

# Guide for Selecting Treated Wood



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**For**  
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## List of Abbreviations and Acronyms

AAC	Alkyl ammonium compound
ACA	Ammoniacal copper arsenate
ACC	Acid copper chromate
ACGIH	American Conference of Governmental Industrial Hygienists
ACQ	Ammoniacal (or amine) copper quat (see below) ACQ-B: Ammoniacal copper quat ACQ-D: Amine copper quat
ACZA	Ammoniacal copper zinc arsenate
AWPA	American Wood Preservers' Association
BaP	Benzo[a]pyrene
CA-B	Copper azole
CBA	Copper boron azole
CC	Copper citrate (or ammoniacal copper citrate)
CCA	Chromated copper arsenate
CDDC	Copper bis(dimethyldithiocarbamate)
CuN	Copper naphthenate
Cu8	Copper-8-quinolinolate
DOT	Disodium octaborate tetrahydrate
IARC	International Agency for Research on Cancer
IPBC	3-iodo-2-propynyl butyl carbamate
LCA	Life cycle analysis
LD50	Lethal dose fifty percent
NTP	National Toxicology Program
NIOSH	National Institute for Occupational Safety and Health
OSHA	Occupational Safety and Health Administration
PAH	Polycyclic aromatic hydrocarbon
PCF	Pounds per cubic foot
PCP	Pentachlorophenol
PEL	Permissible exposure limit
RfD	Reference dose
TCDD	Tetrochlorodibenzodioxin
TEQ	Toxic equivalence
ZnN	Zinc naphthenate

# Guidelines for Selecting Wood Preservatives

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## Introduction

Wood has been the material of choice for many applications such as building construction, decking, outdoor furniture, playground equipment, bulkheads, piers, pilings, utility poles, and other uses. Despite its obvious advantages, including strength, appearance, ease of fabrication, availability, renewability, and cost, in certain situations, particularly outdoors, wood is subject to attack by fungi, insects, and marine organisms. A wide range of wood preservative treatments have been developed to protect wood and prolong its useful life. The U.S. EPA estimates that nearly 700 million pounds of wood preservatives are used annually in the United States (USEPA 1999a).

Most wood preservatives contain toxic or otherwise hazardous chemicals that can cause adverse impacts to human health or to the environment. For example, chemicals applied via “pressure treatment” penetrate some distance into the wood and may be fixed in place by chemical reactions or other mechanisms. Although this fixation process reduces the amount of chemicals that can be rubbed off or leached from the wood, it does not entirely prevent either of these losses from occurring. There is now a considerable body of scientific literature documenting the dislodging of surface residues and the leaching of preservative chemicals from treated wood of various types during its useful life. In addition, preservative chemicals can be released into the environment during processing and storage of treated wood, during sawing or other fabrication, and during or after disposal. The adverse environmental impacts from treated wood can be reduced by selecting the most appropriate material for the application (which may not be treated wood at all), mitigating impacts on site, and by proper disposal of construction materials and ultimately the structure itself.

The San Francisco Department of the Environment contracted with the Washington Toxics Coalition to investigate factors or criteria that might be used to select preferred wood preservative treatments or alternative construction materials for city projects. This project is a follow-up to a previous assessment of the City’s pesticide use in 1999 (Dickey 1999). This document is aimed at providing guidance for selecting the materials that are least likely to cause harm. It should be understood at the outset that this study is neither a risk assessment nor a life-cycle analysis. In a typical risk assessment, the probability or likelihood of harm is estimated by considering the hazards posed by the chemicals, the expected human or environmental exposure levels, and the susceptibility or sensitivity of the organisms under consideration. Although evaluating exposure levels can yield useful information, risk assessment is often limited by insufficient toxicology data on the individual chemicals, incomplete knowledge of likely exposure conditions, and no consideration of the effects of simultaneous exposures to mixtures of chemicals. These uncertainties and data gaps limit the ability of a risk assessment to guarantee that a particular chemical or product is safe in the absolute sense. Many risk assessments have already been performed on the chemicals that will be discussed here. Even when the

scope of risk assessments is narrowed to a single preservative treatment and a single exposure pathway, the results can vary by orders of magnitude, leading to contradictory interpretations. A life-cycle analysis (LCA) catalogues and evaluates environmental impacts during all aspects of a product's life, from extraction of raw materials to disposal and beyond. LCAs are expensive and sometimes difficult to interpret when impacts of different products or processes are qualitatively very different. An LCA is far beyond the scope of this project.

This analysis will take a different approach, which could be called an alternatives hazard assessment. Information was collected on a number of parameters for each chemical. The data include toxicity values, presence of carcinogens and other ingredients of concern, relative leaching rates, and regulatory standards. These data were then combined with information on the existing industry standards, EPA recommendations or restrictions, and California restrictions. Using criteria developed in cooperation with the Department of the Environment, an acceptable list of wood preservatives was identified for each proposed use.

## Profiles of Wood Treatments

Wood preservatives can generally be categorized in two ways: pressure-treated versus surface applied and oil-borne versus water-borne. A few chemicals can be applied via either method or via either carrier, but these are relatively rare. Table 1 lists the known ingredients in all of the wood preservatives considered here. For the pressure-treated materials, the source of information is the American Wood Preservers' Association Book of Standards (AWPA 2001a). For surface-applied preservatives, information was taken from material safety data sheets and product labels for representative products.

**Table 1. Typical Constituents of Wood Preservatives**

Preservative Name	Constituents	Percent		
Creosote	coal tar or distillate	50%		
	petroleum oil	50%		
Pentachlorophenol (PCP)	pentachlorophenol	>95%		
Acid Copper Chromate (ACC)	copper as CuO	31.80%		
	hexavalent chromium, as CrO <sub>3</sub>	68.20%		
Ammoniacal Copper Arsenate (ACA)	copper, as CuO	49.80%		
	arsenic, as As <sub>2</sub> O <sub>5</sub>	50.20%		
Ammoniacal Copper Zinc Arsenate (ACZA)	copper, as CuO	50%		
	zinc, as ZnO	25%		
	arsenic, as As <sub>2</sub> O <sub>5</sub>	25%		
Borates	sodium octaborate, sodium tetraborate, sodium pentaborate, or boric acid			
Chromated Copper Arsenate (CCA)		CCA-A	CCA-B	CCA-C
	hexavalent chromium, as CrO <sub>3</sub>	65.50%	35.30%	47.50%
	copper, as CuO	18.10%	19.60%	18.50%
	arsenic, as As <sub>2</sub> O <sub>5</sub>	16.40%	45.10%	34.00%

Preservative Name	Constituents	Percent		
Alkyl Ammonium Compound (AAC, DDAC)	didecyldimethylammonium chlorides	90% min		
	dialkyldimethylammonium chloride	10% max		
Ammoniacal Copper Quat (ACQ)		ACQ-B	ACQ-D	
	copper, as CuO	66.70%	66.70%	
	didecyldimethylammonium chlorides	33.30%	33.30%	
Ammoniacal Copper Citrate (CC)	copper, as CuO	62.30%		
	citric acid	37.70%		
Copper Azole (CBA-A)	copper, as CuO	49%		
	boron, as boric acid (H <sub>3</sub> BO <sub>3</sub> )	49%		
	tebuconazole	2%		
Copper bis(dimethylthiocarbamate) (CDDC)	copper, as CuO	17-29% <sup>1</sup>		
	SDDC	71-83%		
	sodium dimethylthiocarbamate			
Copper Naphthenate (CuN)	copper	6-8% concentrate	0.5-2% treating solution	
	naphthenic acid			
	petroleum oil			
Copper-8-Quinolinolate (Cu8)	copper-8-quinolinolate	10% min		
	nickel-2-ethylhexoate	10% min		
	hydrocarbon solvents	80% max		
4,5-dichloro-2-n-octyl-4-isothiazolin--3-one	4,5-dichloro-2-n-octyl-4-isothiazolin--3-one	98%		
	related non-volatile impurities	<2%		
	hydrocarbon solvents			
3-iodo-2-propynyl butyl carbamate (IPBC)	IPBC	97%		
	iodine as element	53.40%		
Zinc Naphthenate (ZnN)	zinc	1.8-8%		
	naphthenic acid			
	petroleum oil			
Notes:				
1 Sequential treatment resulting in SDDC:Copper ratio of 2.5 to 5				

Table 2 shows how the preservatives considered are classified as to treatment method and type of solvent.

**Table 2. Categorization of Wood Preservatives**

Pressure-Treated		Surface Applied	
Oil-borne	Water-borne	Oil-borne	Water-borne
Creosote	AAC CDDC	CuN	borates
Pentachlorophenol	ACC CBA	ZnN	
CuN	ACA borates	IPBC	
Cu8	ACZA		
AAC	ACQ		
IPBC	CCA		
	CC		

The regulatory and political situation related to wood preservatives is highly volatile at the present time. Amidst a rising tide of concern about the arsenical preservatives,

especially CCA, and while in the process of conducting a new risk assessment for the material, EPA announced on February 12, 2002 a “voluntary decision by industry to move consumer use of treated lumber products away from a variety of pressure-treated wood that contains arsenic by December 31, 2003, in favor of new alternative wood preservatives.” (USEPA 2002) This decision affects virtually all (but only) residential uses of wood treated with CCA, including wood used in play-structures, decks, picnic tables, landscaping timbers, residential fencing, patios and walkways/boardwalks. The decision may gradually affect non-residential uses as well through increased availability of alternative products. PCP and creosote are also being reviewed by EPA. Beyond Pesticides, formerly the National Coalition Against the Misuse of Pesticides, and several other groups are pursuing legal action against EPA to stop all uses of penta, creosote, and CCA (Feldman 2002). Decisions may occur at any time that would alter the allowed uses for these materials. Given this background, the available preservative treatments could change rather rapidly from those listed in this report.

## **Human Health Concerns**

### **Toxicity**

Table 3 lists acute and chronic toxicity values for the major ingredients in wood preservatives. For all three measures described below, lower values indicate higher toxicity.

- The LD50 (lethal dose fifty percent) is the lethal dose by oral exposure, a measure of short-term toxicity, usually determined in rodents.
- The chronic reference dose (RfD) is the supposedly safe daily dose (for non-carcinogenic effects) by oral ingestion.
- The Permissible Exposure Limit (PEL) is the maximum safe air concentration in occupational settings, averaged over a 40 hour week, an indicator of inhalation toxicity. Numbers quoted represent the range spanned by standards from NIOSH, OSHA and/or ACGIH.

By all three measures, arsenic is by far the most toxic of the preservative components from a human health standpoint. It should be noted that copper, zinc, and chromium III are all essential human nutrients in appropriate amounts. (For metal-based preservatives, toxicity data are given for individual metals rather than for the mixture present in the treating solution because human and environmental exposure to the components will not necessarily occur in proportion to their presence in the treating solution or in the wood.)

Many of the preservative components are carcinogenic, also indicated in the table. Pentachlorophenol (PCP) is considered a probable human carcinogen by EPA (USEPA 2001), a possible human carcinogen by IARC (IARC 2001), and is listed as carcinogenic by the State of California (California 1999). The toxicology of PCP poses particular challenges because the compound is routinely contaminated with a host of other highly toxic compounds, including hexachlorobenzene (HCB), polychlorinated dibenzo dioxins (CDD) and polychlorinated dibenzofurans (CDF) (ATSDR 2001; USEPA 1999b). These contaminants may be responsible for toxic effects seen in some studies. For example,

**Table 3. Toxicity Information for Major Wood Preservative Constituents**

Substance	LD50 <sup>1</sup> (mg/kg)	RfD <sup>2</sup> (mg/kg/d)	PEL <sup>3</sup> (mg/m3)	Carcinogenicity					Rep/Dev	
				EPA	NTP	IARC	CA	ACGIH	CA	
PCP	146-210	.03 .0045 <sup>4</sup>	0.5 (skin)	B2	--	2B	L	A3	--	
HCB	3500-4000	.0008	.025	B2	R	2B	L	A3	L	
PCDD	--	--	--	likely	--	--	L	--	--	
PCDF	--	--	--	likely	--	--	L	--	--	
TCDD*	0.045-0.114	†		A <sup>4</sup>	K	1	L	--	L	
Creosote	525-885	--	0.1-.2	B1	K	2A	L	A1 <sup>#</sup>		
Arsenic	15-175 <sup>7</sup>	.0003	0.002-.01	A**	K**	1**	L**	A1**	L**	
Copper	300 (sulfate)	--	1.0 (dust)	D	--		--	--	--	
Chromium (VI)	25 <sup>7</sup>	.003	0.001-.1	A (in) D (or)	K	1	L	A1	--	
Chromium (III)	183-200; 2365 <sup>7</sup>	1.5	0.5	--	--	3	--	A4	--	
Nickel <sup>##</sup>			.015-1	--	K <sup>##</sup>	1 <sup>##</sup>	L <sup>##</sup>	--	--	
Zinc	7950 (oxide)	.3	10 (dust)	D	--	--	--	--	--	
Cu naphthenate	>5000	--	--	--	--	--	--	--	--	
Zn naphthenate	4920	--	--	--	--	--	--	--	--	
Naphthenic acids	6420-7170	--	--	--	--	--	--	--	--	
Chlorothalonil	>5000	.015	--	likely	--	2B	L	--	--	
DDAC	84-360 <sup>6</sup>	--	--	--	--	--	--	--	--	
Borates/boric acid	466-900 B	--	1-5	E	--	--	--	--	--	
IPBC	1470	--	--	not likely	--	--	--	--	--	
Propiconazole	1517 (rat)	--	--	C	--	--	--	--	--	
Tebuconazole	3933->5000 <sup>5</sup>	--	--	C	--	--	--	--	--	
SDDC	--	--	--	--	--	--	--	--	L	

**Key:**

-- = no data found

Rep/Dev=reproductive or developmental toxicant

Carcinogenicity categories:

EPA (A=human; B=probable human; C=possible human, D=not classifiable; E=evidence noncarcinogenic)

NTP (K=known human; R=reasonably anticipated human)

IARC (1=human; 2A=probable human; 2B=possible human; 3=not classifiable; 4=probably noncarcinogenic)

CA (L=listed as a carcinogen)

ACGIH (A1=confirmed human; A2=suspected human; A3=animal carc.; A4=not classifiable; A5=not suspected)

References:

1 HSDB; 2 IRIS; 3 NIOSH, OSHA or ACGIH; 4 USEPA 1999b; 5 USEPA 1997a; 6 Henderson 1991; 7 USEPA 2001

Other notes:

\* 2,3,7,8-TCDD is not detected as a contaminant in PCP currently manufactured in the US, but it is found in older PCP, including treatments of wood still in service. However, other dioxin-like compounds such as PCDD and PCDF are expected to cause the same health effects, albeit at higher doses.

\*\* Inorganic arsenic compounds.

† EPA considers the RfD uninformative for risk management because on average the U.S. population is already exposed above this level.

# rating is for coal tar pitch volatiles, benzene soluble.

## Nickel-2-ethylhexoate is an ingredient in copper-8-quinolinolate formulations. Nickel compounds are listed as known carcinogens by both NTP and IARC.

EPA does not consider PCP a teratogen, yet recognizes that the contaminant hexachlorodioxin is a teratogen (and hexachlorobenzene is considered a developmental toxicant by the state of California). Thus, EPA feels that the label warnings concerning teratogenicity on pentachlorophenol formulations are still justified (USEPA 1999c).

