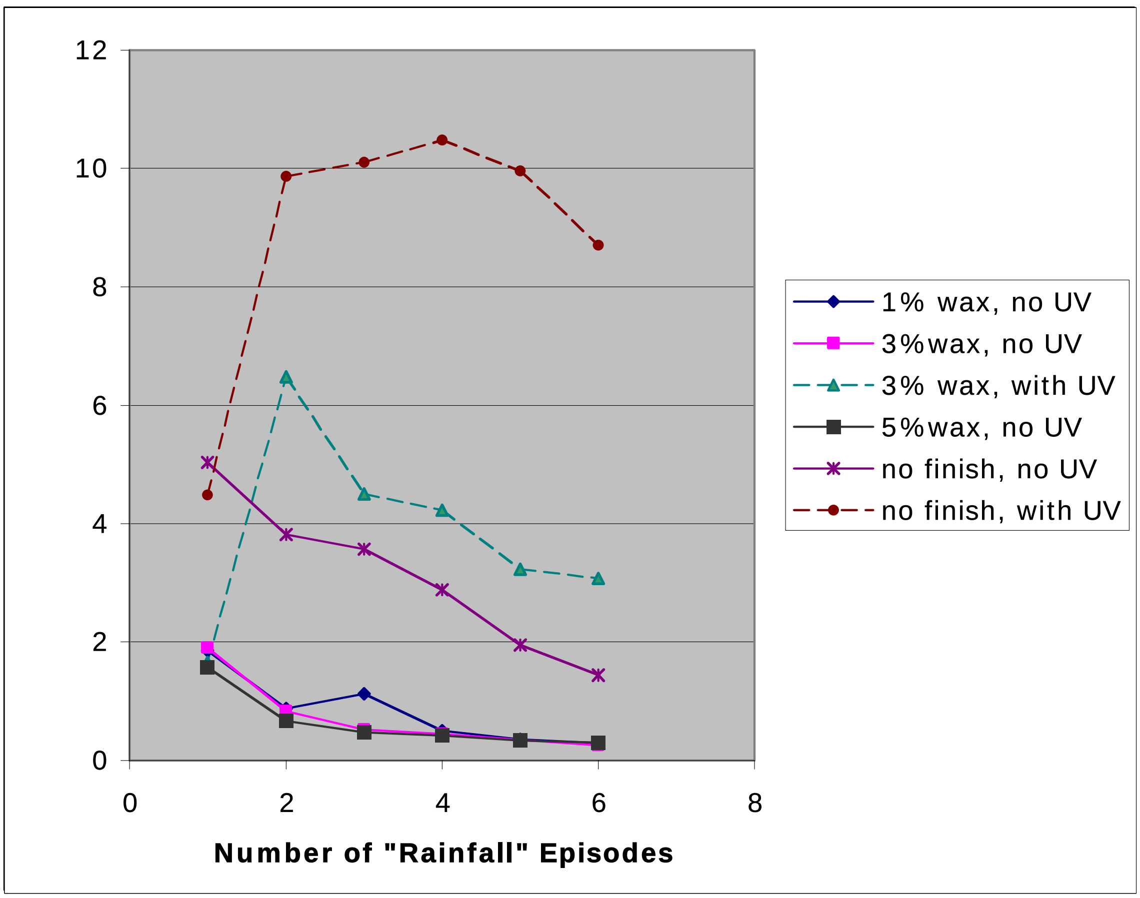
Two types of experiments were conducted. In the first, wood samples treated with 1%, 3%, and 5% water repellent formulations were compared to wood with no water repellent. The samples were exposed to a sequence of six simulated rainfall episodes but no UV radiation. Leaching of arsenic, chromium, and copper was measured after each rainfall episode. In the second experiment, a sample treated with 3% water repellent and one untreated sample were exposed to six rainfall episodes, each followed by a UV exposure. The results for the arsenic leaching are shown in Table 10 and Figure 1.

