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Water-Borne Wood Preservation and End-of-Life Removal History and Projection

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Abstract

Use of water-borne wood preservatives began in approximately the 1950s. Residential and commercial uses rapidly developed for products such as decking, fences, and other outdoor structures. Nearly all such products were treated by preservatives using arsenic as a major ingredient. The most common preservative was chromated copper arsenate (CCA). A smaller volume used ammoniacal copper zinc arsenate (ACZA). Preservative label changes made in 2003 limited uses of these arsenical treatments to industrial or agricultural type uses, such as poles, piles, ties, bridges, and fencing. Use volumes of preservative-treated wood continued to grow after the label change, but the types of preservatives used changed greatly. The amounts of water-borne treated wood reaching end-of-life and being disposed also continued to grow, reflecting the increasing inventory of volume in service. However, the volume of arsenical-treated wood being disposed peaked in approximately 2008 and is now only approximately one-quarter of that volume. Most of the arsenical-treated wood now being disposed consists of large, easily identified and separated pieces, such as round poles, piles, and fence posts and timbers, which can be easily managed separated from other wood construction and demolition (C & D) waste. Thus, managing C & D waste to limit arsenic contamination of potential products, such as mulch, will be much more practical than some have feared.

Keywords

Water-Borne, Wood, Preservative, Arsenic, Copper, Disposal, CCA, C & D, Landfill

1. Introduction

Nearly all preservative treated wood used in U. S. residential and commercial construction is a water-borne variety of preservative. This contrasts with oil-borne preservatives such as pentachlorophenol, creosote, and copper naphthenate that are used mainly for industrial products such as railroad ties, utility poles, piling, and other marine and highway construction. While also used for industrial products, water-borne treatment of wood for use as decks and fencing in residential and commercial applications started to become common during the 1950s. The residential and commercial uses of preservative treated lumber rapidly became very popular, reaching annual production of over 400 million cubic feet by 1987 [1].

Water-borne treatments from inception to 2003 primarily arsenical treatments, meaning that the preservative included arsenic as an active ingredient. Chromated copper arsenate (CCA) was most common and ammoniacal copper zinc arsenate (ACZA) was used less, but could be used for Douglas fir lumber, which does not treat well with CCA.

Public and regulatory concerns regarding human contact with arsenic from wood products, and arsenic in the waste streams, were developed in the 1990s and 2000s. In 2003, the wood preservative manufacturers voluntarily changed the label approved end uses of CCA and ACZA so that residential and commercial uses would not continue and only "heavy duty" industrial and agricultural products would be treated with these preservatives. Thus, annual treatment volume by arsenical preservatives (CCA and ACZA) dropped from nearly 600 million cubic feet to approximately 100 million cubic feet.

Alternative non-arsenical water-borne preservatives were developed and almost immediately became common. Copper azole (CA) and alkaline copper quat (ACQ) preservatives were standardized in several evolving types by the American Wood Protection Association (AWPA) in the late 1990s and early 2000s. Dissolved copper provided most of the decay protection in these systems. Most lumber treated for residential decks and fences used these preservatives.

Preservatives using fine particles of copper, called micronized copper, were approved by the International Codes Council Engineering Service (ICC ES) and began to be commonly used after 2010. The main preservatives of this type were micronized copper azole (MCA), standardized by AWPA in 2016, and micronized copper quat (MCQ). MCA now leads the residential and commercial outdoor lumber market. Other non-arsenic copper-based preservatives currently in the market include Copper HDO (CX-A), Alkaline Copper Betaine (KDS and KDS-B), and water-borne Copper Naphthenate (CuN-W).

Newer preservative systems have recently been marketed for above ground exposures that do not include any metals, but rely on organic pesticides only. Two of these are Ecolife (EL2), using active ingredients 4,5-dichloro-2-N-Octyl-4-Isothiazolin-3-One (DCOI) and Imidacloprid, and Propiconazole-Tebuconazole-Imidacloprid (PTI).

The focus of this report is on dimensional residential and commercial preservative treated lumber for exterior applications. Thus, borate preservative use is not addressed in the report.

While the change of preservatives away from those containing arsenic has largely addressed concerns about exposure to the treated product, concerns remain regarding potential environmental impacts associated with disposal of arsenical wood products treated prior to 2004 and for arsenical-approved products since then. In particular, the U. S. Environmental Protection Agency (EPA) requested information about disposal as part of its 2008 process to reauthorize uses of the preservatives. CCA and ACZA use was re-authorized by the EPA in 2008.

In 2005, the Wood Preservative Science Council (WPSC) sponsored a study [2] on the impact of the voluntary label change that eliminated most residential and commercial uses of CCA-treated wood. That study provided the amounts of CCA preservative used in the U.S. before and the year after the label change and estimated the amounts of wood treated by CCA for the same times. The volume of wood treated with CCA dropped from nearly 600 million cubic feet in 2000 down to an estimated 109 million cubic feet in 2004. The volume after 2003 was approximately 18% of the volume before that year. That study also estimated disposal rates of CCA treated wood in the U.S. Disposal volumes were estimated using estimated average service lives and standard deviations for the treated products with historic reports of wood treatment volumes. After 2004, annual volume of CCA treatment was assumed to be 100 million cubic feet. This study was provided to the EPA, but was not published.

In 2016, the Arsenical Treated Wood Task Force (ATWTF) sponsored a study [3] on the amount of CCA preservative used, and the products for which it was used as a follow up to the 2005 study. This study used both data on total CCA preservative sold in the U. S. and a survey of CCA wood preserving companies. The total CCA preservative used by U.S. treating companies in 2014 was reported to the author by the client as just under 50,000,000 pounds. That amount (50 million pounds) was accepted as the amount used in 2015. CCA use from this time forward was expected to be relatively stable, since the residential market was no longer part of the CCA-treated wood market. A survey of treaters was used to determine the typical product fractions of the total market treated with CCA. Use of CCA preservatives was estimated for the reported products based on required preservative retentions, typical treatable fractions for the wood products, and typical assumed overtreatment to assure retentions are met. Volumes were projected base on the assumed total CCA preservative use of 50 million pounds. This resulted in a projected total CCA-treated wood volume of 78.7 million cubic feet. Again, this study was provided to the EPA, but was not published.

Reflecting on-going concern about arsenic and other metals in the waste disposal stream, Jones *et al.* [4] recently evaluated potential contamination of construction and demolition (C & D) waste utilized for mulch. The authors used published data, industry standards, and assumptions to estimate the amounts of water-borne preservative treated wood entering the waste stream annually. They concluded, in part, that levels of arsenic in C & D waste due to treated wood would "greatly limit the recycling potential for C & D wood." However, since their work was based on published data, it did not include references such as the two listed above. As a result, the amount of arsenic in treated wood waste was over-estimated and the products in the waste were incorrectly characterized as mostly lumber rather than larger dimension timber and round wood.

Published articles, such as the one described above, that mischaracterize treated wood waste and generally contribute to misinformation about treated wood, highlights the need to make more accurate information about treated wood publicly available. Recognizing this need, the Treated Wood Council (TWC) has commissioned this survey and report.

The evaluation and survey covered by this report seek to provide accurate information about historic, current, and near future projected treatment, use, and disposition of wood products treated with water-borne wood preservatives. This goal includes documenting the transition from arsenic based preservatives, primarily chromated copper arsenate (CCA), to water-borne preservatives not containing arsenic.

