

REPORT

FINAL

EVALUATING ACQ AS AN ALTERNATIVE WOOD PRESERVATIVE SYSTEM

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EVALUATING ACO AS AN ALTERNATIVE WOOD PRESERVATIVE SYSTEM

by

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FOREWORD

Today's rapidly developing and changing technologies and industrial products and practices frequently carry with them the increased generation of materials that, if improperly dealt with, can threaten both public health and the environment. The U.S. Environmental Protection Agency (EPA) is charged by Congress with protecting the Nation's land, air, and water resources. Under a mandate of national environmental laws, the agency strives to formulate and implement actions leading to a compatible balance between human activities and the ability of natural systems to support and nurture life. These laws direct the EPA to perform research to define our environmental problems, measure the impacts, and search for solutions.

The Risk Reduction Engineering Laboratory is responsible for planning, implementing, and managing research, development, and demonstration programs to provide an authoritative, defensible engineering basis in support of the policies, programs, and regulations of the EPA with respect to drinking water, wastewater, pesticides, toxic substances, solid and hazardous wastes, Superfund-related activities, and pollution prevention. This publication is one of the products of that research and provides a vital communication link between the researcher and the user community.

Passage of the Pollution Prevention Act of 1990 marked a strong change in the U.S. policies concerning the generation of hazardous and nonhazardous wastes. This bill implements the national objective of pollution prevention by establishing a source reduction program at the EPA and by assisting States in providing information and technical assistance regarding source reduction. In support of the emphasis on pollution prevention, projects have been designed to identify and evaluate ideas and technologies that lead to waste reduction. This Resource Conservation and Recovery Act (RCRA) Problem Wastes Technology Evaluation program emphasizes source reduction and recycling options for selected RCRA wastestreams. These methods reduce or eliminate transportation, handling, treatment, and disposal of hazardous materials in the environment. The technology evaluation project discussed in this report emphasizes the study and development of methods to reduce waste and prevent pollution.

E. Timothy Oppelt, Director
Risk Reduction Engineering Laboratory

ABSTRACT

This evaluation addresses the waste reduction/pollution prevention and economic issues involved in replacing chromated copper arsenate (CCA) with ammoniacal copper/quaternary ammonium compound (ACQ) as a wood preservative for treatment of commodities. The evaluation was conducted at McArthur Lumber & Post Co., Inc. in McArthur, Ohio. The most obvious pollution prevention benefit gained by using ACQ is the complete elimination of arsenic and chromium use, which eliminates the generation of hazardous wastes and the risk of contaminating the environment via chemical spills. Because most treatment plants are self-contained in that they recycle all wastewater produced within the plant and on the drip pads, no liquid waste problems need to be addressed for either the CCA or the ACQ treating process. ACQ, however, produces a greater amount of air emissions, mainly as NH_3 . For a plant with an annual production of 1 million ft^3 (or about 20 million board feet), 90,000 lb of NH_3 per year would be released from the ACQ treatment operations and the ACQ-treated wood. In contrast, a CCA plant that produced four times as much commodities released < 0.021 lb of arsenic (as As_2O_5) and only trace amounts of CrO_3 and CuO annually. During the air monitoring, airborne concentrations of inorganic arsenic were above the Occupational Safety and Health Administration (OSHA) permissible exposure limit (PEL) of 0.01 mg/m^3 . Full-shift exposures to ammonia during ACQ treatment were below applicable exposure limits. Ceiling exposures to ammonia during unloading of the ACQ treating cylinder were above the short-term exposure limit of 35 ppm.

The treated wood, after being transferred from the drip pads to the outside storage yard, could become a major source of contamination. For a plant with an annual production of 1 million ft^3 (or about 20 million board feet) of CCA-treated wood at 0.4 lb/ft^3 retention, 157 lb of As_2O_5 , 1,506 lb of CrO_3 , and 39 lb of CuO could be washed away by the stormwater every year. For the same amount of ACQ-treated wood at the same retention, 1,299 lb of CuO , 3,148 lb of total organic carbon (TOC) (inclusive of extractable wood organics and quat [as didecyldimethylammonium ion, or DDA]), and 3,172 lb of NH_4^+ could be released into the stormwater runoff every year. It must be noted that these releases were estimated based on exposure of all treated wood to about 18 in of rainfall 4 days after treatment, as performed by leaching of $6 \text{ in} \times 6 \text{ in} \times 8 \text{ ft}$ of treated timber. However, these conditions would be very unlikely to occur naturally.

Converting from CCA to ACQ would require a capital investment of about \$191,000. The operating costs for ACQ wood treatment were higher; a net expense of up to 1,100,000 was required. More than 71% of that net expense would be used to purchase ACQ chemicals. Therefore, switching from CCA to ACQ would not produce any immediate quantifiable benefits. Because the economic analysis did not take into account factors such as long-term liability, safety, and the company's public relations, the real benefit of using ACQ could be more than what it would appear.

This report was submitted in partial fulfillment of Contract Number 68-CO-0003, Work Assignment 3-36, under the sponsorship of the U.S. Environmental Protection Agency. This report covers a test period from July 1993 to October 1993, and the study was completed as of January 31, 1994.

CONTENTS

Notice	ii
Foreword	iii
Abstract	iv
Figures	vii
Tables	vii
Acknowledgments	ix
 SECTION 1: INTRODUCTION	 1
General Overview	1
Project Objectives	1
 SECTION 2: CCA and ACQ	 3
Wood-Preserving Industry	3
Arsenical Wood Preservatives	3
Chromated Copper Arsenate (CCA)	4
Development of CCA Formulations	4
Factors Affecting Fixation and Leachability of Arsenic	5
U.S. Manufacturers and Current Demand/Production	5
Treatment Process Description	5
Disposal of Treated Wood	6
Alternative Wood Preservative Systems	6
ACQ	8
Development	8
Compositions	8
Fixation Mechanisms	8
Effectiveness	9
Pressure Treatment	13
Operations	13
Manufacturer	14
Leaching Tests	14
 SECTION 3: TECHNOLOGY EVALUATION SITE	 15
Wood Treating Facility	15
Treatment Building	15
Drip Pad Building	17
Wood-Fabricating/Treating Processes	20
 SECTION 4: EVALUATION APPROACH AND EXPERIMENTAL METHODS	 23
Sources of Pollution	23
Evaluation Approach	23
Experimental Methods	25

CONTENTS (Continued)

CCA and ACQ Treatment	25
Emissions and Worker Exposure Monitoring	31
Chemical Drips and Spills	34
Solid Waste on the Drip Pad	36
Stormwater Runoff	36
Estimation of Economics	36
SECTION 5: WASTE REDUCTION/POLLUTION PREVENTION POTENTIAL EVALUATION	39
Air Emissions and Worker Exposures	39
CCA Wood Treatment	40
ACQ Wood Treatment	43
Outdoor Concentrations	49
Chemical Drips and Spills	49
Stormwater Runoff	50
Amounts of Rainfall Applied	50
Results of Leaching Tests	53
Yearly CCA and ACQ Losses Due to Leaching	67
Waste Reduction/Pollution Prevention Assessment	68
SECTION 6: ECONOMIC EVALUATION	70
Capital Investment	70
Operating Costs	71
Economic Assessment	73
SECTION 7: QUALITY ASSURANCE	74
Quality Assurance Objectives	74
Precision	76
Accuracy	76
Method Detection Limit	76
Completeness	77
Limitations and Qualifications	80
SECTION 8: CONCLUSIONS AND RECOMMENDATIONS	81
SECTION 9: REFERENCES	82
APPENDIX A: MATERIAL SAFETY DATA SHEETS FOR CCA, ACQ-C, AND ACQ-Q50	87
APPENDIX B: LITERATURE SEARCH FOR NON-CCA, NON-PCP, AND NONCREOSOTE WOOD PRESERVATIVES	103
APPENDIX C: CALCULATIONS OF NH₃ EMISSIONS	107

FIGURES

<u>Number</u>		<u>Page</u>
1	Wood preservative pressure-treating facility	6
2	McArthur plant layout	16
3	Treatment building at McArthur Lumber & Post Co.	17
4	Steam drying cylinders and drip pad at McArthur Lumber & Post (not scaled)	19
5	Flow diagram of wood-fabricating operations	21
6	Leaching test layout for ACQ- and CCA-treated wood units	37
7	ACQ-treated and control wood units with plastic liners and sprinkler setup	38
8	Best-fit curves for As concentration estimation — CCA leaching tests	56
9	Best-fit curves for Cr concentration estimation — CCA leaching tests	56
10	Best-fit curves for Cu concentration estimation — CCA leaching tests	57
11	Assumed distribution of sapwood (with CCA retention) and heartwood (without CCA retention) in a timber piece	58
12	Fraction of chemical retained vs. distance from wood surface	59
13	Best-fit curves for TOC mass estimation — CCA leaching tests	61
14	Best-fit curve for Cu concentration estimation — ACQ1	63
15	Best-fit curves for TKN mass estimation — ACQ leaching tests	64
16	Best-fit curves for TOC mass estimation — ACQ leaching tests	64
17	pC-pH diagram for ammonia	66

TABLES

1	Standardized CCA formulations with oxide bases and the ranges in the proportions of the chemical compounds	4
2	CSI efficacy and field tests	10
3	Physical properties of ACQ-treated wood	12
4	Equipment/facility description	18
5	Potential sources of pollution at wood treatment facilities	24
6	List of critical and noncritical measurements	26
7	Primary and duplicate samples	27
8	CCA solution compositions	28
9	ACQ solution compositions	29
10	Material treated with CCA	29
11	CCA treatment	30
12	Material treated with ACQ	31
13	ACQ treatment	32
14	Ambient conditions during air sampling	33

TABLES (Continued)

<u>Number</u>		<u>Page</u>
15	Detection of NH ₃ using Dräger tubes	35
16	PELs, RELs, and TLVs for As, Cr(VI), Cu, and NH ₃	40
17	Results of personnel and area monitoring for arsenic during CCA wood treatment	41
18	Results of personnel and area monitoring for hexavalent chromium during CCA wood treatment	42
19	Results of personnel and area monitoring for copper during CCA wood treatment	43
20	Results of personnel and area monitoring for ammonia during ACQ wood treatment	44
21	NH ₃ monitoring using Dräger tubes	45
22	NH ₃ emissions during ACQ wood treatment	47
23	Results of personnel and area monitoring for copper during ACQ wood treatment	48
24	Results of outdoor personnel monitoring for ammonia, copper, arsenic, and hexavalent chromium during ACQ wood treatment	49
25	Activities associated with short-term samples	50
26	Results of field blank analyses	51
27	Artificial rainfall applied during CCA leaching test	51
28	Artificial rainfall applied during ACQ leaching test	52
29	Volume of runoff collected	52
30	Results of leaching tests	54
31	Leaching of CCA active ingredients in 24 hours	55
32	Loss of CCA active ingredients as a result of leaching	57
33	TOC leached from CCA-treated wood and from wood without treatment	60
34	Leaching of ACQ active ingredients in 24 hours	62
35	Loss of ACQ active ingredients as a result of leaching	65
36	Yearly CCA and ACQ losses due to leaching	67
37	Summary of yearly pollution prevention potential for ACQ wood preservative systems	68
38	Inputs and outputs for capital costs	71
39	Annual operating costs of ACQ wood treatment compared with that of CCA wood treatment	72
40	Quantitative QA objectives	75
41	Precision of laboratory measurements	77
42	Precision of NH ₃ monitoring using Dräger tubes	78
43	Accuracy of laboratory measurements	80

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SECTION 1

INTRODUCTION

GENERAL OVERVIEW

The objective of the U.S. Environmental Protection Agency's (U.S. EPA) Resource Conservation and Recovery Act (RCRA) Problem Wastes Technology Evaluation Program is to evaluate, in a typical workplace environment, examples of innovative technologies that demonstrate a potential (1) to reduce or, preferably, eliminate the use of RCRA-banned metals, including arsenic, in various industrial and agricultural applications, or (2) to minimize the RCRA problem wastes through recycling and recovery. In general, when evaluating each technology, three issues are addressed.