Some of the contaminants in PCP are in themselves carcinogens. The most toxic dioxin, 2,3,7,8-TCDD is not detected in current formulations of PCP at a detection limit of 1 ppb, but it is important to distinguish between a compound not being detected as opposed to not being present at all. Other dioxin-like compounds detected in PCP are expected to cause the same health effects as TCDD, though at higher doses. The Toxic Equivalence (TEQ) of the mixture can be used to relate the total toxicity to that of TCDD.

Creosote contains hundreds of distinct chemical compounds, including a large number of polycyclic aromatic hydrocarbons (PAHs) that are individually classified as carcinogens, and creosote itself is considered a known human carcinogen by the National Toxicology Program (NTP 2001) and the American Conference of Governmental Industrial Hygienists (ACGIH 2001). Creosote is also listed as a carcinogen by the State of California. Hexavalent chromium is listed as a known human carcinogen by EPA, NTP, IARC, ACGIH, and the State of California.

Inorganic arsenic is also listed as a known human carcinogen by all of these same agencies. The National Academy of Sciences National Research Council has recently found greatly increased risks for a variety of cancers from arsenic levels in drinking water (NRC 2001), and EPA has reduced the drinking water standard fivefold from 50 to 10 micrograms per liter (EPA 2001).

Chromium VI (present in the treating solution of ACA, CCA, and ACZA) is a known human carcinogen. However, during the fixing period, chromium VI is largely transformed into chromium III, which is much less toxic and not listed as a carcinogen. Tebuconazole and propiconazole (possible azole components of CBA) are listed as possible human carcinogens by EPA. The AWPA Standards (AWPA 2001a) list nickel-2-ethylhexoate as a component of copper-8-quinolinolate wood preservatives. Nickel compounds are listed as known human carcinogens by a number of government agencies.

Several preservative components or contaminants are listed as reproductive or developmental toxicants by the state of California. These include SDDC, inorganic arsenic compounds, TCDD, and hexachlorobenzene.

Surprisingly little toxicology information is available for copper naphthenate or zinc naphthenate, despite the fact that these wood preservatives have been in use for many years. Although the acute oral toxicity of both is reported as low (~5000 mg/kg, see Table 3), similar to that of naphthenic acids, the composition of the naphthenic acids and petroleum solvents employed in formulations is variable. Naphthenic acids contain 5-25% impurities “whose composition is the same as the petroleum fraction from which the naphthenic acids are derived” (HSDB 2001). Solvents used to dilute copper naphthenate include fuel oils, mineral spirits, naphtha, and toluene (Grove 1987). In indoor uses, the solvents and impurities could be more relevant to toxic exposures than the pure



preservative itself, and neither of these products is currently labeled for indoor use. The amount of copper and zinc present in the naphthenate wood preservatives (e.g. 6-8% Cu in concentrate, 0.5-2% Cu in treating solution (Grove 1987), 1.8-8% Zn) is far lower than in the water-borne treatments containing these metals (typically 15-50% Cu, 25% Zn).

In summary, the information presented in Table 3 suggests that arsenic presents the greatest non-carcinogenic human health hazard of all the preservative components for which data could be found. In addition, as will be seen later, arsenic also can present significant cancer risk. PCP, creosote, and hexavalent chromium also pose major health concerns for both cancer and other health effects. Significant health risks may also be associated with the microcontaminants found in PCP, although a full assessment of those risks is not yet complete.

### **Routes of Exposure**

The probability of toxic effects actually occurring from any chemical depends on the amount of human exposure that occurs.

#### Skin Contact

Exposure to wood preservative components through skin contact can occur if the treated structure is located in proximity to human activities. The highest contact by the general public is likely to occur for playground equipment, tables and benches, decks and deck railings. Somewhat lower contact would be expected with fences and utility poles, but indirect contact with the chemicals may still occur if the chemicals leach into the soil and that soil is readily accessible. Utility workers can also have significant skin contact with utility poles. Least accessible to human skin contact (except during construction) would be support posts and beams isolated from possible contact, structural wood framing and foundations, and pilings. Skin contact with wood preservatives can dislodge residues onto the hands, leading to ingestion exposure (see next paragraph). Some preservative chemicals can also be absorbed through the skin.

One goal of wood preservation selection criteria should be to minimize skin contact with the most toxic wood preservatives. This is particularly important for children, who are most sensitive to toxic chemicals generally (IPCS 1986, NRC 1993, Landrigan 1998, Muckerjee 1998) and whose behavior puts them at elevated risk because they may have additional contact with soils and flooring and are more likely than adults to engage in hand-to-mouth behaviors or ingesting soil (Calabrese 1991, Hawley 1985, Mahaffey 1985). Sealing of preserved wood with surface coatings can significantly reduce dislodgeable residues, but only as long as the coating remains intact (Stilwell 2001). On high-wear surfaces, frequent re-coating will be required. Sealing remains an option for structures already in place, but when selecting materials for construction the preference should be to avoid those materials that are most toxic.

#### Ingestion

Ingestion of wood preservative components is possible through the following mechanisms:

1. hand to mouth contact following skin contact with treated surfaces

2. hand to mouth contact following skin contact with contaminated soil
  3. ingestion of contaminated soil
  4. ingestion of food contaminated by contact with treated surfaces or soil
- The likelihood of each scenario varies with the use and location of the treated wood. Wood preservative selection criteria should seek to minimize ingestion pathways, especially for the most toxic chemicals.

### Inhalation

Inhalation exposures to wood preservative chemicals can occur in two main ways. During fabrication of structures, cutting, drilling, or other mechanical working of treated wood produces sawdust that may be inhaled. This sawdust contains the preservative chemicals, and its toxicity will depend on the type of treatment, retention level of treatment, and depth of penetration into the wood. Although good occupational safety practices would dictate wearing protective gear while working with treated wood, it should be a goal of the selection criteria to give preference to the wood preservatives with the least-toxic sawdust for those applications where considerable on-site fabrication will be necessary.

The second inhalation exposure scenario occurs through vaporization of preservative chemicals from the surface of the wood. The health risk will typically be greatest for indoor uses, but could be significant outdoors as well, especially in workplace settings where large quantities of treated wood may be encountered on a daily basis. Most of the water-borne preservatives are inorganic salts, for which volatilization is probably negligible. For organic compounds such as pentachlorophenol and creosote and for carrier oils, however, significant evaporation may take place. EPA has placed restrictions on the use of penta and creosote in interior construction (USEPA 1987a,b). Other oil-borne wood preservatives may not be good choices for indoor use or may not be registered for indoor uses. Health complaints and elevated urine and serum copper levels were reported in three individuals who lived in a home where copper naphthenate was sprayed on the inner foundation (Bluhm 1992). Both copper naphthenate and zinc naphthenate labels were revised to exclude indoor applications after the California Department of Pesticide Regulation and the EPA reviewed health complaints related to indoor use of the materials (CDPR 1999).

### **Estimates of Human Health Risk**

In toxicology, the concept of risk integrates toxicity, exposure, and individual susceptibility into a probability of harm. While risk assessment (i.e. the estimation of risk) can suffer from serious shortcomings that were discussed in the introduction to this report, a number of recent assessments have raised concerns about some of the chemicals being considered here. In addition, some local jurisdictions have begun to implement restrictions that go beyond what EPA requires because they have determined that the risks of certain products are unacceptable.

### Pentachlorophenol

Pentachlorophenol is currently registered in the United States as a restricted-use pesticide, and many previous uses have been cancelled. Some countries have banned all uses, including as a wood preservative. The EPA is currently evaluating

pentachlorophenol for re-registration as a wood preservative. As part of that process, it has conducted comprehensive risk assessments for both human and environmental hazards. Although the assessment has not been finalized, the draft document identified some shockingly high estimated risks for some workers, especially those who apply penta grease to utility poles. Table 4 shows some of the highest cancer risks found by EPA.

**Table 4. Estimated Cancer Risks from Pentachlorophenol (USEPA 1999c)**

<u>Exposure Scenario</u>	<u>Cancer Risk/million*</u>	<u>Notes</u>
Utility pole installer	6600	dermal only
Applying PCP grease to poles	3,400,000	without gloves
	420,000	with gloves
Child contact with soil contaminated by PCP from utility pole	1.2	minimum
	220	maximum

\*These risks do **not** include contributions from carcinogenic microcontaminants in PCP.

The highest risks were found for occupational exposures, where estimates for 13 of 14 handler scenarios exceeded EPA’s level of concern (risk > 100/million, using maximum protective measures). Additional high risks were found for some other postapplication scenarios in commercial and industrial settings. In addition, non-cancer risk estimates exceeded agency levels of concern for many handler and postapplication scenarios. The risk for workers applying grease formulations to utility poles is particularly striking in that it indicates virtual certainty of cancer over a 40-year exposure period. Given that these estimates do not include the contributions from carcinogenic contaminants in most PCP formulations, they may well be underestimates.

### Creosote

Creosote is also registered as a restricted-use pesticide. Although the composition of creosote mixtures varies, creosote used in preserving wood is made from coal tar, which consists generally of a large number of PAH compounds of varying toxicity, including a group of potentially carcinogenic heavy molecular weight compounds. One of the most toxic is benzo[a]pyrene (BaP). The variability and complexity of creosote composition make toxicity and risk assessments difficult. Creosote was responsible for “the first identified chemical-caused occupational cancer, as described in 1775 by the surgeon Sir Percival Pott that chimney sweeps developed scrotal cancer as a direct consequence of exposure to a defined ‘substance’ (soots) in that occupation.” (Huff 2001) Karlehagen et al. found increased risk of skin cancer among a group of creosote-exposed workers in Sweden and Norway. (Karlehagen 1992)

The National Toxicology Program’s Ninth Report on Carcinogens summarizes the epidemiological data on creosote and human cancer (NTP 2001).

*“There have been a number of case reports of skin cancer in patients who used tar ointments for a variety of skin diseases. A mortality analysis in the United Kingdom from 1946 showed a greatly increased scrotal cancer risk for patent-fuel workers. Furthermore, a large number of case reports describe the development of skin (including the scrotum)cancer in workers*

*exposed to coal tars or coal-tar pitches. Several epidemiological studies have shown an excess of lung cancer among workers exposed to coal tar fumes in coal gasification and coke production. A cohort study of U.S. roofers indicated an increased risk for cancer of the lung and suggested increased risks for cancers of the oral cavity, larynx, esophagus, stomach, skin, and bladder and for leukemia. Some support for excess risks of lung, laryngeal, and oral cavity cancer is provided by other studies of roofers. Several epidemiological studies have shown excesses of lung and urinary bladder cancer among workers exposed to pitch fumes in aluminum production plants. A slight excess of lung cancer was found among furnace and maintenance workers exposed to coal tar pitch fumes in a calcium carbide production plant. One study showed a small excess of bladder cancer in tar distillers and in patent-fuel workers. An elevated risk of cancer of the renal pelvis was seen in workers exposed to "petroleum or tar or pitch." One study of millwrights and welders exposed to coal tars and coal tar pitch in a stamping plant showed significant excesses of leukemia and of cancers of the lung and digestive organs. In a number of case reports, the development of skin cancer in workers exposed to creosotes is described. One study involved a review of 3,753 cases of cutaneous epithelioma and showed that 35 cases (12 of which were of the scrotum) involved exposure to creosotes. Most cases occurred in workers handling creosotes or creosoted wood during timber treatment. A mortality analysis of workers in many occupations indicated an increased risk of scrotal cancer for creosote-exposed brickmakers."*

In 1999, a scientific committee of the European Union evaluated the cancer risk for children exposed to wood treated with creosote containing 50 ppm or less BaP. This report served as the basis for restrictions on the use of creosote in Europe beginning in mid 2003, after which time creosote and creosote-treated wood cannot be sold to consumers (EC 2001). The amount of BaP in creosote serves as a marker for the classification of creosote in Europe. However, a rodent skin-painting study cited by the committee found a fivefold higher risk of cancer than could be accounted for by BaP alone, presumably due to the presence of other carcinogenic substances in creosote. The committee estimated a risk on the order of 100 per million and concluded that "such a risk level gives clear reason for concern." (CTSEE 1999) Many creosote mixtures contain much more than 50 ppm BaP and hence may present higher cancer risk. Brooks cites a typical BaP content of 0.2% or 2000 ppm (Brooks 1995). Bos et al. measured BaP at 0.18% in a creosote solution (Bos 1984).

### Arsenicals

Most of the interest in arsenicals has focused on CCA because it is by far the most widely used, but to the extent that the concerns raised center on arsenic, they apply to all arsenical wood preservatives, some of which contain more arsenic than CCA.

In 1987, the California Department of Health Services (CADHS) issued a report to the state legislature on wood preservatives used on playground equipment (CADHS 1987). This report attributed the highest health risk to arsenic and estimated a skin cancer risk of between 100 and 6000 per million for lifetime exposure to arsenic at playgrounds. CADHS recommended that all treated-wood playground structures (except for wood treated with boric acid) be coated with a sealant every two years to minimize exposure. They also recommended that creosote and PCP not be used for playground or recreational equipment where children could be exposed.

Using different measurement techniques and assumptions, the Consumer Product Safety Commission in 1990 (CPSC 1990) estimated much lower cancer risks, from less than one in a million for wood with no detectable surface arsenic, to 3-4 per million for samples with detectable surface concentrations.

More recent evaluations by the Maine Department of Human Services (MEDHS 1998) and the University of Florida (Roberts and Ochoa 2001) estimated risks more in line with the earlier California DHS report. Roberts and Ochoa criticized a number of assumptions used by CPSC in 1990, including the cancer slope factor and the number of days per year of exposure.

The wood preservation industry has steadfastly maintained that CCA is safe and has recently issued its own risk assessment (Gradient 2001). Cancer risks calculated in this study are generally less than 10 per million, and in some cases go as low as 1.7.

It is not our intention to critique the various risk assessments. Experts disagree about many details of these calculations, including the amount of dislodgeable surface residues, children's behavior patterns, cancer slope factors, bioavailability, and other parameters. The U.S. EPA had undertaken a comprehensive review of CCA risk, but they announced the voluntary agreement to end residential uses before the review was completed. Although EPA stated that they had not concluded there was unreasonable risk to the public from CCA products, they did say that "phase-out of these uses will reduce the potential exposure risk to arsenic, a known human carcinogen, thereby protecting human health, especially children's health and the environment."

Public sentiment was turning against arsenic as a wood treatment before the voluntary ban was announced. The public interest groups Healthy Building Network and Environmental Working Groups had petitioned the CPSC to ban arsenic-treated wood in playground equipment and to review its safety for other uses (EWB/HBN 2001). The Center for Environmental Health in California has filed suit against manufacturers of CCA-treated play equipment, park benches, and picnic tables under California's Safe Drinking Water and Toxic Enforcement Act of 1986 (H&S Code 25249.5 et seq.) also known as "Proposition 65" and the Business & Professions Code 17204 and 17535 (Cappel 2001). Beyond Pesticides and several other groups have petitioned EPA to cancel the registration of CCA (Beyond Pesticides 2001). Local governments are also beginning to take steps. For example, Alachua County, Florida recommended that CCA wood no longer be purchased by the county, and that some structures be removed and

contaminated soil underneath be removed (Alachua 2001). The San Francisco Board of Supervisors voted to ban the use of arsenic-treated wood in all city construction projects (SFBC 2001). Then, on February 12, 2002 the EPA announced the voluntary agreement by CCA registrants to phase out use of the material for home uses by the end of 2003 (USEPA 2002). On June 4, 2003, the State of Maine went beyond the EPA in banning the **sale** of arsenic-treated wood for residential uses (Maine 2003). It also directs the Department of Environmental Protection to develop a plan to restrict the disposal of arsenic treated wood.