2. Methods

Information from previously published documents and some public, but unpublished documents, regarding wood preservatives combined with new survey data about the amounts of water-borne wood preservatives used in the U.S. in recent years has been used, along with wood preservation standards and professional judgement, to estimate volumes of water-borne preservative products annual production and end-of-life removal from service from 1950 to 2050. Annual production is subdivided into production of various products and preservatives used for each product. Products produced are assumed to be put into service in the year of production. Typical service life for each product (average service life and standard deviation) is estimated for each product (The author used several life cycle assessments, industry data, and professional judgement to make these estimates). At end-of-life, products are assumed to be disposed.

Estimates of production of water-borne preserved wood products over past decades were developed using several reports by the wood preserving industry. [1] [5] [6]. These reports were previously used by this author to complete a report on CCA treatment [2] and to prepare a chapter regarding the economics of treated wood [7].

Wood preservation standards, such as minimum retentions and preservative solutions composition, have been obtained from the AWPA Book of Standards [8].

Current preserved wood production by various water-borne preservatives is estimated by using the results of a survey conducted jointly by this author and the TWC of preservative suppliers in the U.S. The survey obtained U.S. sales amounts of arsenic based, non-arsenic copper based, and non-metal wood preservatives sold in 2016 and 2018. Survey results of preservative volumes do not include all preservative suppliers. It is estimated that 95% of arsenical and 80%

of non-arsenic copper preservatives are covered. However, only a small portion of the non-metal preservative volume was reported. Volumes of preserved wood products were estimated using previously estimated wood product type proportions, minimum retentions of preservatives for each product, proportions of non-metal preserved products, and author professional judgement, which included estimates in years 2002 through 2015 to smooth total annual production values.

3. Results

3.1. Production

Statistical reports of wood preservation annual amounts generally categorized preservation into three categories; creosote, oil-borne, and water-borne preservatives. Only the water-borne preservatives are applicable to this report. Prior to 2004, water-borne preservative was nearly all arsenic-based with approximately 96% being chromated copper arsenate (CCA) and 4% being ammoniacal copper zinc arsenate (ACZA). In 2005, an estimate of annual production of CCA treatment from 1950 through 2004 was prepared using these statistical reports along with a 2005 survey of CCA preservative sales from 1996 through 2004. Annual production from 2005 and forward was assumed constant.

In this report, annual production of water-borne preservative treated wood products is the sum of arsenical, non-arsenical copper, and non-metal preservatives and is made based on the survey of 2016 and 2018 preservative sales that is associated with this report. The survey results were refined using AWPA retentions and author professional judgement including product mix estimates. Following 2018, annual production is assumed to increase at 1% per year for each category of preservatives. The resulting annual production of water-borne preservatives from 1950 to 2050 is shown in Table 1.

As noted, a survey of water-borne preservative suppliers was conducted to support this report. A copy of the survey form may be obtained from the author. Suppliers reported sales directly to this author. They remain confidential. A summary of the survey results is included as Table 2. Note that professional judgement was applied to make assumptions regarding the product and preservative mix associated with each preservative category reported in order to calculate estimated product volume and associated arsenic and copper contained in those products.

The AWPA standards require minimum retentions of preservatives for various products based on the service conditions in which they will be used. Use Categories define these exposure conditions and the associated degrees of decay and insect attack hazard. Use Category numbers increase with increasing hazard. UC 1 and UC2 apply to interior applications and UC3A to coated exterior wood with little hazard. UC3B applies to exterior, uncoated, above-ground applications, such as decks, that get and remain wet and are subject to decay and insect attack. UC4 covers situations where the products are in contact with ground

Table 1. Production and disposal by year.

Production of Water-Borne Preserved Wood by Year									
Copied from Smith, 2005, Table 1				Annual Treatment Volume				Disposal Volume	
Treatment Year	Reference/ Method	Waterborne Treatment (1000 cf)	CCA Treatment (1000 cf)	Arsenical Treatments	Non-As Copper Treatments	Other non-metal treatments	All Treatments	Arsenical TW Disposal	All TW Disposal
		(1000 cf)			(Volume in 1000 cf)			(1000 cf)	
1950	Assumed value	0	0	0	0	0	0	0	0
1951	Straight line proportion from 1950 to 1968	425	408	425	0	0	425	9	9
1952		851	817	851	0	0	851	19	19
1953		1276	1225	1276	0	0	1276	28	28
1954		1702	1634	1702	0	0	1702	40	40
1955		2127	2042	2127	0	0	2127	61	61
1956		2553	2451	2553	0	0	2553	97	97
1957		2978	2859	2978	0	0	2978	156	156
1958		3404	3267	3404	0	0	3404	242	242
1959		3829	3676	3829	0	0	3829	356	356
1960		4254	4084	4254	0	0	4254	500	500
1961		4680	4493	4680	0	0	4680	672	672
1962		5105	4901	5105	0	0	5105	871	871
1963		5531	5310	5531	0	0	5531	1096	1096
1964		5956	5718	5956	0	0	5956	1345	1345
1965		6382	6126	6382	0	0	6382	1614	1614
1966		807	6535	6807	0	0	6807	1902	1902
1967		7233	6943	7233	0	0	7233	2207	2207
1968	Maloney & Pagliai, 1978, Table 18	7658	7352	7658	0	0	7658	2524	2524
1969		10,514	10,093	10,514	0	0	10,514	2907	2907
1970		15,135	14,530	15,135	0	0	15,135	3338	3338
1971		20,251	19,441	20,251	0	0	20,251	3789	3789
1972		25,633	24,608	25,633	0	0	25,633	4267	4267
1973		29,414	28,237	29,414	0	0	29,414	4772	4772
1974		41,072	39,429	41,072	0	0	41,072	5586	5586
1975		29,851	28,657	29,851	0	0	29,851	6105	6105
1976		44,781	42,990	44,781	0	0	44,781	7469	7469
1977		42,661	40,955	42,661	0	0	42,661	8772	8772
1978	Ferry, 1982	Reported as CCA Trmt.	62,319	64,916	0	0	64,916	10,922	10,922
1979			95,690	99,677	0	0	99,677	13,585	13,585
1980			111,012	115,638	0	0	115,638	16,044	16,044
1981			131,292	136,763	0	0	136,763	18,896	18,896