First, the new technology's effectiveness must be assessed. Waste reduction and pollution prevention technologies typically involve using substitute materials or techniques, or recycling or reusing materials. It is important to verify that the quality of the materials and the quality of the work product are satisfactory for the intended purpose. Second, the new technology must measurably reduce waste and/or prevent pollution. Finally, the economics of the new technology must be quantified and compared with the economics of the existing technology and/or the technology to be replaced. There may exist harder to quantify justifications such as reduced liability, greater safety, better morale, and improved company public relations that would encourage adoption of new operating approaches.

This evaluation involves a commercially available wood preservative system, offered by a specific manufacturer, for wood treatment. The wood preservative system evaluated is manufactured by Chemical Specialties, Inc. (CSI) in Charlotte, North Carolina. Other alternative wood preservative systems for similar applications may be commercially available from other manufacturers.

PROJECT OBJECTIVES

The goal of this study is to evaluate the use of ammoniacal copper/quaternary ammonium (ACQ) as an alternative wood preservative system to chromated copper arsenate (CCA). This study has three specific objectives:

1. To evaluate the effectiveness of ACQ as a wood preservative,
2. To compare the waste reduction/pollution prevention potential of the ACQ wood preservative system with that of CCA, and
3. To evaluate the cost of using of the ACQ technology versus that of CCA.

The long-term effectiveness of ACQ and CCA as wood preservatives was evaluated through a literature review rather than field testing in view of the lengthy time requirements (e.g., 1 to 5 years) and the limited resources available. The available funds were used to study the waste reduction/pollution prevention potential and to make cost evaluations. ACQ's ability to protect wood against decay fungi, marine borers, or insects and the chemical and physical properties of ACQ-treated wood will be reviewed in this report. The effectiveness of CCA is well known and has been well documented.

SECTION 2

CCA and ACQ

WOOD-PRESERVING INDUSTRY

The wood-preserving industry uses both oilborne and waterborne preservatives for wood treatment. The oilborne preservatives have been used primarily in the older processes for crossties, crossarms, and utility poles. The waterborne preservatives are used for lumber, timber, and other wood products. In 1988, U.S. production of creosote- and pentachlorophenol (PCP)-treated wood was 138 million ft³, equivalent to about 23% of the annual production of treated wood (AWPA, 1990). The volume of wood treated with waterborne preservatives was over 450 million ft³, representing more than 75% of the year's production. The wood-treating industry has been turning gradually from oilborne preservatives to waterborne ones (U.S. EPA, 1992).

ARSENICAL WOOD PRESERVATIVES

Arsenical preservatives have been the most commonly used waterborne preservatives. Because of the solubility of arsenic compounds in water, preservatives with arsenic compounds alone are subject to leaching from the treated wood whenever it is exposed to water. Thus, wood treaters have been using mixed-salt preservatives for wood treatment since the early 1910's. The mixtures are designed to be resistant to leaching due to the formation of reaction compounds or mixtures of compounds that have low water solubility in the treated wood. The mixed-salt preservatives usually contain various arsenic compounds such as arsenic pentoxide, sodium arsenate, or sodium pyroarsenate and metal salts from the metals chromium (Cr), copper (Cu), or zinc (Zn). Currently, the American Wood-Preservers' Association (AWPA) Standard P5-92 (AWPA, 1992) includes five such preservatives: CCA-Types A, B, and C, ammoniacal copper arsenate (ACA), and ammoniacal copper zinc arsenate (ACZA). CCA-Type C is the predominant arsenical wood preservative used in the United States (Baldwin, 1992).

Because of its toxicity and carcinogenicity, arsenic poses a serious threat to the environment and human health (Loebenstein, 1992). Increasingly stringent federal and local regulations have been proposed and enacted. In 1978, the Occupational Safety and Health Administration (OSHA) promulgated the final standard to limit worker exposure to inorganic arsenic. The following year, U.S. EPA listed inorganic arsenic as a hazardous air pollutant. Consequently, the last U.S. arsenic refinery, ASARCO, Inc. at Tacoma, Washington, was forced to close its business in 1986. The U.S. EPA also regulated the use of inorganic arsenic under provisions of the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) (U.S. EPA, 1991). In California, a regulatory goal of no more than 2 parts per trillion (ppt) arsenic is being advocated as California's new drinking water standard (*Science News*, 1992); the current federal standard is 50 parts per billion (ppb).

In the United States, about 70% of the total 1989 arsenic demand was used to produce industrial chemicals such as arsenical wood preservatives (Loebenstein, 1991); 21.9% was used by the agricultural industry to manufacture arsenical herbicides and cotton leaf desiccants; 3% was

used by the electronics and nonferrous alloy industry to make gallium arsenide semiconductors and alloys; and 3.8% was used by the glass industry as a fining agent. Because domestic refineries no longer exist, the demand for 23,700 metric tons in 1989 was supplied solely by imported sources. The imported arsenic trioxide is converted to arsenic acid for use in the production of arsenical preservatives.

CHROMATED COPPER ARSENATE (CCA)

Development of CCA Formulations

CCA has been used in the wood-preserving industry for more than 50 years. The first CCA formula, known as "Ascu," was patented by Kamesam in England in 1933 and was widely used in India after 1938 (Henry and Jeroski, 1967; Wallace, 1968; Arsenault, 1975; Chen, 1979). During the 1930's, the Bell Telephone System began to use the Kamesam patent as Greensalt K for telephone poles. This represented the first large-scale application in the United States. Two other similar formulae, Greensalt S and Greensalt O, were developed later to improve electrical characteristics, corrosion properties, and cost. Between 1930 and 1950, CCA formulations were further studied and developed in Europe. In Sweden, the Boliden Mining Company produced two new preservatives, Boliden BIS and S25, followed by Boliden K-33. Meanwhile, two new CCA formulations were produced in the United Kingdom, Celcure A and Tanalith C.

Greensalt has been a standard preservative of the AWPA since 1953, designated as CCA-Type A. Subsequently, Boliden K-33 was standardized as CCA-Type B and Wolman CCA as CCA-Type C in AWPA Standard P5. CCA-Type C is similar in formulation to the English commercial preservatives Tanalith C and Celcure A. Table 1 presents the standardized CCA formulations and the ranges in the proportions of the chemical compounds. A material safety data sheet (MSDS) of CCA-Type C is presented in Appendix A.

Since the early formulations of CCA were developed, a great number of researchers have studied the effectiveness and toxicity of various formulations for protection against wood-destroying fungi, wood-boring insects, marine borers, and bacteria (Sandstorm, 1948; Purushotham et al., 1969; Da Costa, 1972; Skolmen, 1973; Johnson et al., 1973; Arsenault, 1975; Fougereousse and Lucas, 1976). In general, these researchers have agreed that the various CCA formulations were highly effective in protecting wood from biological deterioration and that the various CCA types provided very satisfactory service records and significantly prolonged the service life of wood used in various forms.

TABLE 1. STANDARDIZED CCA FORMULATIONS WITH OXIDE BASES AND THE RANGES IN THE PROPORTIONS OF THE CHEMICAL COMPOUNDS

Compound	Composition (%)					
	CCA-Type A		CCA-Type B		CCA-Type C	
	Standard	Range	Standard	Range	Standard	Range
CrO ₃	65.5	59.4 - 69.3	35.3	33.0 - 38.0	47.5	44.5 - 50.5
CuO	18.1	16.0 - 20.9	19.6	18.0 - 22.0	18.5	17.0 - 21.0
As ₂ O ₅	16.4	14.7 - 19.7	45.1	42.0 - 48.0	34.0	30.0 - 38.0

Factors Affecting Fixation and Leachability of Arsenic

The CCA solution concentration and composition have a definite influence on arsenic's fixation and leachability in wood (Häger, 1969; Dahlgren, 1975; Rak, 1976). The amount of Cr(VI) in the formulation is one of the most important factors (Häger, 1969). An increase in Cr(VI) with a constant level of Cu and As would increase arsenic's resistance to leaching. The Cr-to-As ratio also is important; a minimum leachability or a maximum fixation can be achieved when the ratio of metallic Cr(VI) to As is between 1.0 and 1.3 (Fahlstrom et al., 1967) or when the CrO_3 to As_2O_5 ratio is 1:0.67 or more (Henry and Jeroski, 1967; Smith and Williams, 1973). Therefore, when looking at the standardized CCA formulations, one might expect wood treated with CCA-Type B solution to lose more arsenic when subjected to leaching, and wood treated with either CCA-Type A or Type C to resist leaching more effectively.

The retention of CCA active ingredients varies with applications. For example, the normal "backyard" retention is about 0.4 lb/ft³. The retention for marine applications can be as high as 2.5 lb/ft³.

U.S. Manufacturers and Current Demand/Production

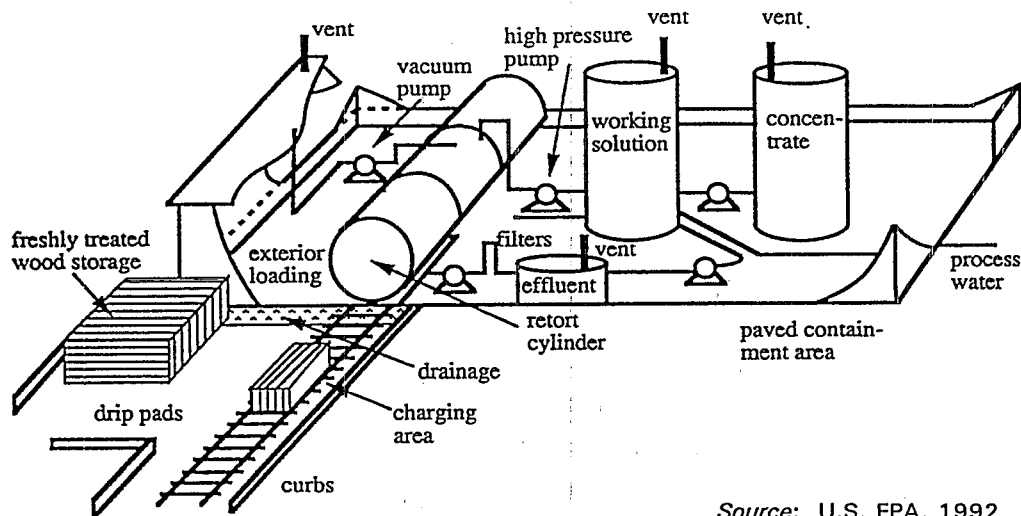
There are three major CCA manufacturers in the United States. Hickson Corp., a subsidiary of Hickson International PLC, Castleford, UK, operates four plants that are located in Conley, Georgia; Hickory Grove, South Carolina; Valparaiso, Indiana; and Kalama, Washington. Chemical Specialties, Inc. (CSI) is a subsidiary of another UK company, LaPorte PLC. CSI manufactures CCA at plants in Valdosta, Georgia; Harrisburg, North Carolina; and Gilmer, Texas. Osmose Corp. produces CCA in Memphis, Tennessee; Tangent, Oregon; and Rock Hill, South Carolina. Currently, U.S. demand for CCA is approximately 150 million pounds/year. U.S. production is about 165 million pounds/year. The cost of CCA to wood-preserving plants is about \$1.05 per pound of active ingredient (i.e., oxide content).

Treatment Process Description

Preblended CCA in 50% or 60% solution is shipped to the treating plant by a tank truck. The solution is transferred to a concentrate storage tank. Before treatment, the concentrate is diluted with water to a 1% to 2% working solution through a closed mixing system and then transferred to a work tank.

Treatment in a pressure cylinder (see Figure 1 for a typical facility) is the preferred commercial approach for treating wood. Pressure-treating processes include full-cell and modified full-cell processes. (The empty-cell process is used only for treatment with oilborne preservatives.) The full-cell process is used to obtain maximum CCA retention. The modified full-cell process is used to reduce CCA retention and drippage (U.S. EPA, 1993). The modified process is essentially the same as the full-cell process except that the modified process uses lower levels of initial vacuum and maintains pressure for an extended period after the initial pressure treatment (USDA, 1987).

During the pressure treatment, an initial vacuum is applied to remove air from the cylinder and the wood cells. CCA working solution at ambient temperature is then transferred to the cylinder through piping from the CCA work tank without breaking the vacuum. Hydrostatic or pneumatic pressure is applied until CCA permeates the wood or until the desired retention is obtained. The excess CCA solution is returned to the work tank for reuse. A final vacuum may be applied to remove excess CCA. The treated wood is removed from the cylinder and placed on a drip pad where it remains until dripping has ceased. The solution dripping onto the drip pad, as well as washdown water, flows to a collection sump from which it is pumped to a water storage tank. The recovered solution is used as a diluent to make fresh working solution. Therefore, no contaminated water



Source: U.S. EPA, 1992.