Table 10. Average arsenic leached after each rainfall episode (Lebow et al. 2003) (units are milligrams of arsenic)

	---------number of rainfall episodes---------						
Test description	1	2	3	4	5	6	total
1% wax, no UV	1.85	0.88	1.13	0.50	0.36	0.29	5.00
3% wax, no UV	1.90	0.83	0.52	0.45	0.35	0.26	4.32
3% wax, with UV	1.65	6.48	4.5	4.23	3.23	3.07	23.17
5% wax, no UV	1.57	0.67	0.48	0.42	0.34	0.30	3.79
no finish, no UV	5.03	3.81	3.57	2.88	1.94	1.44	18.67
no finish, with UV	4.48	9.86	10.10	10.48	9.96	8.71	53.58

The total leaching of arsenic from the samples treated with water repellent was several times less than from the unfinished wood in both experiments, but there was little difference in performance between the 1%, 3%, and 5% wax formulations; all three finishes protected equally well over the course of these tests. In the second experiment, the finished wood again performed better than the unfinished wood, but the leaching in both cases increased markedly after the first UV exposure. The arsenic leaching from the 3% sample then began to decline, while leaching from the unfinished sample continued to increase slightly before beginning to decline. A decline in leaching of arsenic-treated wood over time is normal and has been seen in many other studies.

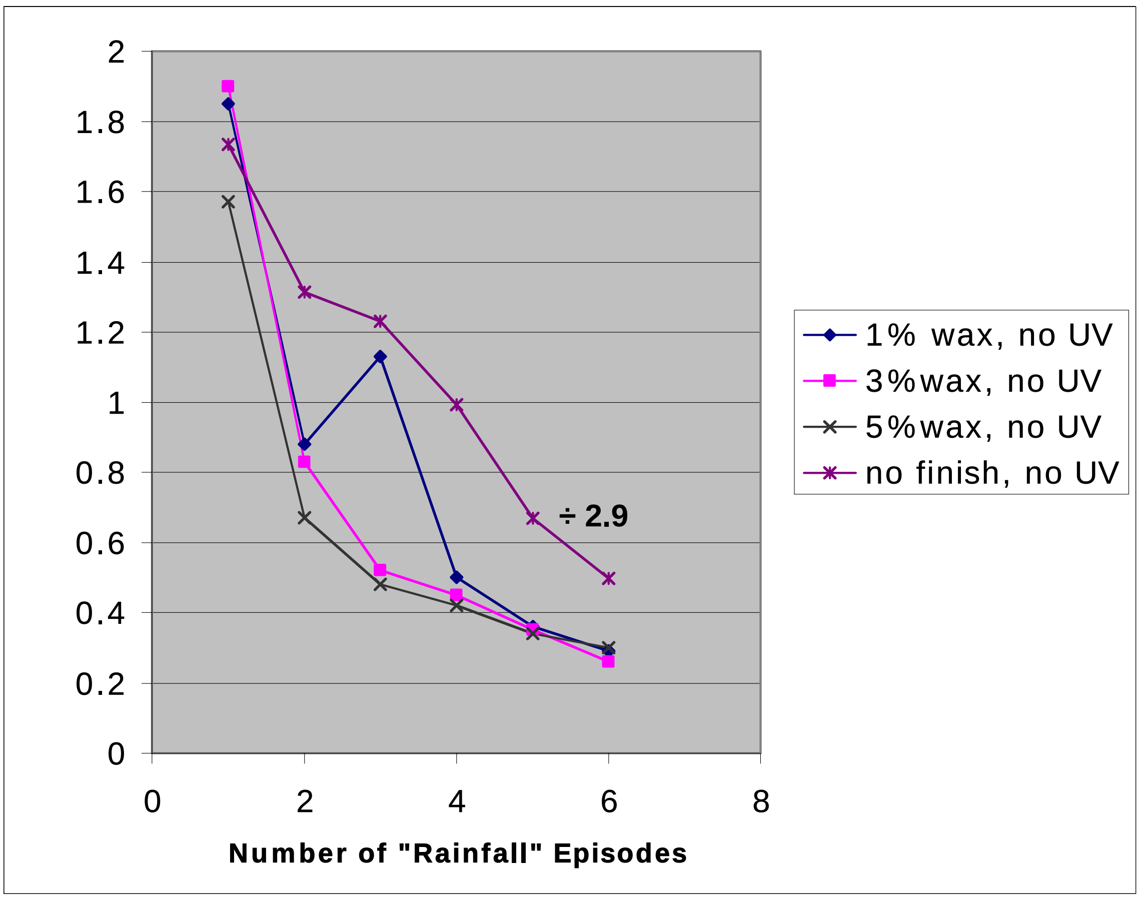
Figure 1. Average Arsenic Leached After Each Rainfall Episode (Lebow et al. 2003)