Continued

1982	Interpolated		185,263	192,982	0	0	192,982	23,085	23,085
1983	Micklewright, 1986	249,202	239,234	249,202	0	0	249,202	28,234	28,234
1984		301,697	289,629	301,697	0	0	301,697	34,534	34,534
1985	AWPI, 1997	328,677	315,530	328,677	0	0	328,677	41,773	41,773
1986		375,458	360,440	375,458	0	0	375,458	51,445	51,445
1987		418,984	402,225	418,984	0	0	418,984	63,613	63,613
1988		450,565	432,542	450,565	0	0	450,565	78,393	78,393
1989		406,941	390,663	406,941	0	0	406,941	94,324	94,324
1990	AWPI, 1997	437,675	420,168	437,675	0	0	437,675	114,509	114,509
1991		424,370	407,395	424,370	0	0	424,370	136,067	136,067
1992	Interpolated	447,437	429,540	447,437	0	0	447,437	160,079	160,079
1993	AWPI, 1997	470,504	451,684	470,504	0	0	470,504	184,636	184,636
1994		496,883	477,008	496,883	0	0	496,883	208,884	208,884
1995		450,596	432,572	450,596	0	0	450,596	230,578	230,578
1996		467,855	449,141	467,855	0	0	467,855	252,573	252,573
1997	Micklewright, 1998	581,382	558,127	581,382	0	0	581,382	275,709	275,709
1998	Calculated from 2005 survey of chemical suppliers (Table 3)		540,204	562,713	0	0	562,713	294,857	294,857
1999			588,427	612,944	0	0	612,944	314,037	314,037
2000			599,525	624,505	0	0	624,505	331,083	331,083
2001			571,134	594,931	0	0	594,931	346,856	346,856
2002			541,873	564,451	25,000	0	589,451	362,882	363,434
2003			505,603	526,670	50,000	0	576,670	379,233	380,336
2004			109,052	113,596	380,000	10,000	503,596	385,361	396,108
2005	Vlosky est 608m cf water-borne			85,000	427,500	10,000	522,500	401,985	413,395
2006				85,000	427,500	10,000	522,500	416,783	429,026
2007				85,000	475,000	10,000	570,000	426,453	443,728
2008				85,000	475,000	20,000	580,000	426,162	454,971
2009				85,000	475,000	20,000	580,000	414,072	463,347
2010				85,000	475,000	20,000	580,000	392,167	469,737
2011				85,000	475,000	25,000	585,000	363,831	475,216
2012				85,000	475,000	25,000	585,000	332,006	480,227
2013				85,000	475,000	25,000	585,000	298,752	485,067
2014				85,000	475,000	25,000	585,000	265,480	489,701
2015	2016 Survey Value		78,665	81,943	475,000	25,000	581,943	233,239	494,033

Continued

2016	70,608	473,851	23,541	568,000	202,851	497,904
2017	70,355	502,847	32,679	605,881	175,016	502,718
2018	70,102	531,843	41,816	643,761	150,117	507,326
2019	70,803	537,161	42,235	650,199	128,358	510,963
2020	71,511	542,533	42,657	656,701	109,746	514,383
2021	72,226	547,958	43,084	663,268	94,139	518,057
2022	72,948	553,438	43,514	669,900	81,296	522,570
2023	73,677	558,972	43,950	676,599	70,912	528,155
2024	74,414	564,562	44,389	683,365	62,659	534,685
2025	75,158	570,208	44,833	690,199	56,211	541,920
2026	75,910	575,910	45,281	697,101	51,264	549,653
2027	76,669	581,669	45,734	704,072	47,544	557,743
2028	77,436	587,486	46,191	711,113	44,818	566,088
2029	78,210	593,360	46,653	718,224	42,890	574,607
2030	78,992	599,294	47,120	725,406	41,601	583,226
2031	79,782	605,287	47,591	732,660	40,829	591,883
2032	80,580	611,340	48,067	739,987	40,479	600,530
2033	81,386	617,453	48,548	747,386	40,478	609,133
2034	82,200	623,628	49,033	754,860	40,774	617,672
2035	83,022	629,864	49,523	762,409	41,321	626,137
2036	83,852	636,163	50,019	770,033	42,086	634,527
2037	84,690	642,524	50,519	777,733	43,034	642,847
2038	85,537	648,949	51,024	785,511	44,139	651,104
2039	86,393	655,439	51,534	793,366	45,371	659,309
2040	87,256	661,993	52,050	801,299	46,707	667,473
2041	88,129	668,613	52,570	809,312	48,121	675,606
2042	89,010	675,299	53,096	817,406	49,593	683,719
2043	89,900	682,052	53,627	825,580	51,103	691,821
2044	90,799	688,873	54,163	833,835	52,634	699,921
2045	91,707	695,762	54,705	842,174	54,170	708,024
2046	92,625	702,719	55,252	850,596	55,699	716,136
2047	93,551	709,747	55,804	859,101	57,209	724,260
2048	94,486	716,844	56,362	867,692	58,690	732,401
2049	95,431	724,012	56,926	876,369	60,134	740,561
2050	96,385	731,253	57,495	885,133	61,534	748,744

Table 2. Preservative production survey results.

2016				
Preservative Category	Preservative Amt (lb)	Treated Wood Amt (cf)	Arsenic Amt (lb)	Copper Amt (lb)
Basis:	Survey	Estimate & Calculation		
Arsenical	49,670,133	70,608,158	10,897,195	7,839,509
Non-Arsenical Copper	45,806,851	473,851,043	0	40,962,980
Non-metal	380,000	23,541,114	0	0
Totals	95,856,985	568,000,314	10,897,195	48,802,489
2018				
Preservative Category	Preservative Amt (lb)	Treated Wood Amt (cf)	Arsenic Amt (lb)	Copper Amt (lb)
Basis:	Survey	Estimate & Calculation		
Arsenical	49,313,732	70,101,519	10,819,004	7,783,258
Non-Arsenical Copper	51,032,076	531,842,974	0	46,307,997
Non-metal	675,000	41,816,453	0	0
Totals	101,020,808	643,760,945	10,819,004	54,091,254

and, therefore, are likely to remain wet for extended periods and also be in contact with soil bacteria and insects. UC 5 covers marine (salt water) exposures, which have the highest decay and insect attack potential. These Use Categories, conditions, applications, product commodities, and required minimum retentions for each preservative are summarized in Table 3. Since products used in UC1, 2, and 3A generally do not require preservative treatment, they are not applicable to this study.

Table 4 uses the same format as Table 3 to list the author's estimates of the fraction of each product currently treated by each preservative. The fractions for each preservative equal 100%. For example, 52% of CCA is used to treat poles, but none is used to treat deck lumber (UC3B). Since only a small portion of non-metal preservative use was reported in the survey, it was necessary to estimate use by alternate means. A paper presented to the AWPA 2016 Annual Meeting [9] provided estimates of fractions of all treatment by various water-borne preservatives. Treatment market share estimates for 2014-2016 developed in this study are shown in Table 5. Since the amounts of non-metal preservatives were mostly not reported, preservative use was assumed so that the volumes of treated wood would approximately match the proportions estimated in this paper. Values from Table 2 and Table 4 are used to calculate estimated fractions for each commodity-preservative item as a percent of all treated wood based on the current product mix in Table 6.

Also included as one column of Table 4 is treatable fraction. Wood preservatives do not penetrate and remain constant through the whole wood product. Typically, the interior of a product will contain less or even no preservative. Generally, heartwood does not accept any preservative. Thus, each product will have treatable and untreatable fractions. For example, a sawn 2-inch by 6-inch

Table 3. Retentions by use category.