Figure 1. Wood preservative pressure-treating facility.

ever has to be discharged from CCA treating plants. The dirt, wood chips, and solid wastes on the drip pad are collected, dried, and drummed for disposal at a hazardous waste landfill.

Disposal of Treated Wood

Disposal of CCA-treated wood products gradually is becoming an environmental issue. Restrictions on landfill disposal are increasing and soon will preclude this option (Barnes and Nicholas, 1992). Therefore, other disposal methods are being studied. Current research focuses on extraction and destruction of the treated wood, followed by recovery and reuse of the preservative components. To date, no practical methods are commercially available.

ALTERNATIVE WOOD PRESERVATIVE SYSTEMS

Concerns over the adverse effects of arsenic on the environment and human health have prompted a search for more environmentally friendly wood preservative systems for wood treatment. The alternatives to be considered must be safe, effective, permanent, and cost effective (Barnes and Nicholas, 1992). The alternatives must be safe to handle during treatment operations, and the treated products must be safe to use. The alternatives must be effective in protecting wood against decay, marine borers, and insects. In this regard, adequate preservative retention and penetration are essential. Further, the alternatives must not be depleted from the treated wood at a rate higher than acceptable levels. This slow depletion rate would cause fewer harmful effects on the environment and human health. Economic considerations would include raw material costs, energy and processing costs, facility refurbishing costs, and waste disposal costs.

During the initial phase of this study, an extensive literature search was conducted for alternative wood preservative systems. The 34 non-CCA, non-PCP, and noncreosote wood preservatives identified included 18 organic, 8 inorganic, and 8 organometallic chemicals (see Appendix B for a detailed listing). Based on information in the literature, the effectiveness of each

of these wood preservatives was compared with that of CCA, PCP, and creosote and rated in accordance with the following rating system:

- +2 = Much better than the performance of CCA, PCP, and/or creosote
- +1 = Better than the performance of CCA, PCP, and/or creosote
- 0 = Similar to the performance of CCA, PCP, and/or creosote
- 1 = Poorer than the performance of CCA, PCP, and/or creosote
- 2 = Much poorer than the performance of CCA, PCP, and/or creosote

When data were lacking, the relative effectiveness simply was rated as good (1), fair (2), or poor (3).

Using the above-mentioned selection criteria and the performance rating system, ten candidate alternatives were selected for further consideration for the present study. These ten preservatives are acid copper chromate (ACC), chromated zinc chloride (CZC), bis-(tributyltin)oxide (TBTO), copper-8-quinolinolate (Cu-8), copper naphthenate, zinc naphthenate, boric acid and borate, quaternary ammonium compounds (QAC), fluoride-containing compounds, and zinc sulfate. Several telephone interviews to the experts were conducted; their comments are briefly summarized as follows:

- CSI has proposed to the AWWA that ammoniacal copper/quaternary ammonium compound (ACQ) be used as an alternative preservative.
- ACC is used primarily for cooling tower applications.
- CZC is an old treatment process and is not currently being used.
- TBTO is not used in the United States and does not perform very well as a wood preservative.
- Cu-8 is not used for wood that must be in contact with the ground. It is the only wood preservative having approval by the Food and Drug Administration (FDA) for wood in contact with food.
- Copper naphthenate and, perhaps, zinc naphthenate, are being accepted as alternatives.
- Borate, boric acid, and related mixtures are used primarily for remedial treatment. They are not used for permanent treatment because they tend to leach from treated wood due to their poor fixation property in wood.

Because ACQ appeared to be a viable alternative, Battelle contacted ACQ's manufacturer, CSI, which confirmed its proposal submission to AWWA's Treatments Committee. The proposal (Archer et al., 1992) was to be considered at the September 1992 AWWA meeting in South Dakota with a view to inclusion of ACQ treatments in selected commodity standards for the protection of southern yellow pine, Douglas fir, and Hem-fir lumber and timbers used in aboveground and ground-contact applications. Further, Battelle was informed that two ACQ formulations, Type A and Type B, had been accepted for inclusion in the AWWA's Preservative Standards. With the consent of EPA's Technical Project Monitor (TPM), Battelle selected ACQ for this evaluation study.

ACQ

Development

ACQ was developed and patented in Canada (Findlay and Richardson, 1983; 1990). It is a two-chemical-component preservative system, containing ammoniacal copper and a quaternary ammonium compound (quat). The combined biocidal effect of copper and quat (quat is used to kill Cu-tolerant fungi) protects wood from biodeterioration but exhibits relatively low mammalian toxicity and environmental impact (Archer et al., 1992). Unamended quaternary ammonium compounds provided protection against decay when used above ground (Butcher et al., 1977; Nicholas and Preston, 1980; Tillot and Coggins, 1981; Nicholas et al., 1991), but did not give adequate control of decay fungi in ground contact. This observation led to the modification of quats with copper salts (Butcher et al., 1979; Drysdale, 1983) and later to the development of ACQ systems (Findlay and Richardson, 1983; 1990; Wallace, 1986). ACQ was approved and commercially used first in Scandinavian countries in 1988 and, more recently, in Japan.

Compositions

ACQ contains copper(II) ion, carbonate, ammonia, and a quaternary ammonium compound. By convention, ACQ content is expressed in terms of CuO plus quaternary ammonium salt. The quat component is didecyldimethylammonium chloride (DDAC), as included in ACQ-Type B in AWWA Standard P5-92 (1992). The ratio of copper (expressed as CuO) to quat (expressed as the DDAC salt) in ACQ-Type B is 2:1, although this ratio may range from 5:1 to 1:5. The ratio of ammonia (as NH_3) to copper (as CuO) is a minimum of 1:1, and the ratio of carbonate (as CO_2) to CuO is a minimum of 0.65:1. These ratios are all expressed on a weight basis.

The active ingredients in the ACQ preservatives are copper salts and quaternary ammonium salts, which have negligible vapor pressure over the temperature range of practical applications; ammonia, which provides necessary alkalinity and forms a complex with Cu during treatment; and water, which evaporates (along with some ammonia) upon drying.

This study evaluated ACQ 2100, which comprises ammoniacal copper carbonate (ACQ-C) and quat (ACQ-Q50). The MSDSs for these chemicals are presented in Appendix A. ACQ-C (EPA Reg. No. 10356-19) is a 10% concentration of copper oxide (CuO) in aqueous ammonia. It is deep blue and has a sharp ammonia odor. Each gallon of ACQ-C weighs 10.0 lb (specific gravity 1.20 at 25°C) and contains 1.0 lb of CuO. ACQ-Q50 (EPA Reg. No. 6831-51-10356) is a 50% concentrate of DDAC. It is a clear to milky, viscous solution and weighs 7.73 lb/gal (specific gravity 0.927 at 25°C). Each gallon of ACQ-Q50 contains 3.86 lb of active ingredient. The two components are mixed with water to form work solutions with concentrations ranging from 0.5% to 10.0% by weight.

Fixation Mechanisms

The quaternary ammonium compound in ACQ fixes in wood through ion exchange with anionic active sites and through other adsorption mechanisms at higher quat concentrations (Archer et al., 1992). Quat is fixed predominantly onto lignin, although interaction with holocellulose also occurs. Copper is fixed in wood through ion exchange reactions between cupriammonium ions and acidic functional groups such as carboxylic acid groups of lignin and hemicellulose. Copper complexes with cellulose through hydrogen bonding with hydroxyl or amine nitrogen groups, or through replacement of an ammonia group from the cupriammonium ion with the hydroxyl ion of cellulose. Copper also forms insoluble copper carbonate salts resulting from the loss of ammonia during drying.

Effectiveness

ACQ's effectiveness to protect wood against decay fungi, marine borers, or insects has been demonstrated by a number of studies performed under a variety of geologic and climatic conditions (Archer et al., 1992; Hosli and Mannion, 1991; Jin and Archer, 1991; Jin and Preston, 1991; Jin et al., 1992). These studies included laboratory and simulated field efficacy tests, field tests, preservative permanence tests, and wood property tests. The results of some laboratory efficacy and field tests carried out by CSI are summarized in Table 2.

Laboratory tests utilized southern yellow pine sapwood blocks (0.75 in × 0.75 in × 0.75 in or 19 mm × 19 mm × 19 mm) treated with different ACQ formulations, CCA-Type C, and/or other water-soluble wood preservatives for performance comparison. The test results provided information on ACQ's efficacy against pure cultures of common wood decay fungi (soil block tests), soft rot fungi (soft rot tests), and termites (termite and termite resistance tests). In general, ACQ exhibited a broad spectrum efficacy in protecting wood against biodeterioration and termite attacks, even at retentions lower than the recommended levels in CSI's proposal to AWP. The simulated field test, or fungus cellar test, exposed treated southern yellow pine sapwood stakes (1 in × 0.5 in × 8 in or 25 mm × 12.5 mm × 200 mm) or stakelets (0.75 in × 0.2 in × 8 in or 19 mm × 5 mm × 200 mm) to an unsterile soil in a controlled environment. Relative humidity (RH) and temperature were maintained at 70 to 80% RH and 25 to 30°C, respectively. The data showed that ACQ's performance was slightly superior to or at least equivalent to that of CCA-Type C.

During the field tests, wood stakes of various dimensions were treated separately with several ACQ formulations and exposed to different soil types and geographical climates at several test sites around the world. The tests examined the performance of both aboveground and ground contact. In ground-contact tests, similar performances of ACQ, CCA, ACA, and/or ACZA were observed at equivalent retentions of active ingredient over an exposure period of up to 60 months at all test sites. ACQ with a 2:1 or even a 1:1 CuO to quat (DDAC, octyldecyldimethylammonium chloride [ODAC], or alkylbenzodimethylammonium chloride [ABAC]) ratio provided equally good protection for wood. The results of the post tests are not yet available.

The results of the aboveground tests also showed comparable performances between ACQ and CCA. One experiment conducted in North Queensland, Australia, indicated that, although ACQ and CCA provided equivalent protection for softwood species at all retentions, ACQ might be slightly superior to CCA for hardwood species. ACQ and CCA also provided identical resistance to termite attacks at all retentions.

In addition to the protection against biodeterioration, the ACQ-treated wood also must possess certain physical properties in terms of strength, corrosivity, electrical resistance, hygroscopicity, fire resistance, paintability, and appearance. Since 1987, CSI has been conducting a number of studies to address these issues. The results of these studies have been included in CSI's proposal to the AWP Treatment Committee. The effects of the ACQ treatment on treated wood physical properties are summarized in Table 3. Eight wood properties were studied — static bending strength, axial compression and lateral bending strength, conductivity, hygroscopicity, fire resistance, paintability, appearance, and corrosivity. No statistically significant difference in static bending was observed between different wood treatments, nor did ACQ treatment significantly influence the modulus of elasticity and maximum crushing stress value. No difference in measured resistance was noticed between ACQ and ACA. Further, treatment with ACQ imparted significant water-repellant properties to wood, thus providing significant protection from weathering to wood surfaces. ACQ-treated posts had afterglow characteristics similar to those of CCA-treated posts. ACQ and ACA provided similar substrates for coatings on wood. As for wood appearance, the inherent color of ACQ-treated wood depended on the wood species. After drying, ACQ-treated wood was free of objectionable odor and felt dry to the touch. ACQ-treated wood was very

TABLE 2. CSI EFFICACY AND FIELD TESTS

Test	Referenced Method	ACQ Formulation	Wood Tested	Exposure Time (months)	Place	Results
<u>Laboratory Tests</u>						
Soil Block Tests	AWPA E10-91	3:1 to 1:1	Southern yellow pine	N/A	Lab	Exhibits broad spectrum efficacy at retentions lower than the recommended levels in CSI's proposal to AWPA.
Soft Rot Tests	CSI Method	2:1	Southern yellow pine	N/A	Lab	See fungus cellar test.
Termite Test	AWPA EI	2:1	Southern yellow pine	N/A	Lab	Test method overly sensitive; modified methods being developed.
Termite Resistance Test	AWPA M12-72	1:1 (ODAC)	Southern yellow pine	N/A	Lab	Effective even at low retention levels against termites.
Simulated Field Tests						
Fungus Cellar Test	CSI Method	5:1 to 1:3	Southern yellow pine	50 or 24	Controlled environment	Performance of 2:1 ACQ slightly superior or equivalent to that of CCA-Type C.
<u>Ground-Contact Field Tests</u>						
Stake Tests	AWPA E7-90	2:1	Southern yellow pine	57	Harrisburg, NC and Hilo, HI	Similar performance of ACQ, CCA, and ACA at equivalent retentions of active ingredient.
		2:1	Southern yellow pine	21	Harrisburg, NC	Similar performance of ACQ, CCA, and ACZA at similar loadings.
		2:1 and 3:1	Southern yellow pine, hoop pine, and radiata pine	14	North Queensland, Australia	Comparable performance of both ACQ formulations vs CCA against decay and termites.
		2:1 and 3:1	<i>Eucalyptus maculata</i>	14	North Queensland, Australia	ACQ and CCA provide similar protection at equivalent loadings; highest loading used likely inadequate to guarantee long-term protection.