It is striking that arsenic leaching more than doubled after one UV exposure, whether the wood had the water repellent coating or not. Since the coated sample still leached much less than the uncoated one, the results don't seem to indicate that the coating has failed but rather that the wood itself has been affected by the radiation so that it releases more arsenic. The water repellents are essentially clear, so they don't shield the wood from UV radiation as much as they do from the water. The authors speculate that the increase may be the combined result of surface checking and loss of wood fiber, which they measured with pull-off tests using cellophane tape. Why the leaching doesn't continue to increase by similar amounts after successive UV exposures is not clear.
The rainfall-only experiment produced a very different result. Here the leaching generally

declined over time, and the time dependence of leaching from finished versus unfinished samples is very similar. Figure 2 compares the results for the three different water repellent coatings with that for the unfinished wood, the latter data divided by 2.9 in order to roughly superimpose the curves. When plotted against rainfall event number (equivalent to exposure time), all the finished samples behaved similarly except for a spike in leaching at rainfall episode 3 for the 1% water repellent. (This spike does not occur in the data for either the chromium or the copper leaching, so perhaps it is an anomaly.) A slight hump does appear at the same point in the data for the unfinished wood. Aside from this one feature, the curves are remarkably similar, although the three finished samples change more from episode 1 to episode 2 than the unfinished sample. Perhaps a slight arsenic contamination is left on top of the water repellent after the application process and this is washed away by the early rainfall episodes.

Figure 2. Overlay of data for rainfall only experiments (Lebow et al. 2003) (Data for "no finish, no UV" divided by 2.9)



The reductions in arsenic leaching reported in this study (two- to four-fold) are much less than the decrease in removable arsenic reported by Stilwell (ten- to twenty-fold) and by some other researchers. The authors point out that because of the small wood samples used in the study, the results overemphasize the importance of end grain, which has higher leaching than the sides of the decking. (The ends were not sealed separately to minimize their effect but were treated with the water repellent test material, since the entire sample was dipped.) The authors also speculate that the pigments present in some wood finishes would be expected to greatly decrease the weathering rate and may thereby minimize the release of wood preservative elements.

This study demonstrates that a water repellent coating can at least temporarily reduce arsenic leaching by several times, roughly a factor of two to four. Similar results were found for leaching of copper and chromium but the finish had the greatest effect on arsenic leaching. The rainfall tests apparently did not subject the surface to enough weathering to compromise the water repellent coating. The sudden increase in leaching after only a single UV exposure is striking and may show that light penetrating the coating can damage the wood and increase leaching without compromising the finish itself. This study did not address the issue of arsenic dislodged by wiping or contacting the surface. It is not known whether the same effects would be seen on the results of wipe sampling.

Environmental Working Group

In 2002, the non-profit Environmental Working Group (EWG) issued a report on the results of a field sampling program conducted jointly with the University of North Carolina-Asheville's Environmental Quality Institute (EQI). In this program, volunteers from around the country purchased sampling test kits with instructions over the Internet from EWG's website and took wipe samples from pressure-treated wood. The sampling method for arsenic wipes "was modified from standard lead dust wipe methods (e.g., American Society for Testing Materials method E1728) that are most commonly used to sample lead dust on windowsills." (EWG 2002) Samples were analyzed by the EQI laboratory according to Standard Method 3113B. In all, 300 wipe tests from 263 decks, playsets, picnic tables, and sandboxes across 45 states were compiled. EWG concluded that dislodgeable arsenic levels remained roughly constant over the full 20-year useful life of the wood. They also found that wood sealed more than six months ago was statistically indistinguishable from wood that had never been sealed. "A standard statistical test called the Mann-Whitney non-parametric test shows that the 103 structures sealed more than six months ago are statistically indistinguishable from the 112 wood structures in our program that, according to information submitted by the testers, had never been treated or sealed, at a 95 percent confidence level. The fifth highest arsenic level of the 300 available tests was found on a backyard playset in Livermore, California sealed just one year ago." In this report, EWG recommended sealing treated wood at least every six months.