## **Environmental Concerns**

### **Leaching**

Leaching refers to the loss of preservative chemicals from treated wood, usually as a result of contact with water. Leaching is of concern because chemicals that leave the wood can accumulate on the ground under or around treated structures, resulting in possible additional human exposures through contact with contaminated soil. Leaching can also cause preservatives to enter surface waters, particularly if the structures are located in or over the water, but also, to a lesser extent, if contaminated runoff from the structure can reach a water body either directly or via a storm sewer.

It is well established that preservative chemicals do leach from treated wood, despite the fact that one often hears that CCA and similar preservatives applied via pressure treatment are “fixed” to the wood and therefore don’t leach to any appreciable degree. Lebow points out that the meaning of “fixation” must be approached with some care (Lebow, 1993):

*“However, this definition must be qualified, because even fully-fixed CCA will leach to some degree, depending on the exposure conditions. Therefore, fixation might be more appropriately defined as the process that minimizes the leaching of preservative components, or according to Cooper and others (1993) in reference to CCA: ‘the state of the chemical components of the preservative and wood or other substrate when all chemical reactions are complete.’”*

Whether or not leaching presents a problem in a given situation depends on many factors, including the extent of leaching, toxicity of the chemicals themselves, mobility and fate of chemicals in the environment, background levels of these and other chemicals in the environment, etc. The point of this analysis is not to measure risk, but rather to minimize it. For that purpose, it is useful to review the factors that determine the extent of leaching.

The factors that influence leaching rates can be divided into those that are characteristic of the treated product itself and those that are characteristic of the exposure conditions. Table 5 summarizes these factors (Lebow, 1993; Hingston et al. 2001) and indicates which generally increase or decrease leaching.

**Table 5. Factors Affecting Leaching of Wood Preservative Components**

PRODUCT FACTORS (Numbers in parentheses refer to explanatory notes following table)	
Less/slower Leaching	More/faster Leaching
old wood (1)	newly treated wood (1)
properly cured treatment (1)	improperly cured treatment (1)
smaller surface area (larger pieces) (2)	larger surface area (smaller pieces) (2)
flat grain (2)	end grain (2)
less-permeable wood (2)	more-permeable wood (2)
sawn lumber (2)	round cross-section posts (2)
softwoods (2)	hardwoods (2)
sapwood (2)	heartwood (2)
lower preservative retention (3)	higher preservative retention (3)
trivalent chromium (4)	hexavalent chromium (4)
pentavalent arsenic (4)	trivalent arsenic (4)
chromium (4)	arsenic, copper (4)
most preservatives (Cr, As, Cu, Zn) (4)	boron (4)
EXPOSURE FACTORS (5)	
Less/slower Leaching	More/faster Leaching
dry conditions	wet conditions
above ground	below ground
soil installation	water installation
heavy rain	drizzling rain (for same total amount of water)
alkaline pH	acid pH
poor soil (Cu)	soil with high organic content (Cu)
freshwater (CCA components)	saltwater (CCA components)
distilled or pure water	water with dissolved minerals or salts
	washing with bleach (oxidizing agent)

**Explanatory Notes**

1. Improperly treated wood will leach more preservative than properly cured wood. However, even properly cured wood will leach more when it is newly installed than after it has been in place for some time. For wood structures installed in water, the decrease in leaching rates over time is particularly dramatic. When preservative penetrates more deeply into wood, the leaching rate will decrease more slowly with time because of the greater reservoir of chemicals at some distance from the surface.

2. Leaching is proportional to the exposed surface area, so large structures will leach more than small ones, but leaching rates expressed on a per volume or per weight of wood basis will actually be larger for small pieces of wood because the ratio of surface area to volume is greater. This fact makes comparisons difficult between measurements on small test blocks and actual structures. Leaching is also greater from end grain than from flat grain, from round posts than from sawn lumber, from hardwoods than from softwoods, and from heartwood than from softwood. These last two cases occur because hardwood and heartwood don't bind preservative components particularly well.

3. Retention refers to the amount of preservative taken up by the wood when treated and is usually expressed in units of pounds per cubic foot. (Note that retention does not refer to how much preservative remains in the wood once it is installed in a structure.) Greater retention usually means greater leaching simply because more preservative is stored in the wood. Greater retention is specified in difficult applications, where extra decay resistance is needed. Highly permeable woods also appear to leach more readily, presumably because leachate moves through them more easily.

4. Differences in inherent leaching rates can be observed for the most common pressure-treated components. Hexavalent chromium, present in the treating solution for CCA, leaches much more readily than trivalent chromium, the predominant form after fixation occurs. (Trivalent chromium can be oxidized to hexavalent chromium in water or soil under certain conditions after leaching from wood.) Similarly, pentavalent arsenic found in CCA leaches less than trivalent arsenic. Both arsenic and copper are more likely to leach from the wood than chromium. Water soluble preservative components such as borates are the most likely to leach, and that is why borates are not recommended in water- or ground-contact exposures.

5. In terms of exposure conditions, faster leaching occurs in wet conditions, water contact, or ground contact. For a given volume of water, a slow drizzling rain causes more leaching than a heavy rain. Acidic water tends to pick up more preservative chemicals than does alkaline water. In water-contact situations, saltwater or water with dissolved minerals or salts leaches more metals from wood than does fresh water or distilled water. The same is true of pentachlorophenol, but creosote behaves differently. PAHs from creosote leach about twice as rapidly in freshwater as in saltwater (Ingram 1982 as quoted in Sinnott 2000). Soils with high organic matter content that are in contact with treated wood can increase copper leaching because copper is specifically bound to certain ions found in the soil. This binding pulls copper from the wood, but it also keeps the copper relatively immobile in the soil.

#### Leaching from Deck Structures into Soil

Analysis of metal levels under various types of deck structures, for example, have given rather widely varied results, but it is clear that concentrations of arsenic and copper under CCA-treated decks can be many times above background levels and arsenic can exceed hazardous waste regulatory or cleanup levels (Stilwell and Gorny 1997; Townsend et al. 2001a and references therein). Contamination is not just at the surface, but can extend downwards 4 to 8 inches (Townsend et al. 2001a). It is possible that in some cases part of the contamination under structures came from sawdust or other construction residues. Arsenic buildup under treated structures can elevate health risks, especially for children who have access to these areas and who may ingest the soil itself or residues picked up on their hands. Given the extensive attention that arsenic leaching has received, as well as the impending rise in the use of copper and other “safer” replacements, we will focus most of our attention here on copper. Copper buildup in soil is less of a concern given its lower human toxicity, but these deck leaching studies are helpful in understanding how much copper would leach from treated structures built over water or impermeable surfaces that drain to surface water.

Relative leaching rates between different wood preservative treatments have not been extensively explored, and the data that do exist are not always useful, either because the conditions in different experiments are not comparable or because leaching rates are not referred to a standard material that can serve as a calibration point. Despite these difficulties, a recent report from Florida (Solo-Gabriele 2000) cited several studies that can be used to compare leaching rates of some preservative components for above ground



or ground contact situations. Of particular interest are the relative leaching rates of copper from CCA as compared to arsenic-free “alternative” treatments such as ACQ or CC. Table 6 below shows some of these results. It is important to notice whether comparisons are made on a percentage or an absolute weight basis. These results show, for example, that the percentage of copper that leaches from CCA, ACQ, and CC is generally about the same. However, many arsenic-free preservatives contain considerably more copper than CCA does, and on a weight basis they will leach considerably more copper. That fact should be taken into account when choosing preservatives for use in or near aquatic systems because copper is much more toxic to the organisms present than either arsenic or chromium.

**Table 6. Comparison of Relative Copper Leaching Rates between ACQ and CCA**

Formulation	Retention	% Cu leached	Mass Cu leached	Method (see below)	Reference	Notes
ACQ-B	.40	14.7	31.3	1	CSI 1995	
ACQ-D	.40	8.3	17.7	1	CSI 1995	
CCA	.40	2.4	1.4	1	CSI 1995	
ACQ-B	.40	17.6	37.5	2	Archer 1992	
ACQ-B	.60	19.0	60.7	2	Archer 1992	
ACQ-B	.40	15.1	32.2	2	Archer 1992	with water repellent
CCA	.60	17.9	15.9	2	Archer 1992	
ACQ-D	.25	7.9	10.5	3	Solo-Gabriele 2000	
CCA	.25	9.9	3.7	3	Solo-Gabriele 2000	
ACQ-B	.25	6.2	8.3	4	Solo-Gabriele 2000	center of deck
CCA	.25	7.9	2.9	4	Solo-Gabriele 2000	center of deck
ACQ-B	.25	12.5	16.6	4	Solo-Gabriele 2000	end of deck
CCA	.25	20.2	7.5	4	Solo-Gabriele 2000	end of deck
ACQ-D	.25	20.3	27.0	5	Solo-Gabriele 2000	
CCA	.25	32.0	11.8	5	Solo-Gabriele 2000	
ACQ-D	.40	31.6	67.3	5	Solo-Gabriele 2000	
CCA	.40	35.3	20.9	5	Solo-Gabriele 2000	
ACQ-D	.25	20.2	26.9	5	Solo-Gabriele 2000	
CCA	.25	13.0	4.8	5	Solo-Gabriele 2000	
ACQ-D	.40	21.6	46.0	5	Solo-Gabriele 2000	
CCA	.40	9.7	5.7	5	Solo-Gabriele 2000	

**Method Descriptions:**

Method 1: laboratory tests with small blocks immersed in de-ionized water or soil impregnated with fungus (AWPA method E11-97 or E10-91)

Method 2: “fungal cellar” tests using small blocks and soil maintained under conditions conducive to decay (AWPA method E14-94)

Method 3: field tests with small wood samples on concrete blocks, 18 month test duration

Method 4: field tests with simulated deck, 18 month test duration

Method 5: field tests with stake samples driven into ground, 18 month test duration.

Looking at these results in detail, we see that on a percentage basis, the copper leaching from ACQ ranges from about 62% to more than six times as much as copper leaching from CCA, with most tests showing roughly equal percentage leaching. However, ACQ

contains 3.69 times as much copper as CCA. When converted to a mass basis, the copper leaching from ACQ is seen to be comparatively much higher, with the lowest being about twice as much as CCA and the highest being more than 20 times higher. Although the test conditions are varied, ACQ apparently consistently leaches much more copper than CCA does under the same conditions.

Table 7 gives a similar comparison between copper leaching from CBA and CCA. The results again show more copper leaching from the arsenic-free treatment.

**Table 7. Comparison of Relative Copper Leaching Rates between CBA and CCA**

<b>Formulation</b>	<b>Retention</b>	<b>% Cu</b>	<b>Mass Cu</b>	<b>Method</b>	<b>Reference</b>	<b>Notes</b>
CBA	.48	2.1	4.9	1	Hickson 1999	above ground
CCA	.34	-11.3	-	1	Hickson 1999	above ground
CBA	.48	12.2	28.7	1	Hickson 1999	below ground
CCA	.34	3.2	1.6	1	Hickson 1999	below ground
CBA	.37	8.1	14.7	2	Hickson 1999	above ground
CCA	.43	2.1	1.3	2	Hickson 1999	above ground
CBA	.37	31	56.2	2	Hickson 1999	below ground
CCA	.43	25.4	16.1	2	Hickson 1999	below ground
CBA	.39	5.4	10.3	3	Hickson 1999	above ground
CCA	.40	-.4	-	3	Hickson 1999	above ground
CBA	.39	32.4	61.9	3	Hickson 1999	below ground
CCA	.40	17.0	10.0	3	Hickson 1999	below ground

**Method Descriptions:**

Method 1: field tests with stake samples, 13 month duration

Method 2: field tests with stake samples, 38 month duration

Method 3: field tests with stake samples, 42 month duration

We see that in these tests the CBA stakes lose more copper than the CCA samples. Even on a percentage basis, the losses are up to four times as much. CBA contains 2.7 times as much copper as CCA does. When expressed on a mass basis, the CBA is losing from 3.5 to 17.9 times as much copper. In addition, although not shown in the table, the CBA is losing virtually all of its boric acid in the below ground portion of the stakes, and about half in the above ground portions. Losses of the azole portion are generally intermediate between the copper and the boric acid.

One more set of tests compare CDDC with CCA, as summarized in Table 8 below.

**Table 8. Comparison of Copper Leaching Rates between CDDC and CCA**

<b>Formulation</b>	<b>Retention</b>	<b>% Cu</b>	<b>Mass Cu</b>	<b>Method</b>	<b>Reference</b>	<b>Notes</b>
CDDC	.065 as Cu	1.2	.78	1	Cooper 1993	
CDDC	.13 as Cu	0.9	1.2	1	Cooper 1993	
CDDC	.27 as Cu	0.59	1.6	1	Cooper 1993	
CCA	.55	4.59	3.7	1	Cooper 1993	
CDDC	.11 as Cu	10.1	11.1	2	McIntyre 1994	
CCA	.10 tot oxide	47.8	7.1	2	McIntyre 1994	
CDDC	.20 as Cu	21.3	42.6	2	McIntyre 1994	
CCA	.20 tot oxide	10.5	3.1	2	McIntyre 1994	
CCA	.43 to oxide	49.3	31.3	2	McIntyre 1994	
CDDC	.2 as Cu	55.3	111	3	McIntyre 1994	above ground
CCA	.6	none	-	3	McIntyre 1994	above ground
CDDC	.2 as Cu	77.4	155	3	McIntyre 1994	below ground
CCA	.6	71.6	63.5	3	McIntyre 1994	below ground

**Method Descriptions:**

Method 1: laboratory tests, small blocks in water, 2 week duration (AWPA Method E11)

Method 2: fungal cellar tests, , 18 month duration

Method 3: field tests with stake samples, 23 year exposure period.

The comparisons between CDDC and CCA are less clear-cut than the others considered above. For one thing, the retention levels are not expressed on the same basis, so the comparisons are not exact. Secondly, the results are somewhat inconsistent. In these sets of tests, the CDDC sometimes leached more and sometimes leached less copper than CCA. Leaching of the SDDC (not shown) was negligible in the two-week block tests, roughly half in the 18 month fungal cellar tests, and 68 to 73% in the 23 year stake tests.

A recent Forest Service Study (Forest Products Laboratory 2000) of a boardwalk structure in the Pacific Northwest is particularly interesting because portions of the structure were treated with four different preservative systems: CCA-C, ACZA, ACQ-B, and CDDC. Unfortunately, this study does not allow a good quantitative comparison of leaching rates between the four preservatives because the construction of the four sections were not simultaneous and thus they were exposed to different weather conditions; the soil, sediment, and water conditions under each section were not the same; the preservative retention levels were not the same for each section; and the ACQ-B timber was apparently over-treated. The authors consider the ACQ data to be a worst-case scenario. The copper levels in soil and sediment near the ACQ-treated wood were much higher than those near the other sections, and water concentrations of copper near the structure exceeded the EPA chronic criterion ninefold at both 15 and 162 days, although short-term copper concentrations near the ACZA portion of the structure actually spiked four times higher. It is not known to what extent the high copper leaching from the ACQ-treated wood was related to the over-treatment. Observed effects on aquatic invertebrates collected near the structures were characterized as subtle and not statistically significant, but the analysis was confined to statistical measures of abundance. Measured environmental levels of metals did decline from their peak values. This report concludes that biological effects from the structure were minimal and transitory, but acknowledges that copper levels in some cases exceeded water quality

criteria and sediment threshold effects levels by a wide margin in a limited area. This report supports the conclusion that copper leaching from ACQ and ACZQ, which contain more copper than the other treatments, is probably greater, but the comparisons are somewhat suspect because these two boardwalk sections were exposed to more rainfall than the others, in addition to the other limitations discussed earlier.