TABLE 2. CSI EFFICACY AND FIELD TESTS (Continued)

Test	Referenced Method	ACQ Formulation	Wood Tested	Exposure Time (months)	Place	Results
<u>Ground-Contact Field Tests (continued)</u>						
Stake Tests	AWPA E7-90	1:1 and 1:1 (ODAC)	Southern yellow pine	36	Saucier and Dorman, MS	ACQ with 1:1 copper to DDAC or ODAC ratio provided good protection against biodeterioration; CCA-Type C performance marginally superior to that of ACQ.
Post Tests	AWPA E8	1:2 and 1:2 (ABAC)	Radiata pine	60	Rotoiua, New Zealand	Both ACQ formulations provided excellent control of decay at all retentions.
		2:1	Southern yellow pine	N/A	N/A	Not yet available.
<u>Aboveground Field Tests</u>						
Aboveground Covered Decay Test	Archer et al., 1989	2:1	Southern yellow pine	12	Hilo, HI	Identical performance of ACQ and CCA at all retentions.
Aboveground Covered Test	Archer et al., 1989	2:1 and 3:1	Southern yellow pine, radiata pine, hoop pine, and <i>Eucalyptus maculata</i>	14	North Queensland, Australia	Both ACQ and CCA provided equivalent protection for softwood species at all retentions; ACQ's superiority over CCA for hardwood species likely.
Field Termite Performance Tests	AWPA P-6	2:1	Southern yellow pine and radiata pine	14	North Queensland, Australia	ACQ and CCA provided equivalent resistance to termite attacks at all retentions.

(a) Expressed as CuO to quat (DDAC) ratio unless stated otherwise.

(b) Method being evaluated by an AWPA P-6 task force.

N/A - Data not available in CSI's literature.

TABLE 3. PHYSICAL PROPERTIES OF ACQ-TREATED WOOD

Test	Reference Method	ACQ Formulation ^(a)	Wood Tested	Results
Static bending strength	ASTM D-143	3:1 to 1:1	Southern yellow pine	No statistically significant differences in static bending strength properties observed between treatments.
Axial compression and lateral bending strength	ASTM D-143	— ^(b)	Red pine	ACQ treatment did not significantly influence the modulus of elasticity and maximum crushing stress values.
Conductivity	CSI Method	1:1 (ODAC)	Red pine	No statistically significant differences in measured resistance between ACQ and ACA.
Hygroscopicity	Jin et al., 1992	1:1	Southern yellow pine	Treatment with ACQ-C imparts significant water-repellant properties to wood.
Fire resistance	CSI Method	— ^(b)	Southern yellow pine	ACQ treatment provides significant protection from weathering to wood surfaces.
Paintability	ASTM D-1008	— ^(b)	Red pine	ACQ-treated posts have afterglow characteristics similar to those of CCA-treated posts.
Appearance	CSI Method	— ^(b)	Most wood species	ACQ provides a substrate similar to that of ACA treatment for coatings on wood.
Corrosivity	MIL-L-19140E (AWPA Standard, 1991)	— ^(b)	Southern yellow pine	The inherent color of ACQ-treated wood is dependent on the wood species.
				After drying, ACQ-treated wood is free of objectionable odor and feels dry to touch.
				ACQ-treated wood is very corrosive to aluminum, but only slightly more corrosive than ACZA to brass and to mild and galvanized steel.

(a) Expressed as ratio of CuO to quat (DDAC) except as otherwise mentioned.

(b) Not specified.

corrosive to aluminum but only slightly more corrosive than ACZA to brass and to both mild and galvanized steel.

Pressure Treatment

The pressure treatment with ACQ is similar to that with CCA for the various wood species and dimensions. Reduced pressure periods may be possible due to the enhanced penetration capabilities of ammoniacal solutions. Typical treatment cycles are as follows (CSI, 1992):

Solution concentration:	1 to 3% actives
Solution temperature:	Ambient to 130°F
Initial steaming:	Optional
Initial vacuum:	≥ 22 in Hg for 0.5 to 2 hours
Pressure:	120 to 150 psi for 0.5 to 20 hours
Final vacuum:	≥ 22 in Hg for 0.5 to 3 hours

Operations

ACQ is corrosive to some metals and requires certain precautions. Valves, fittings, and other equipment that are in contact with ACQ components or work solutions should not contain brass, bronze, copper, or aluminum. Mild steel, stainless steel, fiberglass, and a variety of other nonmetallic materials are compatible with ACQ. Plants treating with ACQ may require the following (CSI, 1992):

- A mild steel or fiberglass ACQ-C concentrate tank with a minimum capacity of 6,000 gallons.
- A stainless steel, polyethylene, or fiberglass ACQ-Q50 concentrate tank with a minimum capacity of 1,500 gallons.
- A minimum of one mild steel or fiberglass work tank.
- A stainless steel or polypropylene mix tank with a minimum capacity of 500 gallons and an air-driven mixer.
- A water storage tank.
- A small measuring system and a diaphragm pump for accurate transfer of ACQ-Q50 to the mix tank.
- An ammonia scrubber system to control possible ammonia releases.
- A covered drip pad to protect freshly treated wood from rain for at least 48 hours after treatment.
- Adequate ventilation in work areas.

In addition, ACQ wood preservative should not be allowed to be contaminated with other treating compounds, such as CCA.

Manufacturer

In 1986, CSI began its effort to search for replacement preservatives for CCA. This effort was driven by its awareness of increasing environmental concerns over the use of As and Cr(VI) in the wood-preserving industry and by the need for a new marketing strategy to sell higher-profit-margin chemicals instead of the old, low-profit-margin CCA commodities. Since 1988, CSI has been conducting a series of laboratory tests, simulated field tests, and field tests. As a result, two ACQ formulations have been accepted by the AWWA Preservatives Committee as preservative standards in AWWA Standard P5. The same Committee has recommended to the Treatments Committee that retentions for aboveground and ground-contact uses of these formulations be the same as for CCA, ACA, and ACZA. In 1992, ACQ-Type B was accepted by the AWWA's Treatment Committee as a preservative standard. The final vote by the AWWA general membership in July, 1993 has also included ACQ in AWWA 1993 standards for selective commodities including lumber, timber, plywood, and posts.

Currently, CSI has exclusive rights to manufacture and market ACQ in the United States. It produces ACQ at plants in North Carolina. ACQ is being sold as two separate components, i.e., ammoniacal copper (ACQ-C) and quat (ACQ-Q50), each for \$3 per pound of active ingredient. ACQ-C and ACQ-Q50 are shipped as 10% and 50% solution, respectively, by tank trucks to the treating plants. So far, ACQ has been tested for commercial use at four treating plants in North Carolina, New York, Ohio, and Oregon. One of these, McArthur Lumber & Post Co., Inc. in McArthur, Ohio was the site selected for this technology evaluation study.

In 1992, 80% of CSI's business was in CCA chemical sales (about 33% market share in the USA) and wood-treating equipment production. Other CSI products include fire retardants (10%) and water repellents (10%). The annual sales volume of this company of 120 employees is about \$55 million.

LEACHING TESTS

Various leaching techniques have been used to investigate the fixation and leachability of active ingredients in wood preservatives. For example, Teichman and Monkman (1966) cut 0.25-in-thick wood discs from CCA-treated blocks and soaked the discs in a beaker of distilled water at room temperature. Da Costa (1967) placed sets of wood blocks in a glass jar with distilled water and shook the jar continuously in a rotary shaker at about 35°C. Fahlstrom et al. (1967) suspended treated wood wafers in a beaker of distilled water with rubber bands and, subsequently, vacuum-treated them at room temperature. The vacuum treatment was repeated and the leach water was then analyzed for Cu, Cr, and As. Other workers also used treated wood shavings (Henry and Jeroski, 1967) or sawdust (Häger, 1969) as test materials. Later, AWWA Standards (AWWA, 1992) provided a standard leaching procedure (E11-87) for the laboratory determination of leachability of wood preservatives. All of these tests were conducted as accelerated laboratory experiments; few large-scale leaching models were used in a simulated practical setting.

Chen and Walters (1979) treated southern yellow pine plywood with different formulations of CCA and subjected the treated material to artificial rainfall using a rain tower facility. The researchers examined the arsenic content in runoff, leachate, and soil, and in the plywood before and after exposure to rainfall. Archer et al. (1992) used field depletion tests as part of their test configurations to determine ACQ's leachability. The field depletion tests showed different depletion rates in soil and water for the active ingredients in most ACQ formulations.

SECTION 3

TECHNOLOGY EVALUATION SITE

McArthur Lumber & Post Co., Inc., a wood-fabricating company, opened for business in the 1950's. Owned by Whitaker-Merrill Co., the company fabricates tree-length wood into fence posts, fence board, guardrail posts, and specialty products for wholesalers and contractors. Located on 50 acres in rural McArthur, Ohio (80 miles southeast of Columbus), the facility has been treating wood primarily with CCA. The facility began treating wood with both CCA and ACQ in July, 1993. McArthur Lumber & Post uses about 300,000 lb of CCA oxide per year, which equates to about 15 million board feet (bd ft) of annual production. The plant operates one shift per day, 5 days a week. Approximately 60 people are employed full time with a seasonal high of 80. The McArthur facility, shown in Figure 2, consists of a treatment plant, a drip pad building, offices, storage yards, and sawmills.

WOOD TREATING FACILITY

Treatment Building

The ground floor of the treatment building (Figure 3) contains three parallel treating cylinders, a machine shop, and several storage areas. Before the spring of 1993, two 6 ft x 40 ft cylinders (No. 9 and No. 10 in Figure 3) were used to treat wood with CCA at low retention (0.4 lb/ft³) and high retention (0.5 to 0.6 lb/ft³), respectively. A 6 ft x 66 ft cylinder (No. 8) was used for steam drying. After the spring of 1993, the 6 ft x 66 ft steam drying cylinder was retrofitted for the low-retention CCA treatment. (Two new steam drying cylinders [each 6 ft x 55 ft] are being installed just outside of the drip pad building [see Figure 4, No. 39].) The 6 ft x 40 ft high-retention cylinder (No. 10) was retrofitted for the ACQ treatment, and the 6 ft x 40 ft low-retention cylinder (No. 9) was converted for the high-retention CCA treatment.

The cylinders are on concrete and/or steel supports sitting in a 9-ft-deep, heated and insulated basement (shaded area in Figure 3) surrounded by concrete walls. A variety of chemical storage tanks, process tanks, and mixing tanks sit on the concrete floor of the basement. The 66-ft cylinder and each of the 40-ft cylinders have one 2,200-gal (46 in x 16 ft [No. 11]) and one 1,200-gal (38 in x 16 ft [No. 12 and No. 13]) combo tank, respectively. Next to the 66-ft cylinder are two 8,000-gal CCA work tanks (tanks A [No. 6] and B [No. 5]) and one 8,000-gal freshwater tank (No. 4). Near the 40-ft ACQ treating cylinder are an 8,000-gal ACQ work tank (No. 16) and two boilers (No. 14 and No. 15). A doorway next to CCA work tank B leads to a separate room on the basement level that houses one 6,000-gal CCA concentrate tank (No. 7), one 8,000-gal process tank (No. 3), and the two 8,000-gal storage tanks containing design wood (No. 2) and Sequoya (No. 1) solutions. All tanks in the basement are steel and sit on 2-in pine boards to facilitate inspection and allow visual reference in case of a leak.