Water-borne Preservatives and Retentions by Use Category																
						Arsenicals		Non-Arsenical Copper Preservatives							Other Preservatives	
						CCA	ACZA	CuN-W	ACQ-D	MCQ	CA-C	MCA	KDS	CX-A	EL2	PTI
USE CATEGORY	SERVICE CONDITIONS	USE ENVIRONMENT	COMMON AGENTS OF DETERIORATION	TYPICAL APPLICATIONS	COMMODITY	Chromated copper arsenate	Ammoniacal copper zinc arsenate	Copper Napththenate	Alkaline Copper Quat	Micronized ACQ	Copper Azole	Micronized CA	Alkaline Copper Betaine	Copper HDO	DCOI & Imidacloprid	Propiconazole, Tebuconazole, Imidacloprid
						Retentions in pcf										
					Retention Source->	AWPA	AWPA	AWPA	AWPA	ICC ES	AWPA	AWPA	AWPA	AWPA	AWPA	AWPA
UC1	Interior construction Above Ground Dry	Continuously protected from weather or other sources of moisture	Insects only	Interior construction and furnishings												
UC2	Interior construction Above Ground Damp	Protected from weather, but may be subject to sources of moisture	Decay fungi and insects	Interior construction		These uses not applicable regarding preservative usage										
UC3A	Exterior construction Above Ground Coated & rapid water runoff	Exposed to all weather cycles, not exposed to prolonged wetting	Decay fungi and insects	Coated millwork, siding and trim												
UC3B	Exterior construction Above Ground Uncoated or poor water run-off	Exposed to all weather cycles including prolonged wetting	Decay fungi and insects	Decking, deck joists, railings, fence pickets, sill plates, uncoated millwork	Sawn Product	0.25	0.25	0.07	0.15	0.15	0.06	0.06	0.19	0.206	0.019	0.013
					Plywood	0.25	0.25	NL	0.15	NL	0.06	0.06	0.19	0.206	0.019	0.013
UC4A	Ground contact or fresh water Non-critical components	Exposed to all weather cycles, normal exposure conditions	Decay fungi and insects	Fence, deck, and guardrail posts, crossties & utility poles (low decay areas)	Sawn Product	0.40	0.40	0.11	0.4	0.34	0.15	0.15	0.47	NL	NL	NL
					Posts	0.40	0.40	0.11	0.40	NL	0.15	0.15	0.47	NL	NL	NL
					Plywood	0.40	0.40	NL	0.40	NL	0.15	0.15	NL	NL	NL	NL
UC4B	Ground contact or fresh water Critical components or difficult replacement	Exposed to all weather cycles, high decay potential includes salt water splash	Decay fungi and insects with increased potential for biodeterioration	Permanent wood foundations, building poles, horticultural posts, crossties & utility poles (high decay areas)	Sawn Product	0.60	0.60	NL	0.60	NL	0.31	0.31	NL	NL	NL	NL
					Posts	0.50	0.50	NL	0.50	NL	0.25	0.25	NL	NL	NL	NL
					Plywood	0.60	0.60	NL	0.60	NL	0.31	0.31	NL	NL	NL	NL

Continued

UC4C	Ground contact or fresh water Critical structural components	Exposed to all weather cycles, severe environments extreme decay potential	Decay fungi and insects with extreme potential for biodeterioration	Land & Freshwater piling, foundation piling, crossties & utility poles (severe decay areas)	Sawn Product	0.60	0.60	NL	0.6	NL	0.31	0.31	NL	NL	NL	NL
					Round piling	0.80	0.80	NL	0.8	NL	0.41	0.41	NL	NL	NL	NL
					Posts	0.60	0.60	NL	NL	NL	0.31	0.31	NL	NL	NL	NL
UC 4A, B, & C	Ground Contact	Decay fungi and insects & high value products	Decay fungi and insects & high value products	All	Poles	0.60	0.60	NL	0.6	NL	0.31	0.31	NL	NL	NL	NL
					Crossties	NL	0.40	NL	NL	NL	NL	NL	NL	NL	NL	NL
UC5A	Salt or brackish water and adjacent mud zone Northern waters	Continuous marine exposure (salt water)	Salt water organisms	Piling, bulkheads, bracing	Sawn Product	1.5	1.9	NL	NL	NL	NL	NL	NL	NL	NL	NL
					Piles	1.5	1.5	NL	NL	NL	NL	NL	NL	NL	NL	NL
UC5B	Salt or brackish water and adjacent mud zone NJ to GA, south of SanFran	Continuous marine exposure (salt water)	Salt water organisms Including creosote tolerant Limnoria tripunctata	Piling, bulkheads, bracing	Sawn Product	2.5	2.5	NL	NL	NL	NL	NL	NL	NL	NL	NL
					Piles	2.5	2.5	NL	NL	NL	NL	NL	NL	NL	NL	NL
UC5C	Salt or brackish water and adjacent mud zone South of GA, Gulf Coast, Hawaii, and Puerto Rico	Continuous marine exposure (salt water)	Salt water organisms Including Martesia, Sphaeroma	Piling, bulkheads, bracing	Sawn Product	2.5	2.5	NL	NL	NL	NL	NL	NL	NL	NL	NL
					Piles	2.5	2.5	NL	NL	NL	NL	NL	NL	NL	NL	NL
UC 5A, B, & C	Marine Exposure	Continuous marine exposure (salt water)	Salt water organisms	All	Plywood	2.5	2.5	NL	NL	NL	NL	NL	NL	NL	NL	NL

Posts, Modified, Farm Use retentions same as for UC4C posts, except ACQ-D added at 0.60 pcf. Round buidling poles and posts, UC4B retentions same as sawn UC4C.

nominal piece of lumber will have more treatable wood than a 6-inch by 8-inch timber. In addition to retention, AWPA states minimum assay zones in which retention is measured and penetration zones, which are deeper than the assay zones where preservative must penetrate but which need not reach the full retention. This information is used to calculate typical treatable fractions in Table 7. Those fractions are then used in Table 4.

In the lower rows of Table 4, retentions, treatable fraction, and overtreatment (assumed to be 10% as discussed below) are used to calculate average retentions applicable to the product mix of each preservative and the amounts of arsenic and copper contained in the mix of products. Note that in the wood preservation process, treaters generally inject a bit more preservative (over treatment) than the minimum to account for wood variability so that when pieces are assayed

Table 4. Preservative uses by commodity.

Water-borne Preservatives Uses by Commodity														
				Arsenicals		Non-Arsenical Copper Preservatives							Non-Metal Preservatives	
				CCA	ACZA	CuN-W	ACQ-D	MCQ	CA-C	MCA	KDS	CX-A	EL2	PTI
USE CATEGORY	SERVICE CONDITIONS	COMMODITY	Treatable Fraction	Chromated copper arsenate	Ammoniacal copper zinc arsenate	Copper Napththenate	Alkaline Copper Quat	Micronized ACQ	Copper Azole	Micronized CA	Alkaline Copper Betaine	Copper HDO	DCOI & Imidacloprid	Propiconazole, Tebuconazole, Imidacloprid
				Estimated Fraction of Each Preservative Used for Each Commodity										
		Retention Source->		AWPA	AWPA	AWPA	AWPA	ICC ES	AWPA	AWPA	AWPA	AWPA	AWPA	AWPA
UC1	Interior construction Above Ground Dry			These uses not applicable regarding preservative usage										
UC2	Interior construction Above Ground Damp													
UC3A	Exterior construction Above Ground Coated & rapid water runoff													
UC3B	Exterior construction Above Ground Uncoated or poor water run-off	Sawn Product	84.4%	0.0%	0.0%	25.0%	25.0%	100.0%	30.0%	75.0%	50.0%	100.0%	100.0%	100.0%
		Plywood	100.0%	0.5%	0.0%	0.0%	2.0%	0.0%	2.0%	0.0%	0.0%	0.0%	0.0%	0.0%
UC4A	Ground contact or fresh water Non-critical components	Sawn Product	84.4%	2.0%	0.0%	50.0%	45.0%	0.0%	40.0%	15.0%	50.0%	0.0%	0.0%	0.0%
		Posts	75.0%	5.0%	0.0%	25.0%	5.0%	0.0%	5.0%	0.0%	0.0%	0.0%	0.0%	0.0%
		Plywood	100.0%	1.0%	0.0%	0.0%	2.0%	0.0%	2.0%	0.0%	0.0%	0.0%	0.0%	0.0%
UC4B	Ground contact or fresh water Critical components or difficult replacement	Sawn Product	84.4%	5.0%	0.0%	0.0%	15.0%	0.0%	15.0%	10.0%	0.0%	0.0%	0.0%	0.0%
		Posts	75.0%	1.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
		Plywood	100.0%	0.5%	0.0%	0.0%	1.0%	0.0%	1.0%	0.0%	0.0%	0.0%	0.0%	0.0%