An extensive laboratory study (Townsend 2001b) comparing the leaching rates and toxicity of leachates from CCA and several arsenic-free alternative treatments immersed in water yielded results similar to the field tests summarized by Solo-Gabriele et al. (Solo-Gabriele 2000). The study compared leachates from CCA, ACQ, CBA, CC, and CDDC. Samples of wood treated with these preservatives, as well as an untreated control, were ground up into pellets less than 3 mm in diameter and exposed to one of four different leaching fluids for 18 hours. The four leaching fluids were de-ionized water, TCLP leaching fluid of pH 4.93, SPLP leaching fluid of pH 4.22, and synthetic seawater. Although the study measured leaching of all preservative components, for the moment we will consider only the results for copper. Since these tests were performed on ground up samples rather than whole wood, the results will only be used for comparisons between treatment types and not for absolute leaching quantities. Table 9 presents the concentrations and percentage of copper leached for each wood type.

**Table 9. Copper Concentration and Percent Leached by Extraction Fluid**

Wood Type	DI	DI	TCLP	TCLP	SPLP	SPLP	SW	SW
	%	mg/L	%	mg/L	%	mg/l	%	mg/L
CCA-I	5.6	3.3	14.6	8.7	6.9	4.1	16.7	10.0
CCA-II	5.8	4.0	12.4	8.7	5.7	4.0	14.3	10.0
ACQ-D	12.0	28.8	32.9	79.2	12.1	29.0	17.5	42.1
CBA-A	22.8	27.4	46.3	55.4	22.3	26.7	36.2	43.4
CC	39.8	64.6	72.9	116.5	38.7	61.8	34.5	55.1
CDDC	3.3	6.8	5.1	10.4	3.5	7.1	5.2	10.5

Key: DI=de-ionized water  
 TCLP=Toxicity Characteristic Leaching Procedure (pH 4.93)  
 SPLP=Synthetic Precipitation Leaching Procedure (pH 4.22)  
 SW=synthetic seawater

On a concentration basis (mg/L is proportional to total copper loss), copper leaching into de-ionized water was least for CCA, slightly higher for CDDC, and much greater for ACQ, CBA, and CC. This trend also held true for the two acidified extraction fluids, although actual amounts leached increased across the board. In the synthetic seawater, the results were similar except that copper leaching from CDDC was the same as from CCA. Except for CC, the amount of copper leaching from each material increased substantially in seawater as compared to de-ionized water. These results demonstrate that several arsenic-free wood treatments will leach much higher amounts of copper than CCA does under a variety of conditions, at least initially. In these short-term tests, CDDC emerged as an arsenic-free treatment that leached much less copper than the others. The co-biocides in the treatments were also measured in the leachate, but comparisons between the materials would require factoring in the toxicity of each co-biocide to the organisms of concern. It is noteworthy that in the leachate aquatic toxicity tests, the researchers

reported that copper was responsible for most of the toxicity observed. However, they caution that before recommending one of these wood treatments over another a careful evaluation of the toxicity of the co-biocides, including toxicity to humans, be conducted by a toxicologist.

Leaching of Copper in Freshwater and Marine Environments

Many of the results cited in the last section suggest strongly that a number of copper-containing wood treatments are likely to leach much higher copper levels into aquatic ecosystems than CCA, raising the question as to whether these alternative treatments are really better choices than CCA for use in or near water. Townsend et al. (2001b) used a variety of toxicity assays to show that the leachate from ACQ, CBA, and CC-treated wood was significantly more toxic to aquatic organisms than leachate from either CCA or CDDC and that copper accounted for the majority of the toxicity of the leachates tested, while the co-biocides were secondary in importance. As will be seen in the section following this one, copper is generally considered one of the most toxic of the preservative components to fish. The Townsend study collected leachate for only 18 hours, so it may not predict long-term leaching trends. However, the small particle size would accelerate the leaching process so that the integrated leaching in this study would be comparable to a much longer exposure period for submerged timbers or pilings.

Brooks has conducted literature reviews of leaching studies in water environments and has derived empirical equations that can be used to estimate the loss rates of preservative components from some wood treatment systems as a function of time and other conditions (Brooks 1995; 1997a; 1997b; 1998; 2003a). Brooks' models are based on data sets that span longer time frames, typically a month to several months. For comparing loss rates between different preservative treatments, there may be some limitations due to differences in conditions in the original experiments on which the models are based. The CCA and ACQ models are based on measurements of treated yellow pine, while the ACZA and CuN models are based on Douglas fir. The ACQ and CuN models are only valid for fresh water. The models allow input of various geometries and water currents, and are designed to calculate both water and sediment concentrations downstream of treated material. The models are constructed in such a way that the preservative loss rate from a small area on the surface of the wood can be calculated independent of the details of the structure geometry and flow.

The equations derived by Brooks for the copper loss rate per unit of surface area (ug/cm<sup>2</sup>/day) are shown below:

Material	Estimated Copper Loss Rate	
CCA	Loss = $\exp(-0.048*t)*0.51 \exp(0.02*S)*(0.65(0.8462+\ln(0.71*R)))$	
ACZA	Loss = $1908.6*\exp(-0.429*t - 0.383*pH)$	in fresh water
	Loss = $32.5*\exp(-1.114*t)$	in salt water
ACQ	Loss = $265.14*\exp(-0.924*t - 0.239*pH)$	for days <4.5 in fresh water
	Loss = $4.25*\exp(-0.0175*t)$	for days ≥4.5 in fresh water

CuN  $\log_{10}(\text{Loss}) = 0.093 + 1.269 \cdot \exp(-0.1375 \cdot t)$  in fresh water

Where: t = time after installation in days  
 S = salinity in parts per thousand  
 R = preservative retention in kg/m<sup>3</sup>

Using these equations to calculate copper loss rates per unit area of wood shows how the copper loss decreases over time from installation. Figure 1 shows the comparison for freshwater environments and Figure 2 shows the rates for marine environments. The calculations represent losses from a square centimeter of wood surface, independent of details of the structure or characteristics of the water except for salinity and pH. Fresh water is assumed to be pH 7 and salinity 0, while salt water is taken as pH 8 and salinity 30 parts per thousand. These calculations assume still water with no currents or flow. Preservative retention values used in the calculations are as follows (in units of pounds per cubic foot, or pcf):

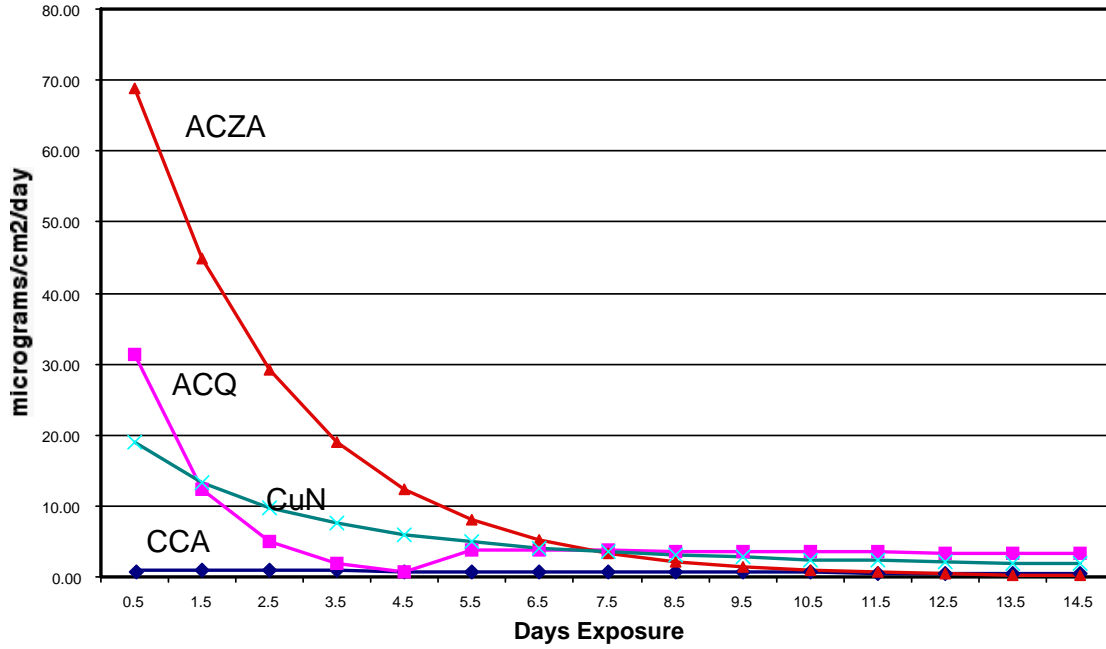
Preservative	Fresh water	Salt water
CCA	0.8	2.5
ACQ	0.4	Not modeled
ACZA	1.0	2.5
CuN	.08-.14	Not modeled

The apparent discontinuity in the ACQ curve at between 4 and 5 days occurs because the model uses two separate curves to fit the data for <4.5 days and for ≥4.5 days. The two equations do not yield the same values near the crossover point for pH = 7. The first data point is calculated at day 0.5 to average over the steeply changing loss rate on the first day.

These model calculations indicate that leaching rates should decrease rather dramatically with time but that the time dependence is different for each treatment. In fresh water, copper coming from CCA has the lowest initial leaching rate but declines less rapidly than the others. Copper from ACQ drops rapidly at first, but then remains roughly constant after about 10 days. Copper from ACZA initially leaches at the highest rate in freshwater but then rapidly falls and is lowest at two weeks. The decline is even more rapid in salt water, but here the initial leaching from ACZA is less. These different decay rates make comparisons between the materials difficult. It is perhaps more instructive to look at cumulative leaching amounts rather than daily contributions. These are graphed below for the first four-week period, and summarized in Table 9 up to three months, except where this time period exceeds that of the measurements upon which the model is based.

Figure 1. Calculated Daily Copper Loss Rates in Aquatic Environments

### Daily Copper Loss Fresh Water



### Daily Copper Loss Salt Water

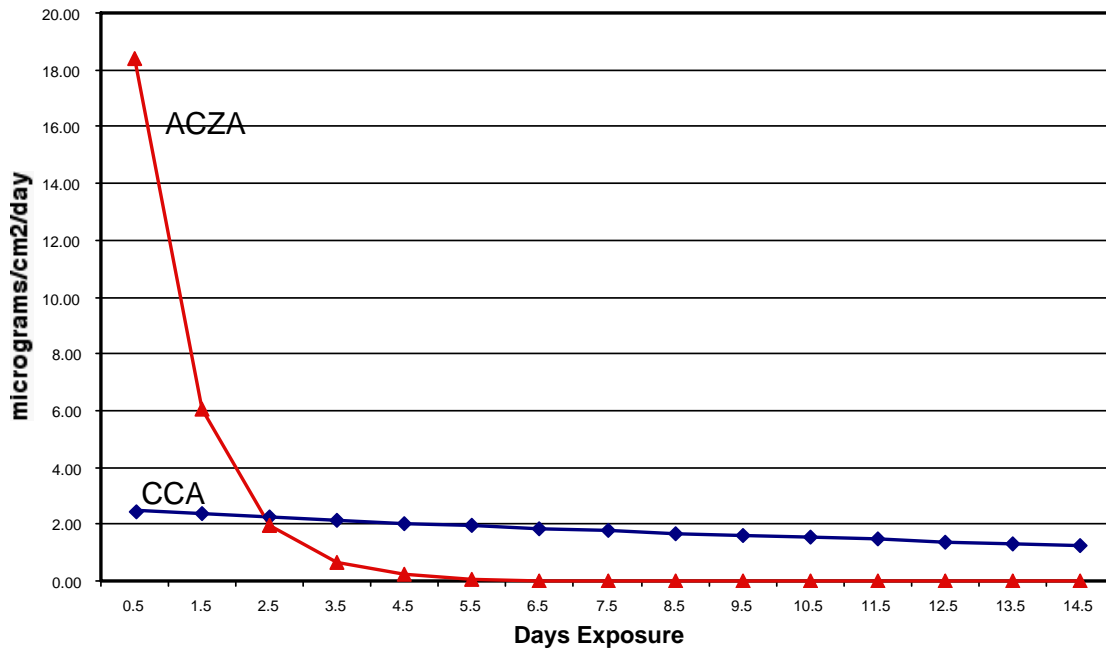
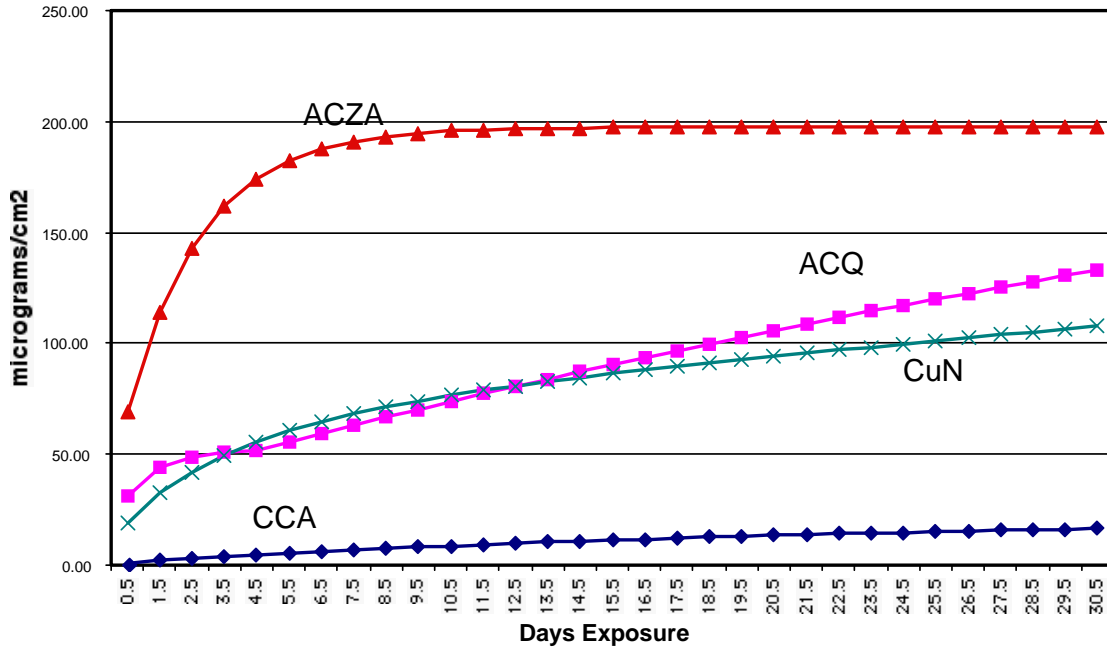
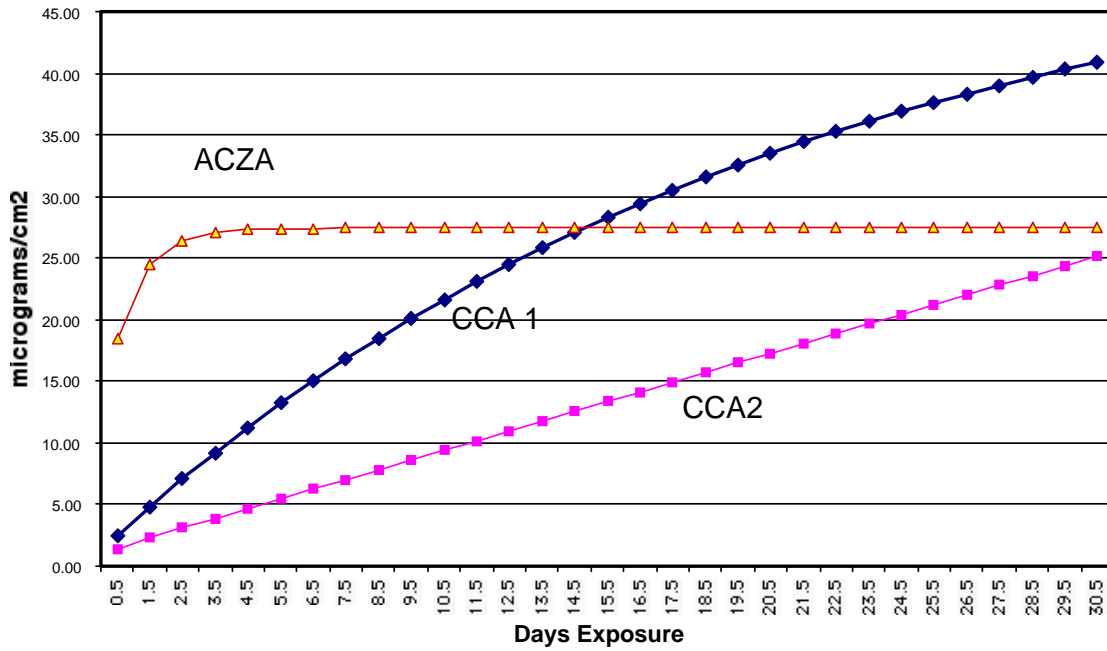