Several aspects of the EWG testing program make its interpretation difficult for our purposes:

1. Samples were taken by many individuals and sampling technique was not monitored;
2. Age of wood and sealants were reported by owners, not measured; identity of sealants was not reported;
3. Time dependence of arsenic levels was inferred from measurements on different structures rather than from sequential measurements on the same samples; initial arsenic content of wood was not measured;

4. Environmental and use conditions would have varied widely between sampling locations, so that data points representing different exposure times were not measured under identical conditions.

The fact that no significant differences were found in dislodgeable arsenic levels as a function of wood age or whether the wood had been sealed six months earlier could be due in part to variations in the data quality due to different individual wiping techniques, uncertainties in the age of the wood or sealant, and different environmental conditions. In other words, these tests might not be as sensitive as tests conducted under more controlled conditions and specifically designed to measure the effects of weathering on arsenic transport. Still, the results are of concern because they raise reasonable doubts about the longevity of sealants in general. More highly controlled experiments may provide the details necessary to more accurately measure the useful life of particular types of sealants for arsenic containment.

U.S. EPA

The U.S. EPA is currently studying the ability of commercial products to reduce the amount of dislodgeable CCA components on the surface of treated wood. Results are not expected until the end of 2004 or perhaps early 2005. There are no preliminary results available yet, but some aspects of the study design are worth reporting here because they can tell us what to expect in terms of the number and types of products being studied, the exposures to which the wood will be exposed, and the analysis that will be done.

The study design document currently available (USEPA 2003b) makes it clear that this preliminary study will not provide all of the specific information that San Francisco would like to have. Specifically, the design document indicates that:

1. Twelve products are being studied, out of a candidate list of 125; they will include representatives of different product types, including products marketed for arsenic encapsulation;
2. Results will be reported by product type only and brand names will not be revealed;
3. Products will be tested on specially constructed decking made from reused CCA-treated wood;
4. Samples will be exposed to normal weathering but not foot traffic or other abrasive wear; and
5. Wipe sampling will be used to determine the amount of dislodgeable CCA components on the surface as a function of time.

Since this study will not explore the effects of foot traffic or other human wear on finish durability, we cannot expect results representative of heavily used decks, railings, and play structures such as those that might be found in parks or other public facilities. This is recognized as a shortcoming in the study design document and is suggested as a future research need. The study will also be very similar to others reviewed here in that a limited number of products will be studied and product names will not be reported. A more complete study of available coatings and recommended application techniques is called for in the EPA study design but will undoubtedly require many years of work. Two aspects of the study will make it more useful than previous work: it will tell us how much and for how long the products reduce the potential arsenic exposure from skin contact, and it will study the effectiveness of the products on used, CCA-treated wood.

The most we can expect, then, seems to be:
1. a better understanding of the inherent arsenic protection offered by carefully selected types of products (but not specific product names) likely to be used by consumers;
2. general guidance for how often these products should be reapplied to provide reasonable protection (but probably with the caveat that individual cases will vary);
3. an answer to the question of whether film-forming coatings are appropriate for the purpose of minimizing arsenic exposure from treated wood.