Continued

UC4C	Ground contact or fresh water Critical structural components	Sawn Product	84.4%	1.0%	5.0%	0.0%	5.0%	0.0%	5.0%	0.0%	0.0%	0.0%	0.0%	0.0%
		Round piling	75.0%	21.0%	20.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
		Posts	75.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
UC 4A, B, & C	Ground Contact	Poles	82.6%	52.0%	46.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
		Crossties	23.8%	0.0%	10.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
UC5A	Salt or brackish water and adjacent mud zone Northern waters	Sawn Product	59.9%	0.0%	3.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
		Piles	75.0%	2.0%	5.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
UC5B	Salt or brackish water and adjacent mud zone NJ to GA, south of SanFran	Sawn Product	59.9%	0.0%	2.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
		Piles	75.0%	3.0%	4.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
UC5C	Salt or brackish water and adjacent mud zone South of GA, Gulf Coast, Hawaii, and Puerto Rico	Sawn Product	59.9%	2.0%	1.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
		Piles	75.0%	3.0%	2.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
UC 5A, B, & C	Marine Exposure	Plywood	100.0%	1.0%	2.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	Total Use for Each Preservative:			100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
	Average Retention for Each Preservative (pcf)			0.702	0.749	0.090	0.348	0.139	0.144	0.091	0.306	0.191	0.018	0.012
	Copper Fraction			14.8%	39.9%	8.4%	53.3%	50.0%	96.1%	96.1%	37.7%	49.1%	0.0%	0.0%
	Arsenic Fraction			22.2%	16.3%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	Avg Copper Retention (pcf)			0.10	0.30	0.008	0.19	0.07	0.14	0.088	0.12	0.09	0.00	0.00
	Avg Arsenic Retention (pcf)			0.16	0.12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

10% Assumed actual treatment retention above minimum.

(tested), each is more likely to meet or exceed the minimum. In the 2016 study [3], overtreatment of 10% was found to fit reported data well and is used in this report. Since some retentions are specified for metal oxide fraction rather than pure metal fraction, conversions from oxide to pure metal fraction are made for the applicable preservatives in **Table 8**.

Table 5. Solo-gabriel estimates of proportions of product by preservative.

Proportions of Water-Borne Treatment Average 2014-2016 per Solo-Gabriele *et al.* 2016.							
CCA	ACZA	ACQ	MCQ	CA	MCA	PTI	EL2
1.0%	0.0%	8.5%	0.0%	10.9%	66.7%	2.4%	10.5%
Arsenical		Copper non-arsenical				Non-metal	
100.0%	0%	9.9%	0.0%	12.6%	77.5%	18.4%	81.6%

Table 6. Product fractions by preservative and commodity.

	Water-Borne Volume Fraction by Preservative and Product														
	Arsenicals		Non-Arsenical Copper Preservatives							Non-Metal Preservatives					
	CCA	ACZA	CuN-W	ACQ-D	MCQ	CA-C	MCA	KDS	CX-A	EL2	PTI	Totals	Arsenic Totals	Non-As Cu Totals	Non-Metal Total
	Chromated copper arsenate	Ammoniacal copper zinc arsenate	Copper Napththenate	Alkaline Copper Quat	Micronized ACQ	Copper Azole	Micronized CA	Alkaline Copper Betaine	Copper HDO	DCOI & Imidacloprid	Propiconazole, Tebuconazole, Imidacloprid	All TW Products	All As Treated	All Cu Treated	All Non-Metal Treated
	These uses not applicable regarding preservative usage														
												100.0%			
Sawn Product	0.0%	0.0%	0.2%	2.2%	0.2%	1.7%	50.3%	0.1%	0.4%	3.0%	1.1%	59.4%	0.0%	55.2%	4.1%
Plywood	0.1%	0.0%	0.0%	0.2%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.4%	0.1%	0.3%	0.0%
Sawn Product	0.2%	0.0%	0.4%	4.0%	0.0%	2.2%	10.1%	0.1%	0.0%	0.0%	0.0%	17.1%	0.2%	16.9%	0.0%
Posts	0.6%	0.0%	0.2%	0.4%	0.0%	0.3%	0.0%	0.0%	0.0%	0.0%	0.0%	1.6%	0.6%	1.0%	0.0%
Plywood	0.1%	0.0%	0.0%	0.2%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.4%	0.1%	0.3%	0.0%
Sawn Product	0.6%	0.0%	0.0%	1.3%	0.0%	0.8%	6.7%	0.0%	0.0%	0.0%	0.0%	9.5%	0.6%	8.9%	0.0%
Posts	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.1%	0.0%	0.0%
Plywood	0.1%	0.0%	0.0%	0.1%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.2%	0.1%	0.1%	0.0%
Sawn Product	0.1%	0.0%	0.0%	0.4%	0.0%	0.3%	0.0%	0.0%	0.0%	0.0%	0.0%	0.9%	0.1%	0.7%	0.0%
Round piling	2.5%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	2.6%	2.6%	0.0%	0.0%
Posts	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Poles	6.2%	0.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	6.4%	6.4%	0.0%	0.0%
Crossties	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Sawn Product	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Piles	0.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.3%	0.3%	0.0%	0.0%
Sawn Product	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Piles	0.4%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.4%	0.4%	0.0%	0.0%
Sawn Product	0.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.2%	0.2%	0.0%	0.0%
Piles	0.4%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.4%	0.4%	0.0%	0.0%
Plywood	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.1%	0.0%	0.0%
% of All TW	12.0%	0.5%	0.9%	9.0%	0.2%	5.6%	67.1%	0.3%	0.4%	3.0%	1.1%	100.0%	12.4%	83.4%	4.1%
														100.0%	
											Large and/or round wood % of all:		10%	0.0%	
											Large and/or round wood % of As TSI:		84%	0.0%	

Table 7. Average preservative retentions by commodity.