Also in the basement are a vacuum pump assembly (No. 22), a small laboratory (No. 21), two process control panels (No. 19 and No. 20), and two large floor pits (No. 17 and No. 18). The

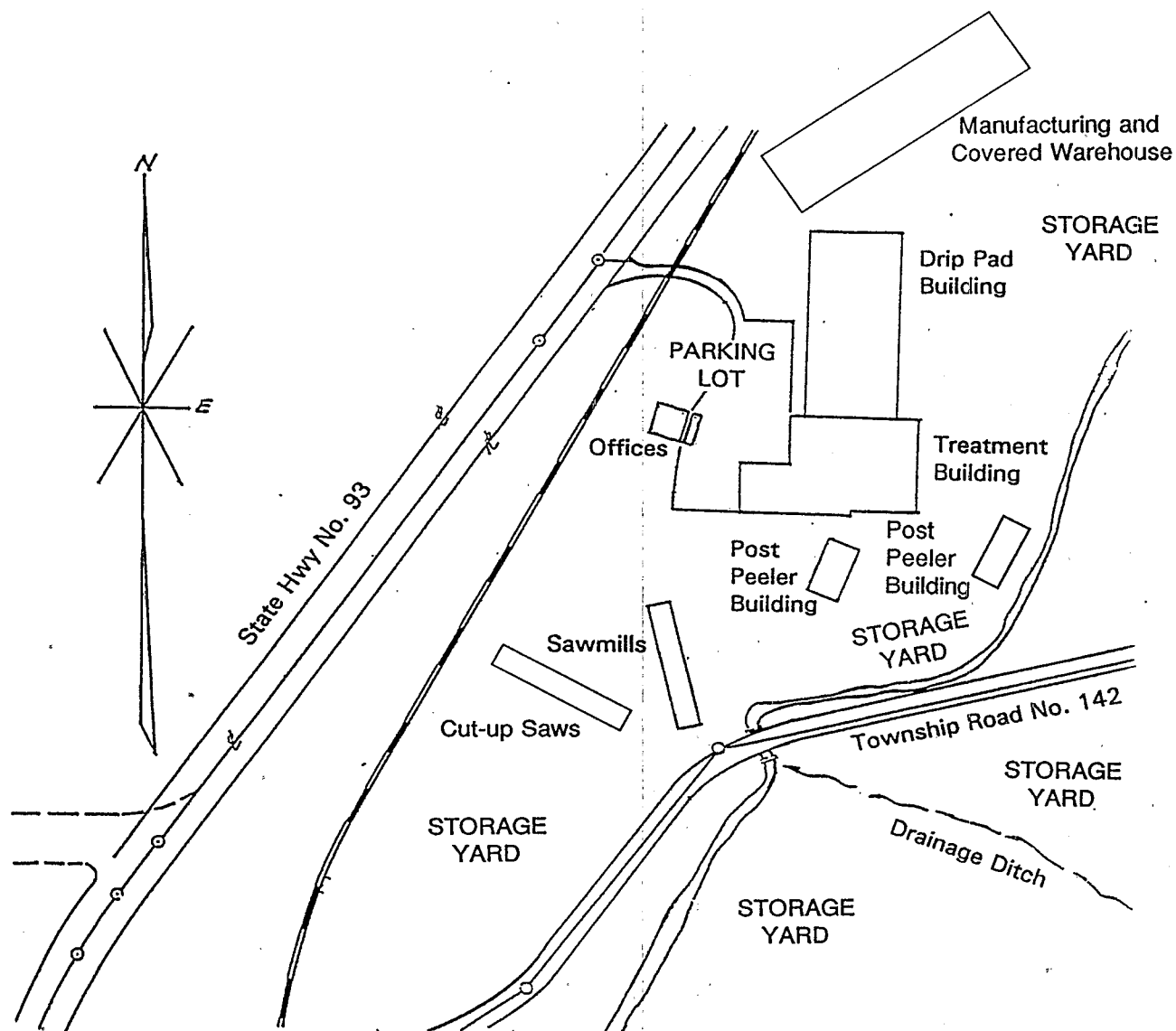
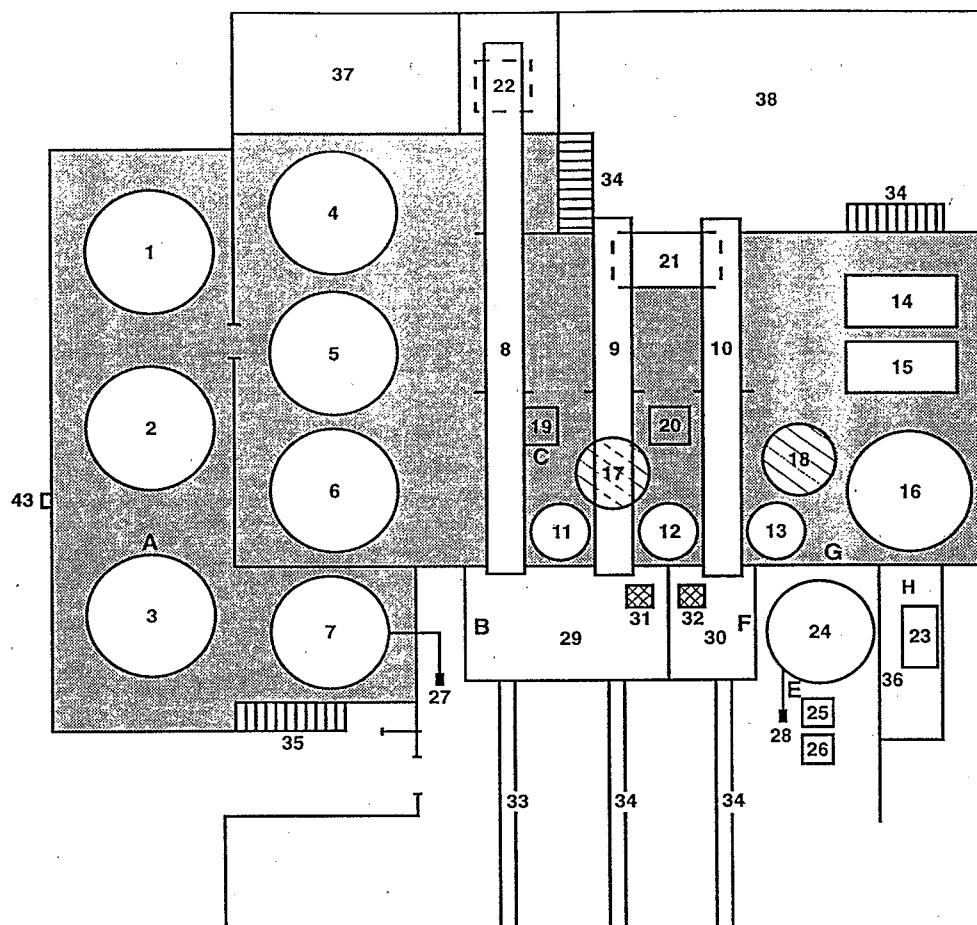


Figure 2. McArthur plant layout.

floor pits have been abandoned and are no longer in use. Chemical drips and washdown water collected in the CCA cylinder door pit ([No. 29] on the ground level) are pumped to either of the CCA combo tanks as a diluent.

During CCA treatment, all vacuum exhaust and pressure relief are vented to the CCA work tanks. The CCA work tanks and concentrate tank vent to the CCA process tank, which, in turn, vents to the atmosphere inside the building. During ACQ treatment, the vacuum exhaust, pressure relief, ACQ work tank, and ACQ concentrate tank are all vented through a 6-in polyvinyl chloride (PVC) pipe to the outside of the treatment plant.



Legend

- Basement Level
- Underneath Ground Level

Note: See Table 4 for equipment/facility identification/description

Figure 3. Treatment building at McArthur Lumber & Post Co. (not scaled).

Drip Pad Building

The 220 ft x 85 ft drip pad building (Figure 4) contains door pits for both the CCA and the ACQ cylinders, three tracks (leading away from the door pits), and drip pads. The building is supported by nine steel beams. The concrete floor slopes latitudinally in two 110-ft segments away from the middle. Washdown water and preservative dripping from the treated wood are drained through a screen (No. 31 or No. 32) at one end of the drip pad building at the cylinder door

TABLE 4. EQUIPMENT/FACILITY DESCRIPTION

No.	Description
1	Sequoia solution storage tank
2	Design wood solution storage tank
3	CCA process tank
4	Freshwater storage tank
5	CCA work tank B
6	CCA work tank A
7	CCA concentrate tank
8	6 ft x 66 ft cylinder (CCA low retention)
9	6 ft x 40 ft cylinder (CCA high retention)
10	6 ft x 40 ft cylinder (ACQ)
11	6 ft x 66 ft cylinder combo tank
12	6 ft x 40 ft cylinder combo tank
13	6 ft x 40 ft cylinder combo tank
14	Boiler 1
15	Boiler 2
16	ACQ work tank
17	Floor pit 1 (not operational)
18	Floor pit 2 (not operational)
19	Control panel 1
20	Control panel 2
21	Laboratory
22	CCA vacuum pump assembly
23	ACQ vacuum pump assembly
24	Ammoniacal copper concentrate tank
25	Quat concentrate tote
26	NH ₃ concentrate tote ^(a)
27	CCA concentrate quick coupler
28	Ammoniacal Cu concentrate quick coupler
29	CCA cylinder door pit
30	ACQ cylinder door pit
31	Screen to floor pit 1
32	Screen to 2 ft x 2 ft x 2 ft box
33	140 ft track
34	80 ft track
35	Staircase
36	Ramp from basement level to ground level
37	Storage area
38	Machine shop
39	6 ft x 55 ft steam drying cylinder
40	Track
41	DOT hazardous waste drum
42	Floor sump
43	ACQ vent

(a) Will not be used during commercial production.

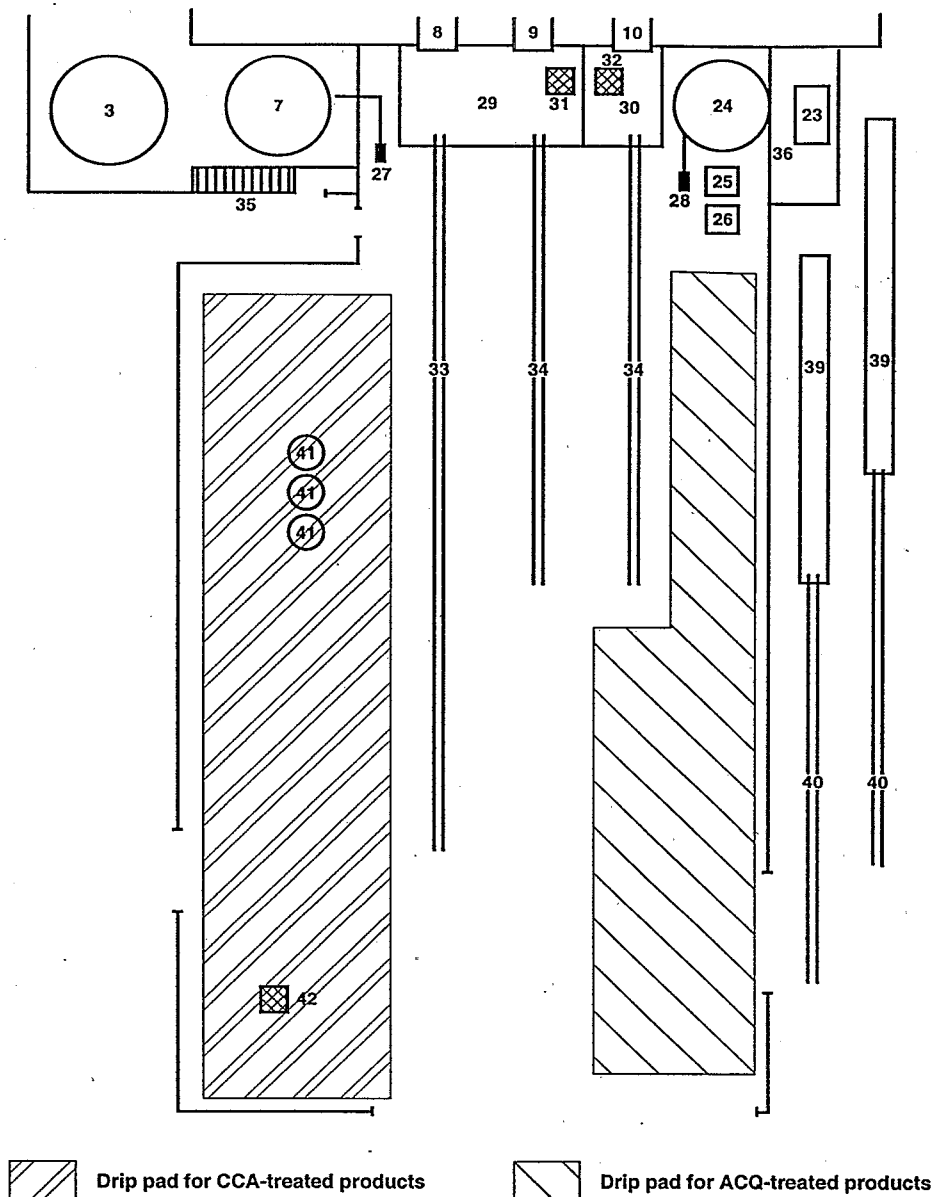


Figure 4. Steam drying cylinders and drip pad at McArthur Lumber & Post (not scaled).