Analysis and Findings

Specific product recommendations can only be fairly speculative at this point due to the paucity of available data on either dislodgeable arsenic residues or arsenic leached from treated wood coated with finishes, coupled with the fact that most studies do not identify products by name. The study of Lebow et al. (2003) indicates that UV radiation exposure greatly increases arsenic leaching, both from unfinished CCA-treated wood and that coated with a water repellent, presumably by causing surface checks and/or damaging wood surface fibers. This finding suggests that the more numerous finish weathering studies (which do not measure arsenic but evaluate the appearance of the wood, e.g. roughness, checking, and warping) may also predict the leaching of arsenic, but we don't know if such studies also predict arsenic that can be removed by wiping. These weathering studies are consistent in finding clear surface treatments to be the least durable, semi-transparent finishes are moderately durable, and opaque finishes are most durable.

While there are many clear finishes labeled for exterior use, the general consensus of academic studies seems to be that they are the least durable finishes. This opinion was echoed by both industry (PQI 2004) and contractor sources (Flexner 1999). Varnishes are prone to cracking and flaking over time, mostly due to the effects of sunlight. UV radiation both damages the surface of the wood causing the coating to detach and at the same time damages the coating itself. Water repellents are also ineffective because even if they still cause water to bead on the surface, they allow UV radiation to penetrate and damage the wood underneath. Clear finishes containing adequate amounts of UV absorbers can work adequately if they are applied in multiple coats and are restored often, but the amount of labor required to keep clear finishes in good condition argues against their use for temporary arsenic sealing work.

Concerns have been raised by numerous authors about the failure mode of opaque, film-forming finishes, but Feist and Ross showed that acrylic latex paint can hold up quite well on treated wood. They are less appropriate for deck use, as indicated by the Forest Products Laboratory recommendations (FPL 1999) and Ross et al. (1992). The Consumers Union tests are the only name-brand product tests we found. They identified several opaque deck stains that seem to hold up to natural weathering for as much as four years.

The semi-transparent stains seem to be the best candidates for most surfaces, especially those receiving moderate to high wear or oriented horizontally. The experiments of Feist and Ross suggest that these products can last for between one and two years. Consumers Union also found a number of products in this category that lasted several years. There seems to be consensus that clear sealers, varnishes, and water repellents have very poor durability in exterior exposures.

The range of re-treatment intervals we identified ran from 6 months (EWG) to 2 years (CDHS), although some products may hold up longer then that in some applications. The Environmental Working Group's field study sets very low expectations for the durability of deck treatments, but since the study was not designed to measure performance of coatings over time its results may be less useful for our purposes than other studies. It is clear that routine on-site inspections will be needed to monitor the performance of arsenic sealants in different exposure conditions and determine when re-coating is necessary.

Because the EPA study due for release in early 2005 will not give guidance on specific products by name, it appears that Consumers Union will continue to be the only source of product-specific information for the foreseeable future.

Surface Preparation and Technique

Even the most effective sealants will not perform well if they are not applied under the correct conditions. Surface preparation, method of application, and number of coats applied all will affect the durability and hence the effectiveness of the sealant. Some preparation techniques such as sanding and pressure washing should be avoided because they will disturb and distribute the toxic constituents of CCA-treated wood.

Ross et al. (1992) provide an overview of the surface preparation, product choice, and application methods for wood coatings most likely to give satisfactory performance on CCA-treated wood. Most of what follows is taken from that source. They point out that while finishes applied to CCA-treated wood are likely to last longer than if applied to untreated wood, some characteristics of CCA-treated wood pose challenges. The pressure-treatment process and subsequent drying often cause the wood to have more cracks and splinters than untreated wood. Also, because the wood is already heavily saturated with preservatives, if it is excessively damp as well, the finish may not penetrate well and eventually will not hold up. Finally, if appearance is a concern, the greenish color of much treated wood will bleed or show through light-colored paints or stains.

Surface Preparation
Surfaces be clean, dry, and free of mildew before application of any finish. Lumber that has been very wet should be allowed to air dry for two to three weeks in dry weather before coating. Some coatings manufacturers recommend preparing weathered wood by applying bleach, cleansers, TSP, or special deck-brightening products. Although these techniques are endorsed by the Ross et al., many sources have cautioned that the use of acid-based deck cleaners can release more arsenic from the wood, and some oxidizing agents can convert chromium III in CCA to the much more toxic and mobile chromium VI (Townsend et al. 2001a). After cleaning, the surface should be rinsed and allowed to dry thoroughly.