Figure 2 Calculated Cumulative Copper Loss Rates in Aquatic Environments

### Cumulative Copper Loss Fresh Water



### Cumulative Copper Loss Salt Water





**Table 9. Cumulative Copper Losses Over Different Periods (Units ug/cm<sup>2</sup>)**

Elapsed Time	-----Fresh water-----				-----Salt water----	
	CCA	ACQ	ACZA	CuN	CCA	ACZA
1 day	1	31	69	19	2.5	18
1 week	6	59	188	65	15	27
1 month	16	128	197	105	40	27
3 months	21	---	---	---	52	---

If these models are correct, we can draw the following conclusions about these treatments under the conditions specified:

For fresh water

1. Copper leaching is least from CCA by a considerable margin, in general agreement with the measurements of Townsend et al.
2. Copper leaching from ACZA is initially largest but declines most rapidly, so that ACQ gradually catches up and may eventually surpass ACZA, though this crossover would occur beyond the proven applicability of the model.
3. Copper leaching from CuN appears closest to ACQ.

For salt water

1. Copper leaching is initially lowest from CCA, though more than twice as much as in fresh water, also in agreement with the measurements of Townsend et al.
2. Copper leaching from CCA surpasses that from ACZA at about 2 weeks. (Note: a newer model by Brooks (Brooks 2003b) appears to give somewhat different results for the CCA leaching rates, shown in the graph as CCA2. Unlike the earlier model, this one includes the effects of temperature and pH on copper leaching rates. The plot shown is for a water temperature of 13.5°C.)
3. No model was available for ACQ or CuN in salt water.

Although arsenic and chromium leaching from wood pilings could also be a concern, Brooks has summarized data from several studies that seem to show that copper would still be the component most likely to cause toxic effects. Townsend et al. also concluded that copper was of most concern. The calculations indicate that of the four preservatives modeled, in fresh water CCA contributes by far the least copper. In salt water, only two treatments were modeled, and their copper leaching rates are much more similar to each other than in fresh water. The next section looks in more detail at the aquatic toxicity of wood preservative leachates.

### **Aquatic Toxicity**

Toxicity of wood preservative components to aquatic life is obviously a major concern when treated wood structures are placed in direct contact with water. Leaching of preservative chemicals is greatest under these conditions, though water concentrations of leached chemicals can be reduced by dilution and adsorption to (i.e. pollution of) sediments. Aquatic toxicity is also a concern for structures built directly over water or wetlands and for structures in close proximity to such habitat, where runoff can carry chemicals from the site to a storm sewer or other conduit.

Many wood preservative chemicals have considerable toxicity to fish and other freshwater or saltwater organisms. Most of the major preservative active ingredients are

listed as Priority Pollutants under the Clean Water Act. The EPA derives water quality criteria or standards for pollutants based on their toxicity levels. The criteria are intended to indicate water concentrations of the pollutants that are protective to most organisms. The lower the criteria, the more toxic the material. Table 12 shows existing criteria levels for chemicals considered here (US EPA 2001). “PP” indicates Priority Pollutant.

**Table 12. Aquatic Toxicity Criteria for Wood Preservative Constituents**

	PP	Fresh water--(units ug/L)—Salt water			
		acute	chronic	acute	chronic
Pentachlorophenol	yes	19	13	15	7.9
Creosote	*				
Arsenic	yes	340	69	150	36
Chromium (VI)	yes	16	11	1100	50
Chromium (III)	yes	570	74		
Copper	yes	13	4.8	9	3.1
Nickel**	yes	470	74	52	8.2
Zinc	yes	120	90	120	81

**Notes:**

\*Creosote is not listed as a priority pollutant, but it contains a large number of PAHs that are individually listed as priority pollutants. \*\*Nickel is a component of copper-8-quinolinolate.

Table 13 itemizes some of the predominant PAHs in creosote. Unfortunately, there are no EPA water quality criteria for any of these chemicals. “Fresh” and “Salt” columns indicate relative migration of each compound from treated pilings into fresh water and marine water, as measured in Alabama (Ingram 1982).

**Table 13. Relative Leaching and Percent Composition of Major Cresote PAHs**

Compound	PP	Relative Leaching		% in creosote
		Fresh	Salt	
<u>Light PAHs</u>				
Naphthalenes	yes	3342	1158	15.45
Phenanthrene	yes	660	620	12.90
Acenaphthene	yes	688	640	8.70
Fluorene	yes	405	388	7.45
Dibenzofuran		482	463	6.25
2-Methylnaphthalene		1151	784	2.15
1-Methylnaphthalene		982	784	incl. in Naphthalenes
Anthracene	yes	169	135	1.45
Biphenyl		196	155	1.35
Acenaphthylene	yes	256	238	1.02
<u>Heavy PAHs</u>				
Carbazole		368	207	
Fluoranthene	yes	184	124	7.45
Pyrene	yes	103	59	5.30
Chrysene	yes	36	9.7	1.63
1,2-Benzanthracene		43	25	0.20

It is quite clear from the tables above that aquatic toxicity is a concern with all of the listed wood preservative components, but copper stands out as the most toxic, with PCP (neglecting its contaminants) and probably creosote not far behind. This is a significant

result because in the San Francisco Bay Area, seven sites, including most of the Bay itself, are currently listed as impaired for copper under Section 303(d) of the Clean Water Act, as listed in Table 14 below (CalEPA 1999).

**Table 14. Bay Area Sites Impaired for Copper**

<u>Site</u>	<u>Current Status</u>	<u>Proposed Status</u>
Carquinez Strait	impaired	threatened
San Francisco Bay, Central	impaired	threatened
San Francisco Bay, Lower	impaired	threatened
San Francisco Bay, South	impaired	threatened
San Pablo Bay	impaired	threatened
Suisun Bay	impaired	threatened
Sacramento S. Joaquin Delta	impaired	threatened
Petaluma River	not listed	impaired

The California Regional Water Quality Control Board is currently proposing to delist most of these sites for copper and move them to a new, preliminary “watch” list subject to action of dischargers over the next listing cycle. Copper is considered to threaten water quality in these areas, and they would be re-listed as impaired if pollution prevention plans are unable to decrease or hold concentrations at current levels. Given this situation, additional copper inputs to these areas would be inadvisable. Selecting copper-based wood preservatives to minimize leaching is complicated by lack of complete data on leaching rates for all of the products. The available science does not seem to support the conclusion that copper leaching rates are simply in proportion to the copper content of the material (shown in Table 15). The results of Townsend et al. (Townsend 2001b) found that CDDC leached the least copper of the non-arsenical alternatives tested in fresh or salt water immersion, with ACQ-D and CBA-A leaching considerably more copper, but still less than CC. Applicability of these results to field conditions is unclear, however, since each material may release copper with a different time dependence, and the laboratory studies are for fixed duration. An interesting alternative for sensitive aquatic environments may be plastic-coated treated lumber, which physically encases the preservative chemicals.

**Table 15. Copper Content of Copper Wood Preservatives**

<u>Preservative</u>	<u>% ingredient</u>	<u>% Copper by weight</u>
ACC	31.8 CuO	25.4
ACA	49.8% CuO	39.8
ACZA	50% CuO	39.9
CCA	18.5% CuO	14.8
ACQ	66.7% CuO	53.3
CC	62.3% CuO	49.8
CBA	49% CuO	39.1
CDDC	17-29% CuO	13.6-23.2
CuN	60-80% CuN	0.5-2% Cu

No sites are listed for any of the other wood preservatives except nickel (which is a component of Copper-8-quinolinolate, but many sites are listed for dioxins and furans (contaminants in PCP), and some sites have significant PAH contamination (See Table

16 below). In addition, four sites are listed as impaired due to sediment toxicity and benthic community effects, but no specific pollutants are named.

**Table 16. Bay Area Sites Impaired for Dioxins, Furans, and Sediment Toxicity/Benthic Community Effects**

Site	Dioxins	Furans	Sediment	Benthic
Carquinez Strait	impaired	impaired		
Richardson Bay	impaired			
San Francisco Bay, Central	impaired	impaired		
San Francisco Bay, Lower	impaired	impaired		
San Francisco Bay, South	impaired	impaired		
San Pablo Bay	impaired	impaired		
Suisun Bay	impaired	impaired		
Sacramento S. Joaquin Delta	impaired	impaired		
Petaluma River	not listed	impaired		
Stege Marsh			impaired	impaired
Mission Creek			impaired	impaired
Islais Creek			impaired	impaired
Peyton Slough			impaired	impaired

Although no water quality criteria currently exist for creosote or any of the PAHs that it contains, the conclusion (Brooks 1995) that sustained concentrations of 30 to 40 ug/L can have chronic effects suggests that valid criteria would need to be well below those levels to guarantee no effect. Thus, we conclude that creosote is potentially as toxic as PCP and perhaps as toxic as copper. Wood treated with creosote and PCP are both prohibited in lakes in Washington state by state law (WAC 220-110-060).

A sense of the relative aquatic hazard posed by the three major wood preservative metals can be obtained by comparing typical leaching rates and water quality standards. Table 17 below (from Brooks 1997b) compares average leaching rates for the metals in CCA from three different water exposures.

**Table 17. Average Leaching of CCA Components In or Above Water End Use and Environment**

End Use and Environment	Copper	Arsenic	Chromium
	(Units ug/cm <sup>2</sup> /day)		
Submerged in fresh water	1.62	8.39	0.52
Submerged in marine water	2.60	1.09	0.12
Above water & exposed to 35 inches average rain	1.20	1.80	0.20

A relative hazard index can be constructed by dividing the leaching rate by a measure of aquatic toxicity such as EPA's chronic water quality criterion (CWQC):

$$\text{Hazard Index} = \text{leaching rate} / \text{CWQC}$$

This index will increase when the leaching rate is high and when the CWQC is low (i.e. more toxic). It has no meaning in the absolute sense and can only be used to compare the three components in CCA. The values for the hazard index are as follows (low numbers are better):

**Table 18. Relative Hazard Index for CCA Components In or Above Water**

<b>End Use and Environment</b>	<b>Copper</b>	<b>Arsenic</b>	<b>Chromium</b>
Submerged in fresh water	34	12	4.7
Above fresh water	25	2.6	1.8
Submerged in salt water	84	3	.24
Above salt water	39	5	0.4

These numbers indicate that for aquatic organisms, copper from CCA poses from about 3 to as much as 28 times as much risk as does arsenic from CCA.

**Conclusions:**

For fresh water, CCA seems clearly to contribute the least copper of the three copper-based treatments. Even though arsenic leaching exceeds copper leaching, the likelihood of exceeding the continuous chronic water quality criterion is still about three times lower than for copper.

For salt water, either CCA or ACZA would be superior to ACQ, based on copper leaching. Arsenic and chromium contributions should be negligible in comparison.

### **Aquatic Risk**

The actual risk posed to aquatic species from wood preservatives is determined by many factors in addition to the toxicity of the chemicals. The rate at which chemicals leach into the water is affected by the size and shape of the structure, the rate of flow of water around it, the age of the structure, water hardness and salinity, and so on. Concentrations of the chemicals in the water are also determined by the flow patterns around the structure and by adsorption to sediments. Mathematical models have been designed to estimate the interplay of these factors and to predict water concentrations that may occur. Comparison of estimated pollutant concentrations to toxicity values or environmental standards is often used to judge whether a particular project is expected to have unacceptable impacts. Such tools can have value when used carefully and within their realm of applicability, and when verified experimentally. They can be misleading, however, if they do not take into account multiple pollutants or stressors in the environment that may simultaneously affect populations. Even when calculations show (and experiments support) that leaching or runoff from a given material is small compared to toxic levels, better choices may be made, especially in water bodies that are already impaired by one or more of these pollutants. Quantitative risk assessments are far beyond the scope of this project and would need to be performed on a site-specific basis. The approach taken will be to avoid using those materials that are most toxic to aquatic species for projects in, over, or near water.

### **Persistent, Bioaccumulative Toxic Chemicals (PBTs)**

In recent years much attention has been paid to toxic chemicals that persist in the environment and bioaccumulate. The nomenclature has varied from POPs (persistent organic pollutants) to BCCs (bioaccumulative chemicals of concern) to PBTs, and we will use the latter designation in this report. Whatever they may be called, PBTs pose a serious threat, and many organizations including the United Nations, International Joint

Commission on the Great Lakes, and U.S. EPA have proposed strategies to reduce or eliminate them. The Washington State Department of Ecology is working on a statewide plan to reduce and where possible eliminate them from the environment.

In 1992, the Province of Ontario Ministry of the Environment constructed a list of 27 candidate substances for future bans or phaseouts. This list was adopted by the Washington State Department of Ecology as a working list, but a new approach resulted in a list of 12 substances, which has now increased to 25. The same 12 chemicals have also been identified by EPA (USEPA 1999d) and the U.S. Canada Binational Agreement (Canada-US Binational Toxics Strategy, 1997) as the highest priority. A second tier of chemicals has been identified as level II substances by the U.S. Canada Binational Agreement. Both the original Ontario list of 27 and the Level II list contain pentachlorophenol and PAHs such as those in creosote. The priority 12 list also contains dioxins and benzo[a]pyrene. These PBT listings are shown in Table 17 below with the symbol “X” or the designation “level I” or “level II.”