pits (at 16 to 24 in depth [No. 29 or No. 30]) and at the other end at a floor sump (No. 42). CCA dripping from the treated wood is returned to the CCA combo tank (No. 11 or No. 12). A 2 ft x 2 ft x 2 ft box under the screen (No. 32) in the ACQ cylinder door pit (No. 30) collects washdown water and ACQ solution. The ACQ-containing water is vacuumed to the ACQ combo tank (No. 13) as a diluent. A steel divider in the cylinder door pit provides additional protection against mixing ACQ with CCA.

The concrete floor also slopes longitudinally down toward each of the three tracks along which treated wood is pulled by tram car from the cylinders. Eleven tram cars are used to pull treated wood from the 66-ft cylinder on a 140-ft track (No. 33). Six tram cars each pull wood from the 40-ft cylinders on 80-ft tracks (No. 34). One stationary forklift is used to transfer wood to and from the storage area, tram cars, and drip pads. The treated wood remains on the drip pads for at least 72 hours.

Several U.S. Department of Transportation (DOT) hazardous waste drums (No. 41) are located in the drip pad building. Approximately 75 to 100 lb of hazardous waste material per year is shipped off site to an approved handling facility. Near the ACQ cylinder door pit is one 6,000-gal fiberglass ammoniacal copper concentrate tank (8 ft x 16 ft [No. 24]) and two 275-gal totes containing quat concentrate (No. 25) and NH_3 concentrate (No. 26). (The NH_3 concentrate will not be used during commercial production.) This area will be separated with walls to maintain ambient temperature during the winter.

Because ACQ-C has the sharp odor of ammonia, an ammonia scrubber system may be needed to control ammonia releases. The ACQ Operator's Manual calls for the use of properly fitting, well-maintained, high-efficiency respirators by operators if ammonia levels in the plant exceed a 35-ppm short-term exposure limit (STEL) in 15 min or 25 ppm averaged over an 8-hour work period. These limits were set by the American Conference of Governmental Industrial Hygienists (ACGIH). An exposure limit of 50 ppm in 5 min also has been set by OSHA and NIOSH. In order to vent the odor of ammonia, a hood vent will be installed on top of the ACQ cylinder door. Meanwhile, a ceiling vent also will be installed to vent the air in the drip pad building.

The drip pad building is open at one end and is insulated, but not heated. Doors on either side of the building provide access to tank trucks to unload CCA, ammoniacal copper, and quat concentrates inside the drip pad building. Both CCA and ammoniacal copper concentrate tanks are equipped with quick couplers (No. 27 and No. 28) to facilitate chemical unloading.

WOOD-FABRICATING/TREATING PROCESSES

Figure 5 shows the wood-fabricating process at McArthur Lumber & Post. After wood is sawed, peeled, trimmed, and classified by diameter, it is either air-dried in the storage yard for 3 months or steam-dried. Steam-dried wood is kept in the storage yard for 10 days prior to treatment. About 25% of the wood is steamed. The remainder is air-dried.

The pressure-treating process is monitored by control panels underneath the treating cylinders in the basement. Wood is treated with CCA under the following conditions:

- Initial vacuum: 27 in Hg for 20 to 25 min
- Flooding: CCA transferred into combo tank and retort; complete in 10 to 12 min
- Pressure treatment: 150 to 160 psi for 25 to 30 min
- Blowback CCA to work tank: complete in about 10 min
- Final vacuum: complete in 20 min
- Door opening
- Wood drying on drip pad: complete in 48 to 72 hours.

Wood is treated with ACQ as follows (the functions of the combo tank are described):

- Initial vacuum: 25 in Hg for 10 min; 2 min after vacuum reaches 25 in Hg
- Flooding: ACQ transferred into combo tank and retort; complete in 10 min (valve shuts off on work tank and vacuum pump is off)

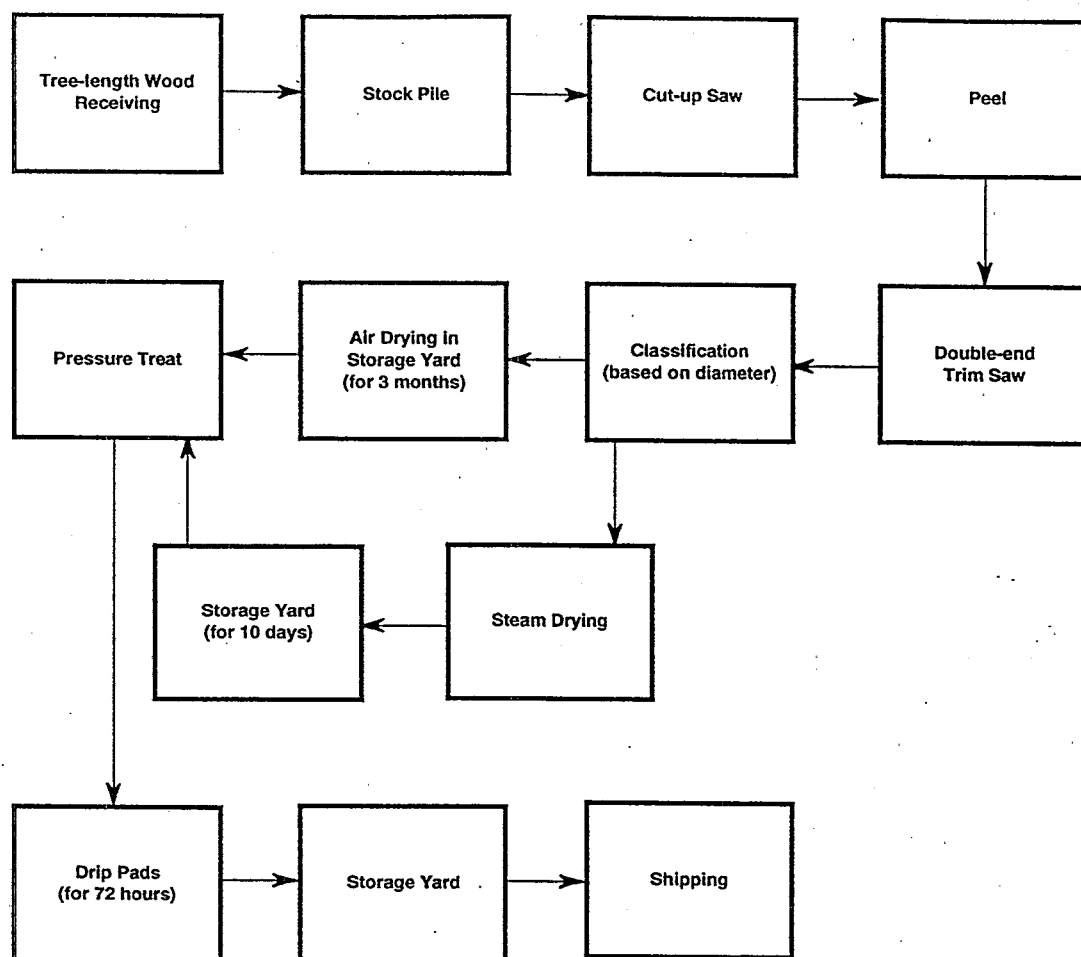


Figure 5. Flow diagram of wood-fabricating operations.

- Pressure treatment: 150 psi for 15 to 30 min (pressure is applied at top of combo tank; valve is opened at bottom of combo tank; solution is pushed into cylinder to replace the void space in the cylinder; this process is complete in 5 min)
- Slow pressure release: pressure vented from 150 psi to 20 psi; complete in 2 min
- Blowback (initial drain): cylinder drained to work tank; complete in 5 min
- Air venting: vent cylinder to atmospheric pressure; complete in 1 min
- Final vacuum: complete in 15 to 20 min
- Door opening
- Wood drying on drip pad (or staging area): under wrap for 48 to 72 hours.

After the treated wood is forklifted to the drip pad (or staging area), the ACQ-treated wood is wrapped with plastic sheets to avoid formation of blue deposits on the wood surface. After 2 to 3 days, the plastic wraps on the wood units are removed and the wood units are forklifted to a covered storage area for about 4 to 5 days to allow ammonia to dissipate. Ordinarily, the freshly treated wood is green and the color gradually turns into light brown after aging.

SECTION 4

EVALUATION APPROACH AND EXPERIMENTAL METHODS

SOURCES OF POLLUTION

The potential sources of pollution at a typical wood treatment facility occur during delivery of chemicals, storage of chemicals, chemical mixing, working solution storage, pressure treating, and treated-wood storage on drip pads and in open storage yards. The potential chemical releases from these occurrences can be in the form of vapors, aerosols, and dust to the ambient air, drips and spills to the ground, and stormwater runoff and seepage to the ground and/or storm sewers.

As indicated in Table 5, before the dried, treated wood units are removed from the drip pad to the open storage yard, releases of aerosols and vapors of wood preservative toxic components pose a potential threat to the environment, primarily the ambient air, and to workers' health. These aerosols and vapors are released mainly through the vents of the process tank, concentrate tanks, and work tanks, as well as from cylinder doors, cylinder door pits, and stacks of treated wood. Dust collected on the drip pad can also become airborne and pose a threat. Drips and/or spills from hoses, pipes, valves, and storage tanks during chemical transfer, mixing, and storage, as well as from pressure-treating cylinders and treated-wood units, generally are contained in lined concrete pads, pits, and sumps, and can be reused as process solutions. Therefore, drips and spills are not as problematic as aerosols and vapors. In the open storage yard, stormwater runoff and seepage can cause soil and groundwater contamination.

EVALUATION APPROACH

Because the ACQ preservative system does not contain As and Cr(VI), its use can result in substantial reduction in toxic waste and prevention of pollution. However, it is important to identify any toxic emissions resulting from ACQ use. Therefore, this study monitored the following potential sources of pollution during the CCA and ACQ treatment:

1. As, Cr(VI), and Cu emissions to the air and worker exposure to these emissions during CCA treatment.
2. Ammonia and Cu emissions to the air and worker exposure to these emissions during ACQ treatment.
3. CCA and ACQ drips and spills associated with the delivery, mixing, and storage of chemicals, with the pressure-treating process, and with storage of treated wood on the drip pads.