Average Retentions per AWPA Required Assay Zones and Penetration Depths for Species and Products																		
				AWPA Minimum Preservative Assays and Penetrations										Calculations of Treatable Fractions				
CCA-Treated Product Information				Assay Zone				Penetration						Representative Size (in)		Untreated size (in)		Treatable fraction
Commodity	Product	Species	Use Category	≤2" thick		>2" thick		<5" thick			≥5" thick			Thick/Dia	Width	Thick/Dia	Width	
Sawn	Sawn Product	SP	all	0.0	0.6	0.0	1.0	2.5	or	85%	2.5	or	85%	1.5	5.5	0.3	4.3	84%
		Spruce, SPF West	all	0.0	0.6	0.0	0.6	0.4	and	90%	0.5	and	90%	1.5	5.5	0.3	4.3	84%
	Decking	HF, DF, LP	3B	0.0	0.2			0.2	and	90%				1.25	5.5	0.85	5.1	37%
Posts								≤10" dia			>10" dia							
	Round building	SP	4B	0.5	2.0			0.5	and	90%	2.5	and	90%	10	dia	5	dia	75%
		DF	4B	0.25	1.0													
	Other & Modified farm	SP	4B	0.0	1.0			2.0	or	85%				6	6	4	4	56%
		LP	4B	0.0	1.0			1.25	or	85%				6	6	4	4	56%
Crossties	Crossties	DF	4A, B, C			0.0	0.5				0	0.5	90%	7	9	6	8	24%
Poles	Poles	SP	4A, B, C	0.5	2.0			3.5	or	90%				12	dia	5	dia	83%
Piles	Foundation	SP	4C	0.0	2.0			2.5	or	85%				12	dia	7	dia	66%
	Land & Fresh water	SP	4C	0.0	3.0			3.0	or	90%				12	dia	6	dia	75%
				Zone 1		Zone 2												
Marine	Sawn	SP	5A, B & C	0.0	0.5	0.5	2.0	3.5	or	90%				6	8	3.5	5.5	60%
	Round	SP	5A, B & C	0.0	0.5	0.5	2.0	3.5	or	90%				12	dia	8	dia	56%

Table 8. Metal fractions in preservatives.

Metal Fractions in Preservatives				
Preservative and Components	Component Fraction	Metal Atomic Weight	Oxygen Atomic Wt.	Component Fraction
CCA (AWPA P23-10)				
Hexavalent Cr as CrO_3	47.50%	52	48	24.70%
Copper as CuO	18.50%	63.5	16	14.78%
Arsenic as As_2O_5	34.00%	150	80	22.17%
ACQ (AWPA P29-11)				
Copper as CuO	66.70%	63.5	16	53.28%
ACZA (AWPA P22-10)				
Copper as CuO	50%	63.5	16	39.94%
Zinc as ZnO	25%	65.4	16	20.09%
Arsenic as As_2O_5	25%	150	80	16.30%
KDS (AWPA P55-16)				
Copper as CuO	47.20%	63.5	16	37.70%

Continued

CX-A (AWPA P33-18)				
Copper as CuO	61.50%	63.5	16	49.12%
Boron as H_3BO_3	24.50%			
HDO as HDO	14.00%			
CuN-W (AWPA P34-14)				
Copper as Cu	5.00%	Copper in CuN		
Copper naphthenate	48.00%		7%	
Total Cu				8.36%
Oxygen Atomic Weight (AW)		16		

Estimates were made of the product mix through 2003 and after 2003, when applications allowed by the new preservative label eliminated most residential and commercial outdoor lumber uses. The product mix data was used to estimate production of the products by year. A summary of the products treated by each preservative type and by all water-borne preservatives is provided in **Table 9**.

Note that for the purpose of estimating disposal amounts, the product mix shown in the All Water-Borne column in **Table 9** is assumed applicable for arsenic-based preservatives for all years prior to 2004, before the label changes became effective. From 2004 forward, the separate mixes are assumed applicable for all years.

The changes in both total treatment volume and product mix through 2003 to 2004 and forward, due to the label changes, were dramatic. Total CCA treatment volume was reduced from nearly 600 million cubic feet per year to about 100 million cubic feet. Lumber, which was mostly used for decks and related outdoor residential and commercial construction, was reduced from about 384 million cubic feet to about 9 million cubic feet. The volume of wood treated with CCA for utility poles was assumed to remain constant, since that use was not affected by the label changes, at approximately 23 million cubic feet. The relative fraction of wood treated with CCA for that product increased from about 4% to about 25%.

3.2. Service Lives

Since the product mix of arsenical-treated wood has changed dramatically since the 2003 label changes, the average service life has also changed. Although industrial products were also being produced, most of the arsenical treated wood prior to 2004 was for relatively short-lived products such as deck lumber. Currently, most arsenical treatment is for larger, longer lived, industrial products such as utility poles, piling, and marine construction.

Estimation of service lives of products is difficult. In the 2005 evaluation [2], data produced by Saxe [10] on service life of decking was used to develop service

Table 9. Post-2003 preservative uses by commodity.

Post-2003 Preservative Types by Product						
USE CATEGORY	SERVICE CONDITIONS	COMMODITY	FRACTION OF TREATED PRODUCT			
			All Water-Borne	Arsenical	Copper	Other
UC3B	Exterior construction Above Ground Uncoated or poor water run-off	Sawn Product	59.4%	0.0%	55.2%	4.1%
		Plywood	0.4%	0.1%	0.3%	0.0%
UC4A	Ground contact or fresh water Non-critical components	Sawn Product	17.1%	0.2%	16.9%	0.0%
		Posts	1.6%	0.6%	1.0%	0.0%
		Plywood	0.4%	0.1%	0.3%	0.0%
UC4B	Ground contact or fresh water Critical components or difficult replacement	Sawn Product	9.5%	0.6%	8.9%	0.0%
		Posts	0.1%	0.1%	0.0%	0.0%
		Plywood	0.2%	0.1%	0.1%	0.0%
UC4C	Ground contact or fresh water Critical structural components	Sawn Product	0.9%	0.1%	0.7%	0.0%
		Round piling	2.6%	2.6%	0.0%	0.0%
		Posts	0.0%	0.0%	0.0%	0.0%
UC 4A, B, & C	Ground Contact	Poles	6.4%	6.4%	0.0%	0.0%
		Crossties	0.0%	0.0%	0.0%	0.0%
UC5A	Salt or brackish water and adjacent mud zone Northern waters	Sawn Product	0.0%	0.0%	0.0%	0.0%
		Piles	0.3%	0.3%	0.0%	0.0%
UC5B	Salt or brackish water and adjacent mud zone NJ to GA, south of SanFran	Sawn Product	0.0%	0.0%	0.0%	0.0%
		Piles	0.4%	0.4%	0.0%	0.0%
UC5C	Salt or brackish water and adjacent mud zone South of GA, Gulf Coast, Hawaii, and Puerto Rico	Sawn Product	0.2%	0.2%	0.0%	0.0%
		Piles	0.4%	0.4%	0.0%	0.0%
UC 5A, B, & C	Marine Exposure	Plywood	0.1%	0.1%	0.0%	0.0%
	Totals		100.0%	12.4%	83.4%	4.1%

life statistical values for decking, concluding that decks had a 9.45 year average service life with a 5 year standard deviation. It was further concluded that applying a lognormal distribution resulted in the best fit to the Saxe data and logically fit realistic circumstances. For example, the average life of a deck may be about 10 years, but some may last 30 years.

This approach of applying assumed average service lives, standard deviations, and lognormal distributions has been applied to all products treated with water-borne preservatives. These statistical values are summarized in **Table 10**. Note that longer service lives are estimated for more extreme service conditions because these products typically are thicker and have higher retentions of preservative. This table also includes a column stating the percent of material assumed to be construction waste that would be disposed immediately as part of the construction work.

Fractions of each product reaching end-of-life were calculated using the statistical values shown in **Table 8**. Results for each category of preservative are shown graphically in **Figure 1**. Service life associated with each preservative is the result of the product mix for which the preservative is used. This represents the current product mix. Note that prior to 2004, the only water-borne treatments were arsenical treatments. In Figure 1, arsenical treatments have longer service lives because they are used only for the heavy-duty industrial type products. Smaller size, less critical or expensive products, such as decking and fencing, are currently treated primarily with the non-arsenical copper and non-metal preservatives that generally have shorter service lives. Prior to 2004, the typical range of service lives for arsenical treated products would match the line for all treated wood, rather than the arsenical line, since all products were then treated with arsenicals. Cumulative fractions of preserved wood products reaching end-of-life are shown numerically by decade in Table 11.