The EPA has developed a prioritized chemical list of 879 chemicals “based on their tendency to persist in the environment once released (i.e., persistence), their tendency to accumulate in animal tissues (i.e., bioaccumulate), and their potential to cause adverse effects in humans or aquatic ecosystems (i.e. toxicity).” (USEPA 1997b) The list was derived using EPA’s Waste Minimization Prioritization Tool. The stated purpose of the prioritized chemical list is threefold:

- 1) “to reduce, as a nation, the presence of the most persistent, bioaccumulative, and toxic chemicals in hazardous wastes 25% by the year 2000 and 50% by the year 2005; For example, “Government agencies could focus source reduction and recycling activities on high-scoring chemicals and the hazardous wastes that are likely to contain these chemicals.”
- 2) to avoid transferring these chemicals across environmental media; and
- 3) to ensure that these chemicals are reduced at their source whenever possible, or, when not possible, that they are recycled in an environmentally sound manner.”

PBT scores from the Waste Minimization Prioritization Tool (WMPT) are also shown in Table 19. Based on the WMPT, pentachlorophenol and the group of potentially carcinogenic PAHs in creosote have by far the highest PBT scores of 17 to 18, respectively, out of a possible 18 points. The group of metals, including arsenic, copper, chromium, nickel, and copper are all ranked at 13 points. These metals score lower mainly because they don’t bioaccumulate. EPA has also developed a list of 30 “Waste Minimization Priority Chemicals” that it considers PBTs based on an “agency-wide expert review of scientific information.” This list includes PCP and most PAHs.

**Table 19. PBT Status of Wood Preservative Components**

	-----Government PBT Lists-----				WMPC List <sup>5</sup>	WMPT score <sup>6</sup> (6=best; 18=worst)
	UN <sup>1</sup>	US/CA <sup>2</sup>	EPA <sup>3</sup>	Ontario <sup>4</sup>		
PCP		level II		X	X	17
HCB	X	level I	X	X	X	18
PCDD	X	level I	X	X	X	ND
PCDF	X	level I	X	X	X	ND
TCDD	X	level I	X	X	X	18
Creosote		level II (see detail below)		(See detail below)		10-18, av=13
Arsenic						13
Chromium (VI)						13
Chromium (III)						13
Copper						13
Nickel						13
Zinc						13

Compound	% in creosote <sup>7</sup>	---PBT Lists---		WMPC List <sup>5</sup>	WMPT Score <sup>6</sup>
		EPA <sup>3</sup>	Ontario <sup>4</sup>		
<u>Light PAH</u>					
Naphthalenes	15.45			X	11
Phenanthrene	12.90		X	X	
Acenaphthene	8.70			X	13
Fluorene	7.45			X	13
Dibenzofuran	6.25			X	10
2-Methylnaphthalene	2.15				
1-Methylnaphthalene					
Anthracene	1.45		X	X	12
Biphenyl	1.35				
Acenaphthylene	1.02X				
<u>Heavy PAH</u>					
Carbazole					
Fluoranthene	7.45			X	17
Pyrene	5.30			X	
Chrysene	1.63				16
1,2-Benzanthracene	0.20				
<u>Potentially Carcinogenic PAHs</u>					
Benzo(a)anthracene	.85		X	X	18
Benzo(k)fluoranthene	.40			X	17
Benzo(ghi)perylene	.08		X	X	17
Indeno(1,2,3-cd)pyrene	.05			X	17
Benzo(b)fluoranthene	.60			X	18
Benzo(a)pyrene	.20	X	X	X	18

Notes:

- 1 United Nations POPs Treaty
- 2 U.S. Canada Binational Agreement
- 3 US EPA highest priority PBTs
- 4 Province of Ontario Ministry of the Environment
- 5 US EPA Waste Minimization Priority Chemicals
- 6 US EPA Waste Minimization Prioritization Tool
- 7 Ingram 1982

Dioxins, including both 2,3,7,8-TCDD and other polychlorinated dibenzo dioxins and furans, are listed on all of the governmental PBT lists referenced in Table 17. Dioxins are not products, but contaminants sometimes generated in the production or destruction of certain chlorine-based materials. Because of their high toxicity, persistence, and bioaccumulation, dioxins are a concern even when present at very small concentrations in products. It is important to distinguish between materials that are sources of dioxins and those that are merely receptors of omnipresent pollution. The goal of policies to limit dioxin sources is ultimately to reduce background levels so that foods such as milk, cheese, meat, and mothers' milk are no longer contaminated.

## **Disposal**

Another important consideration in selecting wood preservatives is whether treated wood or sawdust or other wood waste would need to be disposed of as a hazardous waste rather than as solid waste. At the federal level, treated wood is not specifically listed as a hazardous waste under RCRA and therefore is not considered a hazardous waste unless it exhibits a hazardous waste characteristic. In the case of treated wood, that characteristic would be failing the Toxicity Characteristic Leaching Procedure (TCLP). Wood treated with PCP or creosote routinely passes TCLP. Wood treated with arsenic might be expected to fail TCLP, but arsenic-treated wood and wood waste are exempt from the federal designation as hazardous waste provided they are generated from a person using the wood for its intended purpose. Nonetheless, concerns have been raised in other states regarding the disposal of arsenic-treated wood in municipal landfills (Maine 2003, Solo-Gabriele et al. 2000). Disposal of CCA-treated wood can be expected to increase markedly in the future. In Florida, for example one estimate predicted a seven-fold rise from 1996 to 2016 (Solo-Gabriele et al. 2000), and that estimate was made before EPA's agreement with manufacturers to phase out home uses, an action which will arguably further increase the disposal of arsenic-treated wood as concerned homeowners and others replace decks and other structures with alternatively treated wood.

California law contains two exemptions that can apply to treated wood that would otherwise be classified as hazardous waste (CalHSC 1995). One is for treated wood that has been removed from public or private utility service, provided the material is not considered federally hazardous and provided it is disposed in a landfill with proper leachate control and liner that is authorized to accept such waste. The other exemption applies to wood that is reused in a way consistent with proper use of the preservative.

If a material does not qualify for one of the exemptions, proper disposal is governed by a determination as to whether or not the waste is hazardous. As in other states, California law requires that the generator of the waste characterize the hazards either by using their knowledge about the waste or by analytical means. The classification of the waste as hazardous depends on four characteristics: ignitability, corrosivity, reactivity, and toxicity. For treated wood, the issue would be toxicity. The California toxicity characteristic is determined two waste extraction tests, the TCLP required by RCRA and the Waste Extraction Test (WET). Both tests measure the amount of toxicant solubilized under conditions that might occur in landfills, but the WET test is "more vigorous in extracting inorganic constituents." The threshold for soluble extraction is called the



Soluble Threshold Limit Concentration (STLC). In addition, California has established Total Threshold Limit Concentrations (TTLC) for 20 inorganic and 18 organic substances in an effort to minimize the effects of land disposal of persistent and bioaccumulative substances. STLCs and TTLCs for wood preservative components are listed in Table 20.

Testing conducted at the Florida Center for Solid and Hazardous Waste Management found that samples of CCA-treated wood ground into sawdust routinely failed the TCLP leaching test, with an average arsenic leachate concentration of 6.7 mg/L for all sample types, compared to the regulatory limit of 5 mg/L (Townsend 2001). Copper and chromium levels did not exceed limits for any samples. Leachate concentrations decreased as particle size increased, with extracted arsenic concentrations below the 5 mg/L limit for all but one sample of chipped wood, and all samples of 20-gram and 100-gram blocks. Retention levels in the wood were .25 and .4 pcf, and no correlation was found between retention level and leaching. The implication of this testing seems to be that CCA-treated wood would generally fail the TCLP test (and presumably the more sensitive WET test) for arsenic if ground into sawdust but not if tested whole.

**Table 20. Limit Concentrations for Hazardous Waste Designation in California**

<b>Substance</b>	<b>STLC (mg/kg)</b>	<b>TTLC (mg/kg)</b>
arsenic and/or arsenic compounds	5.0	500
chromium (VI) compounds	5.0	500
chromium and/or chromium (III) compounds	560	2500
copper and/or copper compounds	25	2500
nickel and/or nickel compounds	20	2000
zinc and/or zinc compounds	250	5000
pentachlorophenol	1.7	17

The California Department of Toxic Substances Control has not done a comprehensive study of various treated wood materials to determine which, if any, would be classified as hazardous waste under the WET test. However, according to David Elias of the Regional Water Quality Control Board, pressure-treated wood (presumably mostly CCA) sometimes passes and sometimes fails the tests, possibly because of variations in how the wood was treated and the conditions to which it was exposed before testing. (Elias 2001) Based upon this information, it seems that a large amount of testing would need to be done to understand which waterborne treatments would be expected to fail the STLC test.

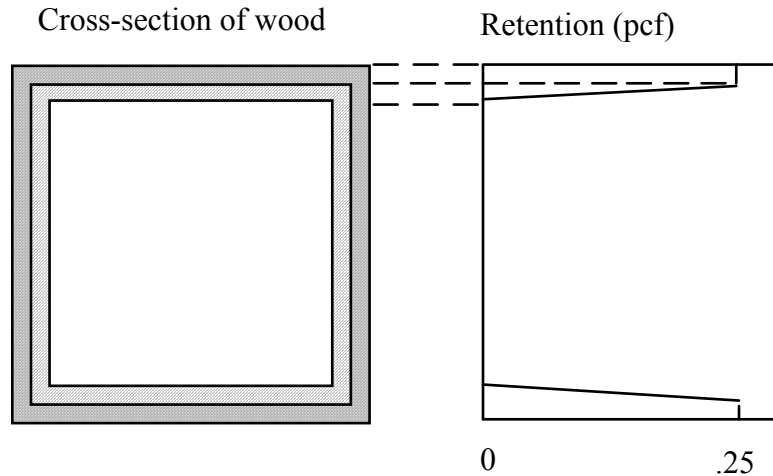
The TTLC test is potentially easier to predict, since only the total concentration of the compound in the wood needs to be determined. In the case of CCA, at a uniform retention of 0.25 pcf, the concentrations of As, Cu, and Cr can be calculated, as shown in Table 21 (Profile A), assuming a typical wood density of 0.45. This calculation shows that CCA has nearly four times the TTLC limit for arsenic, easily classifying the wood as a hazardous waste. In reality, the concentration of metals in the wood will not be uniform, but will be greater in the outer portions of the wood, where the specified retention levels should be met. Average retention thus will be lower, especially for larger pieces of wood. Another factor affecting the concentration of metals is the moisture content of the wood.

Since water is much heavier than wood fiber, the amount of water held in the wood has considerable influence on the weight (density) of a particular piece of wood. As wood dries out, the metals concentrations would rise. To show how more limited penetration of preservative would change the total concentration of arsenic, Profile B was chosen to represent a section of 4x4 timber treated to a retention of .25 pcf for the outer 10 mm, declining to zero over the next 10 mm, with no penetration at all inside 20 mm. In this case, the concentration within each concentric ring is calculated separately and weighted by the corresponding area. The result is an average concentration half that of a fully penetrated sample, but the wood still exceeds the TTLC limit by a factor of two. Wood treated to higher retention levels contains proportionally larger amounts of each metal.

**Table 21. Calculated Total Metal Concentrations for CCA-Treated Wood (.25 pcf)**  
*(Concentrations exceeding TTLC limits are shown in boldface type.)*

Substance	Concentration (mg/kg)		TTLC
	Profile A	Profile B	
Arsenic	<b>1957</b>	<b>978</b>	500
Copper	1305	652	2500
Chromium	2181	1090	2500

**Figure 3. Diagram of Retention Profile B**



Similar calculations for other treated wood products are shown in Table 22. All of the materials containing arsenic appear to fail TTLC, even in Profile B which assumes average preservative retention throughout the wood at 50% of specification. Many of the copper-containing treatments also fail for copper at uniform .25 pcf, but real samples might pass if penetration is much lower. Wood treated to .4 pcf and higher retentions would likely fail. Very thick materials such as pilings might pass if a sufficient volume of untreated wood exists in the core.

**Table 22. Calculated Total Metal Concentrations for Other Treated Wood (.25 pcf)**  
*(Concentrations exceeding TTLC limits are shown in boldface type.)*

Substance	Concentration (mg/kg)		TTLC
	Profile A	Profile B	
<u>ACC</u>			
Copper	2242	1121	2500
Chromium	<b>3130</b>	1565	2500
<u>ACA</u>			
Copper	<b>3511</b>	1755	2500
Arsenic	<b>2888</b>	<b>1444</b>	500
<u>ACZA</u>			
Copper	<b>3525</b>	1762	2500
Zinc	1772	1090	5000
Arsenic	<b>1438</b>	<b>719</b>	500
<u>ACQ</u>			
Copper	<b>4702</b>	2351	2500
<u>CC</u>			
Copper	<b>4392</b>	2196	2500
<u>CBA</u>			
Copper	<b>3454</b>	1727	2500

Conclusion: Wood treatments containing arsenic appear likely to fail the TTLC test in all cases, although detailed measurements should be done to confirm that the distribution of arsenic in the wood is sufficient to exceed the criteria for various timber dimensions. Copper-treated wood probably passes the TTLC in most cases, at least at the lowest retention levels, but measurements should be done on samples of wood with the highest copper retentions, percent copper, and copper penetration depth.

## Local Regulations and Policies

Three resolutions passed by the San Francisco Board of Supervisors (and now official city policy) have implications for the selection of wood preservatives. The first resolution, passed on March 22, 1999, placed a high priority on phasing out sources of dioxin (SFBS 1999). The second resolution, passed on May 21, 2001, expressed the city's preference for non-wood utility poles and directed pole users to step up their use of alternatives (SFBS 2001a). The third resolution, passed on November 20, 2001, requires that arsenic-treated wood not be used on city projects and that departments that maintain existing arsenic-treated structures where human contact is likely keep them sealed and develop plans to remove them. The City's selection criteria for wood preservatives need to be in accord with all appropriate city policies. The three resolutions are spelled out in more detail below.

### Dioxin Policy

The dioxin policy defines dioxins to include not only polychlorinated dibenzo-p-dioxins, but also polychlorinated dibenzofurans (PCDFs) and polychlorinated biphenyls (PCBs). Thus this policy does apply to pentachlorophenol, which contains both PCDD and PCDF. This resolution requires in part that the City and County of San Francisco:

- \* designate dioxin pollution as a high priority for immediate action to restore water, air and total environment quality and protect public health;
- \* direct the San Francisco Public Utilities Commission to exercise its full power and jurisdiction to phase out dioxin at its sources;
- \* work with other local governments to convene a regional task force to identify the sources of regional dioxin pollution, including sources from all municipal practices; this task force would also develop dioxin pollution prevention strategies along with any associated cost implications, and make any further recommendations to implement the intent of this resolution;
- \* implement dioxin pollution prevention practices as recommended by the regional task force in all waste management and recycling programs by City and County departments, and encourage such pollution prevention practices in all hospitals and businesses that operate in the City and County of San Francisco; and be it
- \* assess its current purchasing practices and encourage that less-toxic, non-chlorinated products and processes, such as chlorine-free paper and PVC-free plastics are supported and used by the City and County of San Francisco to the extent possible as recommended by the regional task force.

Conclusion: Continued use of PCP-treated wood appears to be in conflict with city policy.