TABLE 5. POTENTIAL SOURCES OF POLLUTION AT WOOD TREATMENT FACILITIES

Source of Pollution	Potential Chemical Release	Chemical Release Through/From	Receiving Medium	Release Potential
Chemical delivery by tanker	Drips and spills	Tanker hoses and quick coupler	Drip pad	Moderate
Chemical concentrate storage	Aerosols and vapors Spills	Process tank or concentrate vent Pipes and valves	Air Concrete floor	High Low
Chemical mixing	Aerosols and vapors Spills	Process tank or work tank vent Pipes and valves	Air Concrete floor	High Low
Working solution storage	Aerosols and vapors Spills	Process tank or work tank vent Pipes and valves	Air Concrete floor	High Low
Pressure treating	Aerosols and vapors	Process tank or work tank vent	Air	High
- Initial vacuum	Aerosols and vapors	Process tank or work tank vent	Air	High
- Flooding via vacuum	Aerosols and vapors	Cylinder door	Air	Moderate
- Pressure treating	Aerosols and vapors Drips	Cylinder door	Door pit	Moderate
- Pressure relief and blowback	Aerosols and vapors	Process tank or work tank vent	Air	High
- Final vacuum	Aerosols and vapors	Process tank or work tank vent	Air	High
- Door opening	Aerosols and vapors Drips	Cylinder door Cylinder door	Air Door pit	High High
Freshly treated wood storage on drip pad	Drips Dust	Treated wood units Drip pad	Drip pad Air	High High
Wood storage in open storage yard	Stormwater runoff and seepage Dust	Treated wood units Storage yard	Ground Air	High Moderate

4. Solid wastes collected on the drip pads during both CCA and ACQ operations.
5. Stormwater runoff in the open storage yard.

Before being tested, the CCA and ACQ working solutions were prepared as specified by the respective chemical manufacturers. The drip pads were not washed before testing as planned because washing of the drip pads could severely interfere with the plant's normal operations. Further, washing of the drip pads could not prevent the drip pads from being cross-contaminated with either CCA or ACQ. During the test runs, air quality and worker exposure were monitored. The respective cylinders were charged with a number of wood units consisting of southern yellow pine (SYP) lumber, timber, and fence posts. After their respective pressure treatments, the CCA- and ACQ-treated wood were removed from the cylinders and placed separately in a designated area on the drip pads. The ACQ-treated wood was immediately covered with plastic wraps to avoid formation of blue deposits on the wood surface. After 4 days, four 36 in \times 42 in \times 8 ft wood units, each consisting of 42 pieces of 6 in \times 6 in \times 8 ft rough-cut timber, were taken from the CCA- and ACQ-treated wood units (two each) for leaching. These four treated units along with one untreated wood unit were sprinkled with tap water to generate simulated stormwater runoff.

EXPERIMENTAL METHODS

The waste reduction and pollution prevention characteristics of the CCA and ACQ treatments were evaluated and compared using the parameters listed in Table 6. Table 7 summarizes the number of samples to be collected and the sampling locations. Some of these sampling locations also have been identified in Figures 3 and 4.

CCA and ACQ Treatment

Solution Compositions

The solution compositions for some of the CCA and ACQ treatment charges are presented in Tables 8 and 9, respectively. The 1.5% CCA solutions contained As, Cr(VI), and Cu active oxide ingredients that met the AWWA Standard P5-92 (1992). The composition of two ACQ solutions deviated beyond the limits specified in the same AWWA Standard. However, this deviation did not impact the results of this study.

CCA Wood Treatment

During CCA wood treatment, wood units consisting of SYP lumber, timber, and fence posts were charged to both the low-retention cylinder (No. 8 in Figure 3) and the high-retention cylinder (No. 9). Three charges to each cylinder were completed during the testing; the total wood volume treated for each charge is listed in Table 10. The CCA uptake, total active ingredients absorbed, and calculated retention of CCA by each charge are presented in Table 11. The CCA retention was calculated by dividing the total active ingredients absorbed by the sapwood volume, which was estimated by the treatment plant operator. (Generally speaking, heartwood is too hard for preservative solutions to penetrate.) As shown in the table, the CCA retention for the low-retention charges ranged from 0.41 to 0.46 lb/ft³. The CCA retention for the high-retention charges varied from 0.48 to 0.68 lb/ft³. The treatment targets for the low and high retention were 0.4 and 0.6 lb/ft³, respectively.

TABLE 6. LIST OF CRITICAL AND NONCRITICAL MEASUREMENTS

Objective	Matrix	Measurement	Critical Measurement
<u>Ambient Emissions and Worker Exposure</u>			
CCA treatment	Aerosols and vapors	As	Yes
		Cr(VI)	Yes
		Cu	Yes
ACQ treatment	Aerosols and vapors	Cu	Yes
		NH ₃ (by NIOSH method)	Yes
		NH ₃ (by Dräger-tube method)	No
<u>Chemical Drips and Spills</u>			
CCA treatment	Drips and spills	Volume	No
ACQ treatment	Drips and spills	Volume	No
<u>Stormwater Runoff</u>			
CCA treatment	Simulated stormwater	As	Yes
		Cr	Yes
		Cu	Yes
		pH	Yes
		TSS	No
		TDS	No
		TKN	No
		TOC	No
ACQ treatment	Simulated stormwater	As	No
		Cr	No
		Cu	Yes
		pH	Yes
		TSS	No
		TDS	No
		TKN	Yes
		TOC	Yes

TSS = Total suspended solids.

TDS = Total dissolved solids.

TKN = Total Kjeldahl nitrogen.

TOC = Total organic carbon.

ACQ Wood Treatment

During ACQ wood treatment, wood units of SYP lumber, timber, and fence posts were charged to the ACQ cylinder (No. 10). One and three charges were treated on September 24 and 28, respectively. The September 24 test runs were discontinued following an operational error made by the treatment plant operator. As a result, ACQ testing was repeated on September 28. The total wood volume treated for each charge is listed in Table 12. The ACQ uptake, total active ingredients absorbed, and calculated and analyzed retention of ACQ by each charge are presented in Table 13. The calculated ACQ retentions for charges A9, A10, and A11 were 0.35, 0.25, and 0.42 lb/ft³, respectively, which were about 10 to 30% lower than the analyzed values according to

TABLE 7. PRIMARY AND DUPLICATE SAMPLES

Matrix	Sampling Location ^(a)	Parameter	Sampling Type	Number of Samples		
<u>Aerosols and Vapors</u>						
CCA treatment	A,B,C,D	As	Primary	6		
			Duplicate ^(b)	2		
		Cr(VI)	Primary	6		
			Duplicate ^(b)	2		
		Cu	Primary	6		
			Duplicate ^(b)	2		
ACQ treatment	E,F,G,H,I	Cu	Primary	8		
			Duplicate ^(c)	1		
		NH ₃	Primary	8		
			Duplicate ^(c)	1		
		<u>Chemical Drips and Spills^(d)</u>				
		CCA treatment	J,K,L,M,N	N/A	N/A	0
ACQ treatment	O,P,Q,R,S,T	N/A	N/A	0		
<u>Stormwater Runoff</u>						
CCA treatment	U ^(a)	Metals ^(f)	Primary	6		
		TSS	Primary	6		
		TDS	Primary	6		
		pH	Primary	6		
		TKN ^(g)	Primary	6		
		TOC ^(h)	Primary	6		
ACQ treatment	U ^(h)	Metals ^(f)	Primary	6		
		TSS	Primary	6		
		TDS	Primary	6		
		pH	Primary	6		
		TKN ^(g)	Primary	6		
		TOC ^(h)	Primary	6		

(a) Sampling locations:

- A - Approximately 1 ft south of CCA process tank (No. 3), about 5 ft above the basement floor.
 B - Approximately 4 ft from door to CCA treating cylinder (No. 8), on nearby ledge.
 C - On top of file cabinet adjacent to control panel (No. 19), about 5 ft above the basement floor.
 D - Samplers worn by the treatment plant operator, the drip pad loader operator, and the drip pad ground man.
 E - Between ammoniacal copper concentrate tank (No. 24) and quat concentrate tote (No. 25), about 5 ft above the drip pad floor.
 F - Approximately 5 ft from door to ACQ treating cylinder (No. 10), on nearby ledge.
 G - Approximately 5 ft west of ACQ combo tank (No. 13), against north wall of the basement, about 4 ft above the basement floor.
 H - About 1 ft above and 4 ft south of the ACQ vacuum pump assembly (No. 23).
 I - Samplers worn by the treatment plant operator, the drip pad loader operator, the drip pad ground man, the yard boss, and the one outside loader operator.
 J - CCA chemical delivery area (No. 27).
 K - CCA concentrate storage area (No. 7).
 L - CCA work tanks area (No. 5 and No. 6).
 M - CCA combo tanks area (No. 11 and No. 12).
 N - Tracking from CCA treatment cylinders (No. 8 and No. 9) to CCA drip pad.
 O - ACQ chemical delivery area (No. 28).

TABLE 7. PRIMARY AND DUPLICATE SAMPLES (Continued)

- P - Ammoniacal copper concentrate tank area (No. 24).
 Q - Quat and NH_3 concentrate totes area (No. 25 and No. 26).
 R - ACQ combo tank area (No. 13).
 S - ACQ work tank area (No. 16).
 T - Tracking from ACQ treatment cylinder (No. 10) to ACQ drip pad.
 U - Samples collected from 32-gal drums. The simulated stormwater runoff was created by sprinkling water on wood units using garden sprinklers.
 (b) Duplicate sample collected at sampling locations A and B.
 (c) Duplicate sample collected at sampling location F.
 (d) No sampling performed; observation of drips and spills recorded.
 (e) Samples collected from two treated wood units at three time intervals.
 (f) Including As, Cr, and Cu.
 (g) Total Kjeldahl nitrogen.
 (h) Total organic carbon.
 N/A - not applicable

Standard Method M2-91 (AWPA, 1992). These discrepancies most likely were the result of underestimating the heartwood volume (or overestimating the sapwood volume). The ACQ solution for charge A7 was not analyzed; the wood borings sampled from that charge contained 0.85 lb/ft^3 active ingredient, which was about twice as much as the target retention (e.g., 0.4 lb/ft^3). As also shown in Table 13, at least 19 out of 20 wood borings sampled from the four charges met the penetration requirements specified by Standard C2-92 (AWPA, 1992), indicating that these charges would be accepted as adequately treated commodities.

Analytical Methods

To determine CCA and ACQ solution composition, As, Cr, and Cu were analyzed using X-ray fluorescence spectroscopy (Standard A9-90, AWPA, 1992). The concentrations of

TABLE 8. CCA SOLUTION COMPOSITIONS

Composition	Charge Number			Target	AWPA Standard ^(d)	
	B 357 ^(a)	B 383 ^(b)	B 437 ^(c)		min (%)	max (%)
Cr (% by wt., as CrO_3)	0.728	0.730	0.723	↓	44.5	50.5
Cr (%)	48.0	48.3	48.0			
Cu (% by wt., as CuO)	0.261	0.256	0.257		17.0	21.0
Cu (%)	17.0	16.9	17.1			
As (% by wt., as As_2O_5)	0.527	0.526	0.526		30.0	38.0
As (%)	30.0	34.8	34.9			
Total (% by wt.)	1.516	1.511	1.506	1.5		
Total (%)	100.0	100.00	100.00			

(a) Treatment occurred on September 7, 1993.

(b) Treatment occurred on September 15, 1993.

(c) Treatment occurred on October 11, 1993.

(d) AWPA Standard P5-92, Standards for Waterborne Preservatives: CCA-Type C (AWPA, 1992).

TABLE 9. ACQ SOLUTION COMPOSITIONS

Composition	Charge Number			Target
	A9	A10	A11	
Cu (% by wt., as CuO)	0.95	0.79	0.98	1.00 ^(b)
quat (% by wt., as DDAC ^(a))	0.36	0.54	0.50	0.50 ^(c)
NH ₃ (% by wt., as NH ₃)	1.13	1.08	1.23	1.00
CuO/quat	2.6	1.5	2.0	2.0
NH ₃ /CuO	1.2	1.4	1.3	1.0
Total active ingredients (% by wt.)	1.31	1.33	1.48	1.50

(a) Didecyltrimethylammonium chloride

(b) AWP Standard P5-92: minimum 0.93%; maximum 1.07% (AWPA, 1992).

(c) AWP Standard P5-92: minimum 0.44%; maximum 0.57% (AWPA, 1992).