Table 10. Statistical values for commodities.

USE CATEGORY	SERVICE CONDITIONS	COMMODITY	Statistical Values				
			Construction Waste (%)	Mean Service Life (yr)	Standard Deviation (yr)	Geometric Mean of Service Life (yr)	SD of Lognormal Service Life (yr)
UC1	Interior construction Above Ground Dry		These uses not applicable regarding preservative usage				
UC2	Interior construction Above Ground Damp						
UC3A	Exterior construction Above Ground Coated & rapid water runoff						
UC3B	Exterior construction Above Ground Uncoated or poor water run-off	Sawn Product	2.5%	10	5	2.2	0.47
		Plywood	2.5%	10	5	2.2	0.47
UC4A	Ground contact or fresh water Non-critical components	Sawn Product	2.5%	15	5	2.7	0.32
		Posts	0.0%	20	5	3.0	0.25
		Plywood	2.5%	15	5	2.7	0.32
UC4B	Ground contact or fresh water Critical components or difficult replacement	Sawn Product	2.5%	15	5	2.7	0.32
		Posts	0.0%	20	5	3.0	0.25
		Plywood	2.5%	15	5	2.7	0.32
UC4C	Ground contact or fresh water Critical structural components	Sawn Product	2.5%	30	5	3.4	0.17
		Round piling	0.0%	50	10	3.9	0.20
		Posts	0.0%	25	5	3.2	0.20
UC 4A, B, & C	Ground Contact	Poles	0.0%	60	15	4.1	0.25
		Crossties	0.0%	40	10	3.7	0.25
UC5A	Salt or brackish water and adjacent mud zone Northern waters	Sawn Product	2.5%	40	10	3.7	0.25
		Piles	0.0%	40	10	3.7	0.25
UC5B	Salt or brackish water and adjacent mud zone NJ to GA, south of SanFran	Sawn Product	2.5%	40	10	3.7	0.25
		Piles	0.0%	40	10	3.7	0.25
UC5C	Salt or brackish water and adjacent mud zone South of GA, Gulf Coast, Hawaii, and Puerto Rico	Sawn Product	2.5%	40	10	3.7	0.25
		Piles	0.0%	40	10	3.7	0.25
UC 5A, B, & C	Marine Exposure	Plywood	2.5%	40	10	3.7	0.25

Table 11. Cumulative end-of-life by preservative class.

Cumulative Fraction of Treated Wood Reaching End-of-Life by Decade	End-of-Life at Years After Treatment										
	0	10	20	30	40	50	60	70	80	90	100
All Treated Wood	2.2%	40.4%	81.4%	88.7%	91.0%	93.9%	96.6%	98.4%	99.3%	99.7%	99.9%
Arsenical Treated Wood	0.3%	1.7%	10.9%	17.0%	28.7%	51.1%	73.5%	88.0%	95.4%	98.7%	100.0%
Non-Arsenic Copper Treated Wood	2.5%	45.2%	91.3%	98.9%	99.9%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
Non-Metal Treated Wood	2.5%	60.4%	95.7%	99.5%	99.9%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

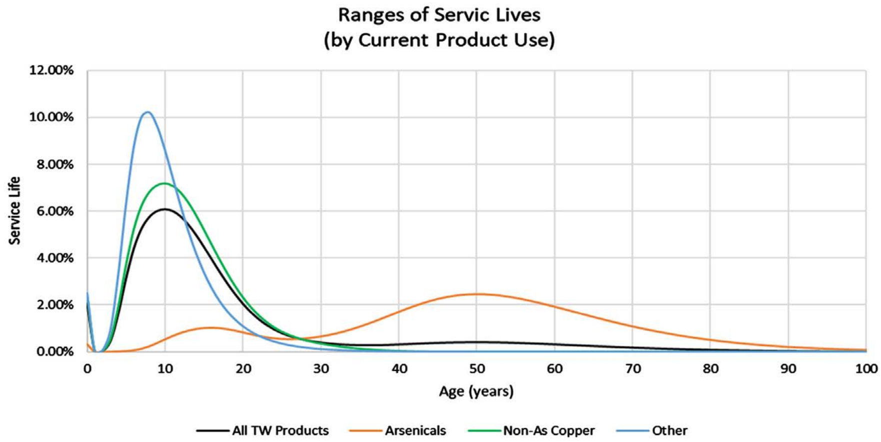

Figure 1. Service lives of products.

Table 11 indicates that about 90% of all water-borne preserved wood products reach end-of-life by age 40. However, 90% of the copper and other preserved products have reached their end-of-life by only age 20.

3.3. Disposal

Annual disposal of water-borne preservative treated wood is calculated using annual treatment times the fraction disposed by age following treatment. This was accomplished by creating a spreadsheet with years of disposal from 1950 to 2050 horizontally and years of treatment from 1950 to 2050 vertically. For each treatment times disposal cell, disposal volume was calculated using the fraction disposed for all treated wood. Columns were summed for each disposal year to calculate the total amount of disposal in that year. Obviously, no disposal could occur for years prior to the product's treatment year.

A nearly identical spreadsheet was created for arsenical-treated wood. It differed for treatment years from 2004 through 2050 in that the fraction of disposal by age reflected to current product mix for arsenical-treated wood rather than for all treated wood. Annual treatment and disposal volumes of all and arsenical treated wood products are listed for each year in **Table 1** and are shown graphically in **Figure 2**. (These spreadsheets are too large to include, so are available from the author.) Note that a similar graph showing the impact of the label change of 2003 on CCA-treated wood disposal was created in 2007 [10].

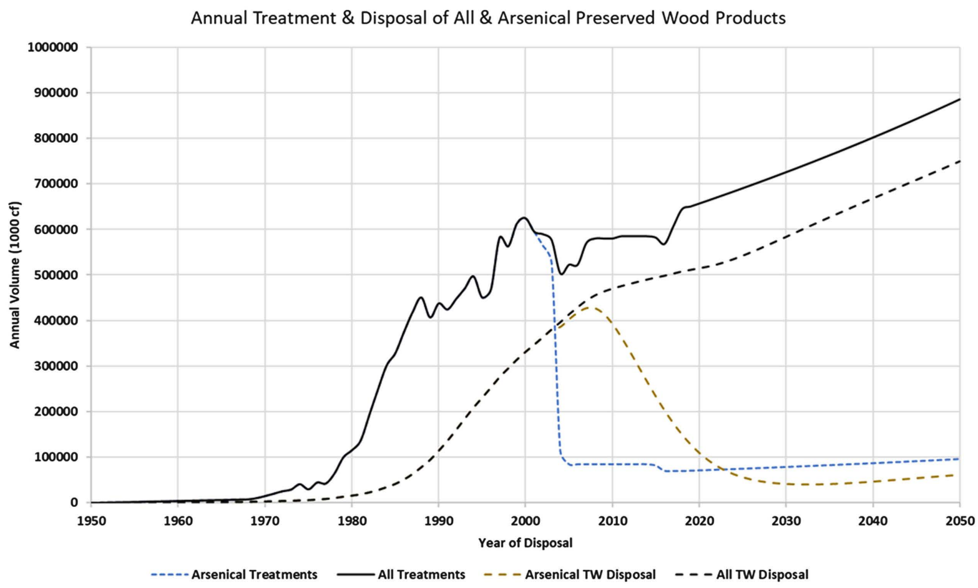

Figure 2. Annual treatment and disposal.