### Wood Pole Policy

The wood pole policy urges the City and County of San Francisco to “urge PG&E, Pacific Bell, and manufacturers of non-wood utility poles to conduct a feasibility study of alternatives to chemically treated wood utility poles and to urge all utility pole owners to take steps to protect public health and the environment from wood preservatives in utility poles.” Although not binding on the private utilities, the resolution also requests that they:

- \* cover the first five feet above the ground of all existing treated wood poles within 100 feet of elementary schools and parks (and daycare centers if requested to do so)
- \* report annually on the materials used when poles are replaced.

Conclusion: This policy expresses a clear preference for poles not made of treated wood. In recognition of this policy, it is suggested that before making any selection of wood preservatives for any purpose that the following questions be asked:

- \* is wood necessary for this project?
- \* if wood is chosen, is treated wood necessary for this project?

### Arsenic Ordinance

The arsenic ordinance is aimed at phasing out the use of arsenic-treated wood in city projects and protecting residents from such wood already in place. This resolution requires:

- \* developing a list of environmentally preferable alternatives to preservative-treated wood containing arsenic for non-saltwater immersion uses;
  
- \* all City Departments and contractors performing work pursuant to City contracts to purchase only pressure treated wood products from the Department of the Environment's approved list of environmentally preferable alternatives to preservative-treated wood containing arsenic;
  
- \* all City departments who own or maintain existing City playground and park equipment, such as benches, picnic tables and playsets, constructed with preservative-treated wood containing arsenic to develop a timeline and cost analysis for replacing them with arsenic-free alternatives and present the timeline within six months of the passage of this resolution to the Commission on the Environment;
  
- \* 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 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;
  
- \* preservative-treated wood containing arsenic not be re-used, burned or used for wood chips or mulch, but be disposed of in an approved landfill;
  
- \* all City Departments who own, purchase or maintain City playground and park equipment to place warning labels indicating they are constructed out of preservative-treated wood containing arsenic;
  
- \* urging the State of California to stop purchasing preservative-treated wood containing arsenic, replace all existing state park equipment (such as benches and picnic tables) constructed with preservative-treated wood containing arsenic with arsenic-free alternatives as soon as practicable, and ensure sealing of existing structures in accordance with California Health and Safety Code section 115775 until such time that all structures have been replaced with arsenic-free alternatives;
  
- \* investigating the possibility of a citywide ban on the sale and installation of preservative-treated wood containing arsenic and report back to the Commission on the Environment within six months;
  
- \* the Port of San Francisco to report back to the Commission on the Environment within six months and annually thereafter on alternatives to preservative-treated wood containing arsenic for use in saltwater immersion environments and to seal sections of docks and piers where frequent human contact is likely;

\* the Port of San Francisco to require that all treated wood purchased for use in Port facilities be certified as produced in conformance with the Best Management Practices for Treated Wood Used in Aquatic Environments; and

Conclusion: the use of arsenic-treated wood (except in saltwater immersion environments until viable alternatives are identified) is against city policy.

## **Drawbacks of Alternative Materials**

The hazards presented by wood preservatives can be eliminated if wood preservatives are not used. This statement does not necessarily mean that alternative materials are hazard-free or do not present other drawbacks. For example, the Western Wood Preservers Institute (WWPI 2001) claims that if steel utility poles are used instead of wooden ones, almost twice as many poles of the same size would be required. In addition, they cite limited research indicating that zinc leaching from galvanized steel poles can contaminate surrounding soil. Steel production uses energy and produces pollution, although it does recycle scrap materials. To adequately compare such different materials as steel and treated wood would require a life-cycle analysis that is beyond the scope of this project. Life cycle analyses are difficult to interpret when different materials or processes score better in one aspect but worse in another, requiring “apples versus oranges” comparisons.

Recycled plastic wood may also leach chemicals that could affect aquatic life. A 1992 study (Weis et al. 1992) compared the effects of leachates from CCA-treated wood and recycled plastic on a limited number of estuarine species. The effects observed from CCA leachate were clearly more severe, including depression of limb regeneration in fiddler crabs, reduced or inhibited fertilization in sea urchins, snail mortality, and chlorosis of algae. Effects were seen from the plastics as well. Limb regeneration was accelerated in fiddler crabs. Some reduction of fertilization and reduction of larval growth in sea urchins was observed. Spectrometry revealed a large number of chemicals leached in various quantities from the plastic. The environmental significance of the results is not known, but the researchers conclude that the plastic is a far less toxic material than the treated wood on the basis of the leachate tests.

Some alternative wood treatments may have other disadvantages, such as corrosion of metal hardware, mechanical properties, and higher costs. Solo-Gabriele et al. recently reported on the results of corrosion tests for ACQ-D, CBA, CC, and CDDC relative to CCA (Solo-Gabriele 2000). They report that ACQ is corrosive to mild steel and aluminum, and may be mildly corrosive to brass and hot-dipped galvanized fasteners. Copper citrate (CC) is also corrosive to mild steel and hot-dipped galvanized fasteners, but not to aluminum. CBA and CDDC have low corrosivity, comparable to CCA. It is very important that manufacturer’s recommendations be followed in selecting hardware for use with treated wood. Table 23 lists recommendations for some alternative wood treatments as compiled by Solo-Gabriele.

**Table 23. Manufacturer Metal Fastener Recommendations**

<b>Chemical</b>	<b>Metal Fastener Recommendation</b>
ACQ	hot-dipped galvanized or stainless steel
CBA	hot-dipped galvanized, nickel coated, stainless steel fasteners, or non-ferrous metals
CC	stainless steel, galvanized staples and galvanized wire for use in vineyards
CCA	hot-dipped galvanized or stainless steel fasteners
CDDC	hot-dipped galvanized or stainless steel fasteners

With regard to mechanical properties, Solo-Gabriele found that the mechanical properties of alternative–chemical treated wood (ACQ, CC, CBA, and CDDC) were similar to those of CCA. Their cost comparison for a 12-foot deck board treated with CCA, CDDC, and ACQ found the alternatives to be slightly more expensive. The average price for CCA was \$8.94, while CDDC cost \$10.29 on average, and ACQ cost \$9.90. The cost differential may be expected to narrow as the market adapts to new restrictions on CCA.

## **Selection Criteria for Acceptable Wood Treatments**

In consideration of the information presented in this report and in consultation with the San Francisco Department of the Environment, the following selection criteria are proposed for identifying acceptable wood treatments:

1. If a pressure treated product, treatment must be standardized by AWWA for the intended use. This requirement helps ensure that the treatment meets specifications to minimize leaching.
2. Product must not be used in ways that EPA prohibits or discourages.
3. Product or use must not violate state or local law, policy, or published best management practices.
4. Product may not result in the release or creation of dioxins during manufacture or disposal.
5. Product, constituents, or contaminants may not be listed on the EPA Priority PBT list or the EPA Waste Minimization Priority Chemicals list.
6. Product (or components) should not contain known, likely, or probable human carcinogens listed by EPA, NTP, IARC, or the State of California.
7. Product (or components) should not be listed as reproductive or developmental toxicants by the State of California.
8. For structures built in or over water, or where significant runoff is likely to occur, the use of copper should be minimized. If copper-based products are used, products with the lowest leaching potential should be chosen.
9. Product must not designate as a hazardous waste using criteria set by the State of California.

## **Results**

The criteria listed above should be applied separately for each proposed wood use, as detailed below. However, certain preservatives fail some of the criteria regardless of the use scenario. Table 24 shows the results of the screening against each of the selection criteria. Table 25 provides more detail on the relative copper leaching rates used to derive the values listed under the heading “copper” in Table 24. Table 26 summarizes the results of the criteria screening.



**Table 24. Screening of Wood Preservative Treatments Against Proposed Criteria**

Treatment	AWPA Std	EPA	City Policy	Dioxin	PBT	Carc	Rep/Dev	Copper <sup>10</sup>	Haz Waste
<b>CuN</b>	See appendix <sup>1</sup>	Note 2	Pass	Pass	Pass	Pass	Pass	ND, -, ND	Pass <sup>11</sup>
<b>Cu8</b>	See appendix <sup>1</sup>		Pass	Pass	Pass	Fail	Pass	ND	Pass <sup>11</sup>
<b>Creosote</b>	See appendix <sup>1</sup>	Note 3	Pass	Pass	Fail	Fail	Pass	No copper	Pass
<b>PCP</b>	See appendix <sup>1</sup>	Note 4	Fail <sup>6</sup>	Fail <sup>8</sup>	Fail	Fail	Pass <sup>9</sup>	No copper	Pass
<b>ACA</b>	See appendix <sup>1</sup>	Note 5	Fail <sup>7</sup>	Pass	Pass	Fail	Pass	ND	Fail
<b>ACC</b>	See appendix <sup>1</sup>		Pass	Fail	Pass	Fail	Pass	ND	Pass <sup>11</sup>
<b>ACQ</b>	See appendix <sup>1</sup>		Pass	Pass	Pass	Pass	Pass	0 to -, -, 0	Pass <sup>11</sup>
<b>ACZA</b>	See appendix <sup>1</sup>	Note 5	Fail <sup>7</sup>	Pass	Pass	Fail	Pass	ND, -, +	Fail
<b>CA-B</b>	See appendix <sup>1</sup>		Pass	Pass	Pass	Pass	Pass	No data	Pass <sup>11</sup>
<b>CBA</b>	See appendix <sup>1</sup>		Pass	Pass	Pass	Pass	Pass	ND, -, 0	Pass <sup>11</sup>
<b>CCA</b>	See appendix <sup>1</sup>	Note 5	Fail <sup>7</sup>	Pass	Pass	Fail	Pass	+ + +	Fail
<b>CC</b>	See appendix <sup>1</sup>		Pass	Pass	Pass	Pass	Pass	ND, -, -	Pass <sup>11</sup>
<b>DOT, borates</b>	See appendix <sup>1</sup>		Pass	Pass	Pass	Pass	Pass	No copper	Pass
<b>CDDC</b>	See appendix <sup>1</sup>		Pass	Pass	Pass	Pass	Fail	+, +, +	Pass <sup>11</sup>
<b>ZnN</b>	NA		Pass	Pass	Pass	Pass	Pass	No copper	Pass

**Notes:**

1. Each treatment has been standardized by AWPA for particular uses, as indicated in Appendix 1. Refer to the AWPA Standards for more details.
2. Copper naphthenate not allowed for indoor uses except as pressure treatment.
3. Not allowed by EPA for railings, outdoor benches and tables, playground equipment, or other uses where significant skin contact occurs unless sealed to prevent skin contact. Creosote-treated wood should not be used in residential interiors. Creosote-treated wood in interiors of industrial building should be used only for industrial building components which are in ground contact and are subject to decay or insect infestation and wood block flooring. Only allowed for patios and walkways if clean and free of residue
4. Not allowed by EPA for railings, outdoor benches and tables, playground equipment, or other uses where significant skin contact occurs unless sealed to prevent skin contact. Pentachlorophenol-treated wood should not be used in residential, industrial, or commercial interiors except for laminated beams or for building components which are in ground contact and are subject to decay or insect infestation and where two coats of an appropriate sealer is applied. Only allowed for patios and walkways if clean and free of residue.
5. Arsenic-treated wood may not be used in homes after 2003.
6. PCP fails San Francisco city policy that seeks to minimize sources of dioxins.
7. Exception for salt water immersion uses until alternatives can be found.
8. PCP fails the dioxin criterion because it contains dioxins created during the manufacturing process.
9. PCP itself is not listed as a reproductive or developmental toxicant by the State of California, but it contains contaminants that are listed.
10. Copper criterion only applies to uses in or over water or where runoff may be a concern.  
Score relative to CCA copper leaching in three environments: above ground or soil contact, fresh water immersion, salt water immersion, where + = similar to CCA, 0 = 2-5 times CCA, - = >5 times CCA  
ND = no data. See Table 25 for more information.
11. There is a possibility that some copper-treated wood may fail the TTLC test and thus be designated as a hazardous waste in California. The result depends on the quantity of copper in the treatment, retention level, and depth of preservative penetration.

To determine the copper-based treatments that may be expected to have the smallest copper leaching in various environmental exposures, the data discussed earlier in this report are summarized below in Table 25. No single test is expected to predict field measurements. All results are referenced to CCA as a standard. Numbers greater than 1 indicate that the material leaches more copper than CCA does. The results stated in columns 2 through 6 are all measurements in which both CCA and the indicated material were tested simultaneously under the same conditions. The columns headed “Fresh-2” and “Salt-2” are the results of model calculations. These results were grouped into three categories as follows:

“+” indicates Cu leaching essentially similar to that from CCA (from 0.5 to 1.9 times)

“0” indicates Cu leaching greater than from CCA (2.0 to 4.9 times)

“-“ indicates Cu leaching much greater than from CCA (5 times or more)

The symbols +, 0, or - are placed in the “copper” column of Table 24 for each of the three exposures: above ground or in soil contact, fresh water immersion, and salt water immersion.

**Table 25. Comparison of Copper Leaching Results from Various Studies**

(Numerical values are dimensionless and normalized to CCA = 1. See key below table for references to studies.)

Treatment	Above	Deck	Stake	Fresh-1	Salt-1	Fresh-2	Salt-2
CCA	1	1	1	1	1	1	1
ACQ-D	2.8		2.3, 3.2, 5.6, 8.1	8	4.2		
ACQ-B		2.9, 2.2					
ACQ unspec.						8-10	
CBA			3.5, 6.2, 18	7.6	3.6		
CC				18	5.5		
CDDC				1.9	1.05		
ACZA						12-31	0.7-1.8
CuN						6-10	

**Key:**

Above = above ground test, block on concrete 18 month duration (see Solo-Gabriele 2000)

Deck = simulated deck, 18 month duration (see Solo-Gabriele 2000)

Stake = stakes driven into ground, results from below ground portion, duration 13 to 42 months (see Solo-Gabriele 2000, Hickson 1999)

Fresh-1 = de-ionized immersion, ground up wood, 18 hour duration (see Townsend 2001b)

Salt-1 = synthetic sea water immersion, ground up wood, 18 hour duration (see Townsend 2001b)

Fresh-2 = fresh water model calculations after Brooks (see Brooks 1997a, 1997b, 2003a, 2003b).

Results quoted are calculated cumulative leaching from one week to one month.

Salt-2 = salt water model calculations after Brooks (see Brooks 1997a, 1997b, 2003b). Results quoted are calculated cumulative leaching from one week to one month.

**Table 26. Results of Criteria Screening**

<b>Treatment</b>	<b>Result</b>
<b>CuN</b>	Acceptable for some uses. See Table 24.
<b>Cu8</b>	Not acceptable.
<b>Creosote</b>	Not acceptable.
<b>PCP</b>	Not acceptable.
<b>ACA</b>	Not acceptable. Exception for salt water immersion.
<b>ACC</b>	Not acceptable.
<b>ACQ</b>	Acceptable for some uses. See Table 24.
<b>ACZA</b>	Not acceptable. Exception for salt water immersion.
<b>CA-B</b>	Acceptable for some uses. See Table 24.
<b>CBA</b>	Acceptable for some uses. See Table 24.
<b>CCA</b>	Not acceptable. Exception for salt water immersion.
<b>CC</b>	Acceptable for some uses. See Table 24.
<b>DOT, borates</b>	Acceptable for some uses. See Table 24.
<b>CDDC</b>	Not acceptable.
<b>ZnN</b>	Acceptable for some uses. See Table 24

The treatments that passed the screening criteria for at least some uses were then cross-checked with the AWPAs standards. Those for which standards exist are listed in Table 27 below as acceptable materials.