Application Methods
Most coatings for CCA-treated wood can be applied by brush, spray, roller, or pad. (Note: some special-purpose coatings may have special application requirements.) Spray application is quickest for large surfaces and offers the additional advantage that arsenic is not moved around or transferred to the brush or supply of coating. Rollers can be used, especially on vertical surfaces. Brushing is easiest for detail work.

There may be a temptation to over-apply coatings in order to provide a thick barrier against arsenic. This temptation should be avoided, especially on penetrating finishes, because if the product is applied more heavily than the manufacturer intends, it may form a thick film that will eventually peel or crack. Further, the product may not dry properly, resulting in a sticky or slippery finish. If a thicker barrier is desired, it should be built up with multiple thin coats according to manufacturer recommendations.

While UV absorbers in exterior polyurethane varnishes extend the coatings' life, they are used up over time and lose their protection. According to the website for the Paint Quality Institute, a coatings industry source, it is wise to recommend multiple coats of any exterior clear coating to give added film thickness. This will render the finish more durable and provide greater protection for the wood substrate (PQI 2004).

Observe the usual weather requirements for painting. Solvent-borne coatings can usually be applied in a temperature range of 40-90 degrees F. Water-based products should not be applied if the temperature will go below 50 degrees during the 24 hours after application. In addition, deck coatings should not be applied if precipitation is expected within 12-24 hours after application.

Miminizing Arsenic Contamination
Brush application will pick up some arsenic from the surface and distribute it to other parts of the structure as well as contaminate the container (USEPA 2003). Roller application is less likely to move the contaminants because there is less abrasion during the application process. Spray application is least likely to move contaminants. For this reason, spray or roller application is preferred when practical. If using a brush, work from small supplies of material rather than the original container. Do not pour used material

back into original container. If a second coat is applied, use a clean applicator and a clean supply of coating. Brushes or rollers used for arsenic sealing should not be used for other purposes.

Recommendations

1. Whenever possible, CCA-treated materials that will receive significant skin contact should be removed immediately rather than coated with a finish. Priority should go to those items used by children and where hand contact is most likely. Coating to encapsulate arsenic is an imperfect solution that requires maintenance and inspection to guarantee acceptable results.
2. Clear sealers, water repellents, and varnishes do not appear to provide much durability, and should generally be avoided as single-treatment finishes.
3. Acrylic, latex paint should be considered for fences, tables, and other furniture that receive moderate to low wear or are vertically oriented. They may also be appropriate for hand rails. Inspection should look for evidence of blistering, peeling, or cracking.
4. Semi-transparent deck stains should be used for deck surfaces and play structures.
5. All coated items should receive inspections at a six-month interval to assess the need for retreatment. Horizontal surfaces can be expected to need retreatment most frequently, tilted surfaces next, and vertical surfaces least frequently.
6. If possible, wipe testing should be done when items are inspected to provide additional basis for decisionmaking.
7. The *Consumer Reports* studies appear to be the only ones that can give guidance on specific products within the recommended categories. These ratings should be used to identify the most promising products, and if desired the City’s wipe testing could be used to compare the performance of the best candidate products.
8. Surfaces should not be sanded or pressure washed before coating. Surface preparation should focus on cleaning, rinsing, and drying. Avoid acid-based or highly oxidizing cleaners or deck brighteners.
9. Follow manufacturers’ instructions for best results. Surfaces should be clean, dry, and free of mildew. Lumber that has been very wet should be allowed to air dry for two to three weeks in dry weather before coating. Avoid finishing when rain is expected within 24 hours. If water-based products are used, do not apply if temperature will drop below 50 degrees during the 24 hours following application. Do not over-apply product; follow label directions.
10. To avoid dispersing arsenic contamination, minimize brush applications, work from small containers, and use up excess rather than pouring back into original can. Brushes and rollers used for arsenic protection should not be used for other purposes.

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