In **Figure 2**, prior to 2004, treatment and disposal of all water borne treated wood is the same as for arsenical treated wood. In 2004, the lines diverge as treatment with arsenicals declines precipitously from approximately 600 million to about 100 million cubic feet per year. Disposal of arsenical preserved products declines more gradually as previously treated products reach end-of-life and as ongoing treatments occur with a different, longer-lived product mix. However, the decline in arsenical treated products from approximately 400 million cubic feet in 2008 to approximately 100 million cubic feet in 2020 is still dramatic.

The types of arsenical treated products reaching the end-of-life stage from now forward is important to understand as it relates to solid waste disposal and potential recycling of biomass to mulch or other products. It has been 17 years since the label changes restricted arsenical treatments to industrial type products. As of 2020, 59% of all preserved wood products and 76% of arsenical treated products have reached their end-of-life and been disposed. Of the arsenical treated products being disposed from 2020 forward, approximately 84% consist of poles, piles, and other heavy-duty products (posts, piles, poles, and marine timbers) that are round and/or of large dimensions relative to residential and commercial lumber. Thus, such arsenical treated products being disposed can easily be visually distinguished and can be kept separate or be manually separated from other wood wastes. Most could be managed separately by the generators, so that most would never enter the general waste stream.

Based on the service life statistics, within 20 years of treatment approximately 95% of above-ground and 85% of ground-contact treated lumber (Use Categories 3B through 4B) for residential and commercial uses, such as for decks and fencing, has reached its expected end-of-life and been disposed. Thus, only a very small fraction of this arsenical treated lumber produced prior to 2004 remains in service.

3.4. Uncertainty

Due to limited company involvement, the survey results are incomplete, especially for the non-metal type preservatives. Results of the preservative suppliers' survey indicate only approximately 2% of total treated wood by non-metal preservatives. In contrast, Solo-Gabriele reported [9] that of all treated wood, approximately 11% was by EL2 and 2% by PTI. The survey results seem low and the Solo-Gabriele estimates seem high. For this report, the author estimated the fractions of preservatives reported so that total U.S. preservatives use could be estimated. For the non-metal preservatives, 2% are estimated to be included in the survey results. Where higher reporting is estimated, reported non-arsenical copper preservatives are estimated to be 80% of totals and arsenical preservatives reported amounts are estimated to be 95% of totals. With these adjustments, non-metal preservative treated wood represents approximately 4% in 2016 and 6% in 2018 of all treated wood compared to approximately 13% estimated by Solo-Gabriele. The results in this report, as shown in **Table 2**, seem reasonable.

Annual treatment volumes, as shown in **Table 1**, required judgement to estimate amounts for years and preservative types where no relevant data was available. In particular, for the years from 2002 through 2015, it was necessary to simply enter estimates that would represent a reasonable total treatment volume and annual trend. Non-arsenical copper treatments are assumed to begin in 2002, ramp up rapidly with the label change restricting use of CCA through 2005, and then remain consistent through 2015. Non-metal preservatives are assumed to begin use in 2004 and ramp up gradually through 2015. Values for 2015 are chosen to be reasonably close to the estimated 2016 values resulting from this survey.

The product mix of non-arsenical copper preservatives from 2004 through 2015 has evolved from dissolved copper preservatives, such as ACQ, to micronized copper, as in MCA. This evolution is not included. Rather, the current mix is assumed constant. This assumption likely introduces some small inaccuracy related to the amounts of copper in waste.

Future treatment volumes are simply assumed to increase at 1% annually, beginning with the volumes estimated for 2018 for each preservative type. Future changes are likely, but unknowable.

Similarly, technology evolution related to recycling wastes to energy and other options are likely to present new options for waste management other than landfill disposal. Impacts of such technologies remain unknowable.

As a result of the above and other sources of uncertainty, annual treatment volumes and disposal volumes should be considered rough estimates, generally with an accuracy of about plus or minus 25%.

4. Conclusions

Water-borne preservative treated wood has been and is likely to continue to be widely used. However, due to the label changes made in 2003 for arsenical wood preservatives, the mix of products now treated with water-borne preservatives has changed dramatically. Prior to 2004, nearly all water-borne preservative was arsenic-based. From 2004 forward, less than 20% (by volume of treated wood) is treated with arsenic-based preservative. 2018 production of water-borne preserved wood products is estimated, based on the survey of preservative suppliers, to be 70 million cubic feet of arsenical treatments, 532 million cubic feet of non-arsenic copper treatments, and 42 million cubic feet of non-metal treatments for a total of 644 million cubic feet.

As water-borne preserved wood products reach the end of their service lives, they are assumed to be disposed. As more preserved wood enters use, more also enters the disposal sector. However, as is clear from Figure 2, most of the arsenic-based volume treated prior to 2003 has already been disposed. As of 2019, over 75% of all arsenic treated wood has been disposed. National disposal of arsenic treated wood peaked in 2007-2008 at approximately 426 million cubic feet per year, is at approximately 110 million cubic feet now, and will reach a minimum of approximately 42 million cubic feet per year in 2030. As noted above, nearly all arsenical preserved wood being disposed will be large, heavy duty poles, piles, and timbers that can easily be kept separate or be separated from other wastes.

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Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

References

[1] AWPI (1997) The 1996 Wood Preserving Industry Statistical Report. American Wood Preservers Institute.

[2] Smith, S.T. (2005) CCA Treated Wood Production, Uses, and Disposal. Wood Preservatives Science Council, Not Published.

[3] (2016) Production Volumes and Benefits of CCA-Treated Wood. American Chemistry Council, Biocides Panel, Arsenical Wood Preservers Task Force, Not Published.

[4] Jones, A.S., Marini, J., Solo-Gabriele, H.M., Robey, N.M. and Townsend, T.G. (2019) Arsenic, Copper, and Chromium from Treated Wood Products in the U.S. Disposal Sector. *Waste Management*, **87**, 731-740. https://doi.org/10.1016/j.wasman.2019.03.004

[5] AWPI (1996) The 1995 Wood Preserving Industry Statistical Report. American Wood Preservers Institute.

[6] Micklewright, J.T. (1998) Wood Preservation Statistics 1997. American Wood Preservers' Association.

[7] Smith, S.T. (2011) Economics of Treated Wood in Aquatic Environments. In: Morrell, J.J., Brooks, K.M., C.M., Davis, Eds., *Managing Treated Wood in Aquatic Environments,* Forest Products Society.

[8] American Wood Protection Association (2018) Book of Standards. AWPA, Birmingham, AL.

[9] Solo-Gabriele, H., Jones, A., Marini, J., Townsend, T. and Robey, N. (2016) Trends in Waterborne Treated Wood Production and Implications for Wood Waste Disposal. American Wood Protection Association, San Juan, Puerto Rico.

[10] Saxe, J.K., Wannamaker, E.J., Conklin, S.W., Shupe, T.F. and Beck, B.D. (2007) Evaluating Landfill Disposal of Chromated Copper Arsenate (CCA) Treated Wood and Potential Effects on Groundwater: Evidence from Florida. *Chemosphere*, **66**, 496-504. https://doi.org/10.1016/j.chemosphere.2006.05.063