**Table 27. Summary of Acceptable Materials by Use**

(List will be updated periodically to allow for the inclusion of new materials.)

<b>DESCRIPTION OF USE</b>	<b>UCS (AWPA Use Classification)</b>	<b>C (AWPA Standard )</b>	<b>Acceptable Materials (must also be allowed by building code for specific intended use)</b>
<b>BEAMS &amp; TIMBERS (GLUE LAM.)</b>			
Dry environment, above ground	1,2	C28	CuN <sup>1</sup>
Damp environment, above ground	3B	C28	CuN <sup>1</sup>
Ground contact	4A	C28	CuN <sup>1</sup>
Highway construction	4B, 4C	C14	ACQ <sup>2,3</sup>
<b>BUILDING CONSTRUCTION MATERIAL</b>			
Floor plate	2, 3B	C2, 15, 31	ACQ <sup>3</sup> , CA-B, CBA, CC, DOT or other borates
Flooring, residential			
Damp environment	3B	C2	ACQ <sup>3</sup> , CA-B, CBA, CC
Dry environment	1, 2	C2, 31	DOT or other borates
Framing, interior	1, 2	C2, 15, 31	DOT or other borates
Joists			
Interior, above ground	1, 2	C2, 15, 31	DOT or other borates
Exterior, above ground	3B	C2, 15	ACQ <sup>3</sup> , CA-B, CBA, CC
Soil contact	4A	C2, 15	ACQ <sup>3</sup> , CA-B, CBA
Lumber			
Above ground	3B	C2	CuN <sup>1</sup> , ACQ <sup>3</sup> , CA-B, CBA, ZnN <sup>1</sup>
Ground contact	4A	C2	CuN <sup>1</sup> , ACQ <sup>3</sup> , CA-B, CBA
Tree stakes	4A	C2	CuN, ACQ <sup>3</sup> , CA-B, CBA
Fresh water use	4A	C2	Plastic-coated lumber <sup>4</sup> , CuN,

			ACQ <sup>3</sup>
No ground contact, protected from liquid water	2	C31	DOT or other borates
Permanent wood foundation (lumber or plywood)	4B	C22	None
<b>Plywood</b>			
Sub-floor, damp above ground	2	C9	ACQ <sup>3</sup> , CA-B, CBA, CC
Exterior, above ground	3B	C9	ACQ <sup>3</sup> , CA-B, CBA, CC
Ground contact	4A	C9	ACQ <sup>3</sup> , CA-B, CBA, CC
Fresh water use	4A	C9	None
No ground contact, protected from liquid water	2	C31	DOT or other borates
<b>Poles, building</b>			
Round	4A, 4B	C4, 16	ACQ
Sawn	4A, 4B	C2, 16	CuN <sup>1</sup> , ACQ <sup>3</sup> , CA-B, CBA, CC, DOT or other borates
Studs	3B	C2, 15	DOT or other borates
<b>DECKING</b>			
Highway bridge	4B	C2, 14	CuN, ACQ <sup>3</sup>
<b>Above ground</b>			
Not over or near water	3B	C2, 15	CuN, ACQ <sup>3</sup> , CA-B, CBA,
Over or near water	3B	C2, 15	Plastic-coated wood <sup>4</sup> , CuN, ACQ, ZnN
Ground contact	4B	C2, 15	CuN, ACQ <sup>3</sup> , CA-B, CBA
<b>FENCES</b>			
Pickets, slats, trim	3A, 3B	C2, 15	CuN, ACQ <sup>3</sup> , CA-B, CBA
Posts, sawn	4A	C2, 15	ACC, ACQ <sup>3</sup> , CA-B
Posts, round	4A	C5	CuN, ACQ <sup>3</sup> , CA-B, CC
<b>HIGHWAY MATERIAL</b>			
Lumber and timbers for bridges, structural members, cribbing, and culverts	4B	C2, 14	CuN, ACQ <sup>3</sup>
<b>Structural lumber and timbers</b>			
In salt water use	5A, 5B, 5C	C3, C14	(ACA, CCA, ACZA) <sup>5</sup>
Piles, foundation, land use	4C	C3, 14	No acceptable non-arsenic materials available
Piles, foundation, fresh water use	4C	C3, 14	No acceptable non-arsenic materials available
Piling in salt water use	5A, 5B, 5C	C3, 14	(ACA, CCA, ACZA) <sup>5</sup>
Posts: round, half-round, quarter round	4A	C5, 14	CuN, ACQ <sup>3</sup>
Posts: sawn	4A	C2, 14	CuN, ACQ <sup>3</sup> , CA-B, CBA
Handrails and guardrails	3B	C2, 14	CuN, ACQ <sup>3</sup> , CA-B, CBA
<b>Posts, guardrail</b>			
Round	4A	C2, 14	CuN, ACQ <sup>3</sup>
Sawn	4A	C2, 14	CuN, ACQ <sup>3</sup> , CA-B, CBA
<b>MARINE LUMBER &amp; TIMBERS</b>			
Fresh water	4A	C2	Plastic-coated wood <sup>4</sup> , CuN, ACQ <sup>3</sup> , CA-B
Brackish water or salt water	5A, 5B, 5C	C2, 18	Plastic-coated wood <sup>4</sup>
<b>PILES</b>			
Foundation (round)	4C	C3	No acceptable non-arsenic materials available

Land use (round)	4C	C3	CuN
Fresh water use (round)	4C	C3	Plastic-coated piles, CuN
Marine (round) in salt or brackish water	5A, 5B, 5C	C3, 18	(ACA, CCA, ACZA) <sup>5</sup>
Marine, dual treatment (round)	5A, 5B, 5C	C3, 18	(ACA, CCA, ACZA) <sup>5</sup>
Sawn timber piles	4B	C24	(ACA, CCA, ACZA) <sup>5</sup>
<b>UTILITY POLES</b>			
Sited in soil	4A, 4B	C4	CuN, ACQ <sup>3</sup>
Sited in impervious surface	4A, 4B	C4	CuN (butt-treatment preferred)

**Notes:**

1. CuN and ZnN allowed for indoor use only as pressure-treated wood. Other applications are not registered for indoor use.
2. Only standardized if treated before lamination.
3. Select either ACQ-B or ACQ-D as appropriate based on AWPA standards.
4. Non-PVC plastic only. Lumber should not be treated with arsenic.
5. Non wood materials are preferred. When pressure treated wood is required, an exemption exists for saltwater immersion environments for structures such as pilings and piers until a viable alternative is available.

## Summary

The primary wood treatments have been reviewed for their toxicity and other hazards. It is recognized that a distinction must be made between the wood preservative itself and the treated wood. However, the studies reviewed indicated that preservative chemicals do leach from treated wood and are picked up on hands from contact with the wood. Thus, the same health effects associated with the chemicals can also be caused by contact with the wood or contaminated environmental media such as soil or water.

The primary human health concerns are associated with PCP, creosote, and arsenical preservatives. All contain carcinogens, and some risk assessments have identified unacceptably high risk levels for certain exposure scenarios. In addition, PCP is contaminated with several highly toxic compounds, including dioxins.

Copper is the treatment most toxic to aquatic organisms, and copper levels are already an important issue in parts of San Francisco Bay. Although the amount of copper (or other chemicals) that leach from wood structures in or around water may in many cases be less than that expected to impact aquatic life, the same may not be true when background levels of these and other chemicals or other stressors are included. The prudent course is to minimize the use of copper in aquatic environments or where runoff is expected to occur.

PCP, some components of creosote, and some contaminants of PCP display the characteristics of persistence, bioaccumulation, and toxicity that have identified these materials as PBTs by some agency criteria. Metals such as arsenic, copper, chromium, and zinc are not considered PBTs because they do not bioaccumulate.

Some types of treated wood appear to qualify as hazardous waste in California and if discarded (except by utilities) would not legally be allowed in municipal landfills. Wood treated with arsenic is the most likely to fail state standards, but some copper treated wood may also be a disposal concern.

Based on the information presented in this report and in consultation with the San Francisco Department of the Environment, a set of nine selection criteria were proposed for identifying acceptable wood treatments:

1. If a pressure treated product, treatment must be standardized by AWPA for the intended use. This requirement helps ensure that the treatment meets specifications to minimize leaching.
2. Product must not be used in ways that EPA prohibits or discourages.
3. Product or use must not violate state or local law, policy, or published best management practices.
4. Product may not result in the release or creation of dioxins during manufacture or disposal.
5. Product, constituents, or contaminants may not be listed on the EPA Priority PBT list or the EPA Waste Minimization Priority Chemicals list.
6. Product (or components) should not contain known, likely, or probable human carcinogens listed by EPA, NTP, IARC, or the State of California.
7. Product (or components) should not be listed as reproductive or developmental toxicants by the State of California.

8. For structures built in or over water, or where significant runoff is likely to occur, the use of copper should be minimized. If copper-based products are used, products with the lowest leaching potential should be chosen.

9. Product must not designate as a hazardous waste using criteria set by the State of California.

When applied to the wood treatments for which AWPAs standards exist, these criteria eliminated pentachlorophenol, creosote, and arsenicals as acceptable wood treatments. Copper-8-quinolinolate and CDDC were also eliminated. The acceptable treatments have been presented in the form of a list indexed by use and cross referenced to the appropriate AWPAs standards and use codes.

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# Appendix 1

Pressure Treatments for which AWPA Standards Exist

(Uses with standards are shown as shaded cells. Refer to the AWPA Standards for details)

DESCRIPTION OF USE	AWPA Standards		Wood Preservatives													
	UCS	C	CuN	Cu8	Creo	PCP	ACA	ACC	ACQ	ACZA	CA-B	CBA	CCA	CC	DOT	CDDC
<b>BEAMS &amp; TIMBERS (GLUE LAM. Treated before lamination)</b>																
Dry environment, above ground	1,2	C28		Note 1					NL	Note 2	NL	NL	NL	NL	NL	NL
Damp environment, above ground	3B	C28		Note 1					NL	Note 2	NL	NL	NL	NL	NL	NL
Ground contact	4A	C28		NL					NL	Note 2	NL	NL	NL	NL	NL	NL
Highway construction	4A, 4C	C14		Note 1					NL	NL	NL	NL	NL	NL	NL	NL
<b>BUILDING CONSTRUCTION MATERIAL</b>																
Floor plate	2, 3B	C2, 15, 31	NL	Note 3	NR	NR										
Flooring, residential																
Damp environment	3B	C2	NL	Note 3	NR	NR									NL	
Dry environment	1, 2	C2, 31	NL	Note 3	NR	NR										
Framing, interior	1, 2	C2, 15, 31	NL	Note 3	NR	NR										
Joists																
Interior, above ground	1, 2	C2, 15, 31	NL	Note 3	NR	NR										
Exterior, above ground	3B	C2, 15	NL	Note 3	NR	NR									NL	
Soil contact	4A	C2, 15	NL	NR	NR	NR								NL	NL	
Lumber																
Above ground	3B	C2		Note 3	Notes 4,5	Notes 4,6									NL	
Ground contact and fresh water use	4A	C2		NR	Note 5	Note 6									NL	
No ground contact, protected from liquid water	2	C31	NL	NL	NL	NL	NL	NL	NL	NL	NL	NL	NL	NL	NL	NL
Permanent wood foundation (lumber or plywood)	4B	C22	NL	NL	NL	NL		NR			NL	NL		NL	NL	
Plywood																
Sub-floor, damp above ground	2	C9	NL		Note 5	Note 6									NL	NL
Exterior, above ground	3B	C9	NL		Note 5	Note 6									NL	NL
Ground contact and fresh water use	4A	C9	NL	NR	Note 5	Note 6									NL	NL
No ground contact, protected from liquid water	2	C31	NL	NL	NL	NL	NL	NL	NL	NL	NL	NL	NL	NL	NL	NL
Poles, building																

Round	4A, 4B	C4, 16	NL	NR					NR			NL	NL		NL	NL	NL
Sawn	4A, 4B	C2, 16		NR					NR						NL	NL	NL
Studs	3B	C2, 15	NL	Note 3	NR	NR											
<b>DECKING</b>																	
Highway bridge	4B	C2, 14		NL					NR			NL	NL		NL	NL	NL
Above ground	3B	C2, 15		Note 3	Note 7	Note 7									NL	NL	NL
Ground contact	4B	C2, 15		NR	Note 7	Note 7									NL	NL	NL
<b>FENCES</b>																	
Pickets, slats, trim	3A, 3B	C2, 15		Note 3											NL	NL	
Posts, sawn	4A	C2, 15	NL	NL								NL			NL	NL	
Posts, round	4A	C5		NL								NL				NL	NL
<b>HIGHWAY MATERIAL</b>																	
Lumber and timbers for bridges, structural members, decking, cribbing, and culverts	4B	C2, 14		NL					NR			NL	NL		NL	NL	NL
Structural lumber and timbers																	NL
In salt water use	5A, 5B, 5C	C3, C14	NL	NL					NR	NL		NL	NI		NL	NL	NL
Piles, foundation, land and fresh water use	4C	C3, 14	NL	NL					NR	NL		NL	NL		NI	NL	NL
Piling in salt water use	5A, 5B, 5C	C3, 14	NL	NL			NR		NR	NL		NL	NL		NL	NL	NL
Posts: round, half-round, quarter round	4A	C5, 15		NL								NL	NL		NI	NL	NL
Posts: sawn	4A	C2, 14		NL			NL								NL	NL	NL
Handrails and guardrails	3B	C2, 14		Note 3											NL	NL	NL
Posts, guardrail																	
Round	4A	C2, 14		NL					NR			NL	NL		NI	NL	NL
Sawn	4A	C2, 14		NL					NR						NL	NL	NL
<b>MARINE LUMBER &amp; TIMBERS</b>																	
Fresh water	4A	C2		NR									NL		NL	NL	NL
Brackish water or salt water	5A, 5B, 5C	C2, 18	NL	NR		NR			NR	NL		NL	NL		NL	NL	NL
<b>PILES</b>																	
Foundation (round)	4C	C3	NL	NL					NL	NL		NL	NL		NL	NL	NL
Land and fresh water use (round)	4C	C3		NL					NL	NL		NL	NL		NL	NL	NL
Marine (round) in salt or brackish water	5A, 5B, 5C	C3, 18	NL	NL			NR		NL	NL		NL	NL		NL	NL	NL
Marine, dual treatment (round)	5A, 5B, 5C	C3, 18	NL	NL			NR		NL	NL		NL	NL		NL	NL	NL

Sawn timber piles	4B	C24	NL	NL				NL	NL		NL	NL		NL	NL	Note 1
<b>UTILITY POLES</b>	4A, 4B	C4		NL				NL			NL	NL		NL	NL	NL

Notes

NL = not listed in AWPA Standards

NR = not recommended

1. Southern Pine only
2. Douglas Fir only
3. Not for Douglas fir
4. Not allowed by EPA for railings, outdoor benches and tables, playground equipment, or other uses where significant skin contact occurs unless sealed to prevent skin contact.
5. Creosote-treated wood should not be used in residential interiors. Creosote-treated wood in interiors of industrial building should be used only for industrial building components which are in ground contact and are subject to decay or insect infestation and wood block flooring.
6. Pentachlorophenol-treated wood should not be used in residential, industrial, or commercial interiors except for laminated beams or for building components which are in ground contact and are subject to decay or insect infestation and where two coats of an appropriate sealer is applied.
7. Only allowed for patios and walkways if clean and free of residue