TABLE 10. MATERIAL TREATED WITH CCA

Charge Number	No. of Pieces	Size	Volume (ft ³)	Total Volume (ft ³)	% Heartwood ^(a)
B364 ^(b)	109	3.5 in to 5 in x 7.5 ft ^(c)	71	304	40
	349	1 in x 6 in x 16 ft	233		
C129 ^(d)	185	7 in to 9 in x 6 ft ^(c)	388	780	50
	90	6 in x 8 in x 6 ft	180		
	75	8 in x 8 in x 6 ft	200		
	2	8 in x 12 in x 9 ft	12		
B365 ^(b)	109	3.5 in to 5 in x 7.5 ft ^(c)	71	337	50
	42	6 in x 6 in x 8 ft	84		
	273	1 in x 6 in x 16 ft	182		
C130 ^(d)	222	7 in to 9 in x 6 ft ^(c)	466	780	60
	150	6 in x 8 in x 6 ft	300		
	19	1 in x 6 in x 18 in	1		
	7	1 in x 10.75 in x 22 in	1		
	12	4 in x 4 in x 8 ft	11		
	24	4 in x 4 in x 4 in	1		
B366 ^(b)	100	6 in to 7 in x 9 ft ^(c)	207	395	40
	60	8 in to 9 in x 9 ft ^(c)	188		
C131 ^(d)	333	7 in to 9 in x 6 ft ^(c)	699	819	60
	60	6 in x 8 in x 6 ft	120		

(a) Heartwood percentage estimated by treatment plant operator.

(b) Low-retention charge.

(c) Cylindrical posts.

(d) High-retention charge.

TABLE 11. CCA TREATMENT

	Charge Number					
	B364	C129	B365	C130	B366	C131
<u>CCA Working Solution</u>						
Active ingredients (%)	1.5	1.8	1.5	1.8	1.5	1.8
Specific gravity	1.0131	1.0156	1.0131	1.0156	1.0131	1.0156
Active ingredients per gallon of solution (lb/gal)	0.1263	0.1520	0.1263	0.1520	0.1263	0.1520
CCA uptake ^(a) (gal)	594	1220	594	1284	864	1485
Total active ingredients absorbed (lb)	75.02	185.44	75.02	195.17	109.30	225.72
<u>Wood Treated</u>						
Total wood volume (ft ³)	304	780	337	780	395	819
Estimated heartwood volume (ft ³)	122	390	169	468	158	491
Estimated sapwood volume ^(b) (ft ³)	182	390	168	312	237	328
Calculated retention ^(c) (lb/ft ³)	0.41	0.48	0.44	0.63	0.46	0.68

(a) Solution absorbed by wood.

(b) Estimated sapwood volume was used to calculate CCA retention.

(c) Calculated CCA retention = (Total active ingredients absorbed)/(Estimated sapwood volume).

TABLE 12. MATERIAL TREATED WITH ACQ

Charge Number	No. of Pieces	Size	Volume (ft ³)	Total Volume (ft ³)	% Heartwood ^(a)
A7 ^(b)	210	6 in x 6 in x 8 ft	420	420	50
A9	240	N/A	227	391	25
	109	3.5 in to 5 in x 7.5 ft ^(c)	71		
	75	5 in to 6 in x 7.5 ft ^(c)	93		
A10	182	1 in x 6 in x 8 ft	61	290	25
	91	1 in x 6 in x 10 ft	38		
	91	1 in x 6 in x 12 ft	46		
	112	1 in x 6 in x 16 ft	75		
	105	1 in x 6 in x 16 ft	70		
A11	208	2 in x 4 in x 8 ft	61	481	25
	256	2 in x 6 in x 12 ft	176		
	128	2 in x 6 in x 16 ft	117		
	80	2 in x 10 in x 16 ft	127		

(a) Heartwood percentage estimated by treatment plant operator.

(b) Charge A7 was treated on September 24, 1993. The rest of the charges were treated on September 28, 1993.

(c) Cylindrical posts.

N/A = Data not available.

long-chain quaternary ammonium compounds in ACQ were measured by a titrimetric method using sodium tetraphenylborate as a titrant and 2',7'-dichlorofluorescein as a color indicator (Archer et al., 1992). The ammonia content in ACQ was determined by Standard Method A2 Part 1 (AWPA, 1992).

To determine retention and penetration in the treated wood, Standards M2-91 and C2-92 call for the extraction of 20 of the 2-in-diameter wood borings from each charge for inspection (AWPA, 1992). Penetration to 2.5 in or 85% of sapwood will pass the test. If 90% of the borings pass the penetration test, the charge will be accepted. For retention measurements, the outer 1 in thickness of the 20 wood borings from materials with sizes over 2 in was used for analyses. (For those with sizes up to 2 in, the outer 0.6 in thickness would be used.) The cut wood drills were grounded and dried before being analyzed for As, Cr, and/or Cu using X-ray fluorescence spectroscopy. The quat content was analyzed using a two-phase titration method or a high-performance liquid chromatography (HPLC) method (Archer et al., 1992).

Emissions and Worker Exposure Monitoring

Industrial hygiene monitoring for worker exposures to As, Cr(VI), Cu, and NH₃ was conducted during CCA and ACQ testing. Airborne concentrations of As, Cr(VI), and Cu were measured during CCA wood treatment on September 8, 1993. Airborne concentrations of NH₃ and Cu were measured during ACQ wood treatment on September 24 and September 28, 1993. Sampling conducted on September 24, 1993 was halted following the spill of ACQ working solution as mentioned above.

As shown in Table 7, primary and/or duplicate samples were collected and analyzed to ascertain approximated full-shift (8-hour) and short-term (15-minute) occupational exposures to

TABLE 13. ACQ TREATMENT

	Charge Number			
	A7 ^(a)	A9 ^(b)	A10 ^(b)	A11 ^(b)
<u>ACQ Working Solution</u>				
Active ingredients ^(c) (%)	N/A	1.31	1.33	1.5
Specific gravity	N/A	1.0111	1.0113	1.0130
Active ingredients per gallon of solution (lb/gal)	N/A	0.1105	0.1122	0.1268
ACQ uptake ^(d) (gal)	600	915	495	1200
Total active ingredients absorbed (lb)	N/A	101.11	55.54	152.16
<u>Wood Treated</u>				
Total wood volume (ft ³)	420	391	290	481
Estimated heartwood volume (ft ³)	183	98	72	120
Estimated sapwood volume ^(e) (ft ³)	237	293	218	361
Calculated retention ^(f) (lb/ft ³)	N/A	0.35	0.25	0.42
Analyzed retention ^(c,g) (lb/ft ³)	0.85	0.51	0.40	0.47
Penetration ^(h)	19/20	20/20	20/20	20/20

(a) Treated on September 24, 1993.

(b) Treated on September 28, 1993.

(c) Analyzed by CSI Laboratory.

(d) Solution absorbed by wood.

(e) Estimated sapwood volume was used to calculate ACQ retention.

(f) Calculated ACQ retention = (Total active ingredients absorbed)/(Estimated sapwood volume).

(g) CuO/quat ratio was approximately 2:1.

(h) x/20 = number out of 20 wood borings with penetration to 2.5 in of wood or 85% of sapwood.

N/A = data not available.

As, Cr(VI), Cu, and NH₃. Sampling devices were positioned in the employee's breathing zone (defined by OSHA as a sphere of 2-ft radius surrounding a worker's head) or in stationary locations and operated for a full shift; short-term, or ceiling samples, were collected for 15 minutes. Exposures were calculated as the time-weighted average of the full-shift and 15-minute samples.

The workshift began at 6:30 a.m. and continued until 3:30 p.m., with two 15-minute paid breaks and a one-half hour unpaid lunch. Samplers worn by personnel were operated during the entire workshift, except during lunch. Stationary samplers were operated continuously for about 8 hours.

Sampling Locations

During CCA wood treatment, sampling devices were worn by the treatment plant operator, the drip pad loader, and the drip pad ground man. Stationary samplers were positioned at three locations (see Table 7 and Figure 3):

- Location A (primary and duplicate samples): approximately 1 ft south of the CCA process tank (No. 3), about 5 ft above the basement floor
- Location B (primary and duplicate samples): approximately 4 ft from the door to the CCA treating cylinder (No. 9), on a nearby ledge

- Location C (primary sample only): on top of file cabinet, adjacent to control panel (No. 20), about 5 ft above the basement floor.

During ACQ wood treatment, sampling devices were worn by the treatment plant operator, the drip pad loader operator, and the drip pad ground man. Stationary samplers were positioned at four locations:

- Location E (primary sample only): between ammoniacal copper concentrate tank (No. 24) and quat concentrate tote (No. 25), about 5 ft above the drip pad floor.
- Location F (primary and duplicate samples): approximately 5 ft from the door to ACQ treating cylinder (No. 10), on a nearby ledge.
- Location G (primary sample only): approximately 5 ft from ACQ combo tank (No. 13), about 4 ft above the basement floor.
- Location H (primary sample only): about 1 ft above and 4 ft south of the ACQ vacuum pump assembly (No. 23).

In addition, the personal exposures of the yard boss to As and the outside loader operator to Cr(VI) also were measured during ACQ wood treatment to provide information on background (outdoor) concentrations of these metals.

General Workplace and Ambient Conditions

The north end of the drip pad building was open. The treatment building was below grade. Ambient conditions such as temperature and relative humidity were monitored and are presented in Table 14. The treatment plant operator spent the entire workshift in the treatment plant. The drip pad ground man and drip pad loader operator were in the drip pad building while loading untreated lumber prior to a treatment charge and during unloading of the newly treated lumber following the treatment. At all other times, the drip pad personnel were outside the drip pad building, usually involved in loading and unloading trucks in the lumber yard. Approximately 25% of their workday was spent in the drip pad building.

TABLE 14. AMBIENT CONDITIONS DURING AIR SAMPLING

Date	Time	Location	Temperature, °F	Percent Relative Humidity	Comments
9/8/93	0815	Drip pad	64	80	Sunny, breezy
	0820	Treatment building	69	66	—
	1330	Drip pad	75	Not measured	Sunny, breezy
	1335	Treatment building	77	Not measured	—
9/28/93	0900	Drip pad	56	88	Sunny, cool
	0905	Treatment plant	60	60	—
	1245	Drip pad	62	Not measured	Sunny, cool
	1250	Treatment plant	62	Not measured	—

Sampling and Analytical Methods

All air samples were collected using SKC Model 224PCXR3 or Gillian HFS-113 personal sampling pumps. The sampling pumps were calibrated according to the manufacturers' specifications before and after each use. Metal samples collected during CCA wood treatment were held overnight before being shipped by Federal Express to the analytical laboratory. Ammonium samples collected during ACQ wood treatment on September 24, 1993 were kept refrigerated until the remaining ammonia and metal samples were obtained on September 28, 1993. All ammonia samples were kept refrigerated until they were shipped overnight to the analytical laboratory on October 4, 1993. The sorbent tubes used for ammonia sampling are stable at ambient temperature for 29 days; there are no special storage or handling requirements for metal samples collected on membrane filters.

The samples were analyzed according to techniques specified in the appropriate NIOSH and OSHA analytical methods: As and Cu by modified National Institute for Occupational Safety and Health (NIOSH) Method 7029 and Occupational Safety and Health Administration (OSHA) ID 105 (atomic absorption spectrophotometry); Cr(VI) by NIOSH 7600 (visible absorption spectrophotometry); and ammonia by NIOSH P&CAM205 (visible absorption spectrophotometry). The analytical laboratory is accredited under the Laboratory Accreditation Program of the American Industrial Hygiene Association (AIHA).

NH₃ Monitoring by Dräger Tubes

In addition to the NIOSH air sampling devices, a semi-quantitative detecting device, the Dräger tube, was used to obtain a rough estimate of ammonia concentrations at various monitoring locations throughout the ACQ pressure treatment process. The monitoring was carried out during mixing, transfer, and storage of chemicals; during pressure treating (including initial vacuum, flooding, pressure treating, slow pressure release, blowback (or initial draining), air pressure venting, final vacuum, and door opening); and during treated-wood unloading to the drip pad. The monitoring was performed at locations around concentrate storage tanks and totes, combo tanks, work tanks, and cylinder doors; and just outside the vent. On a few occasions, the monitoring also was done at different levels above ground. The treated wood units on the drip pad also were monitored for NH₃ at several distances away from the surface of the wood. The monitoring locations and monitoring times are summarized in Table 15.

The results of the Dräger tube measurements also were used to obtain rough estimates of the quantities of NH₃ emitted from the stack (vent) associated with the concentrate and working solution tanks, combo tank, treating cylinder, and evacuation pump. These quantities in conjunction with those emitted from the treated wood were used to calculate yearly NH₃ emissions during ACQ wood treatment.

The Dräger tube measurements were accomplished using a Dräger accuro® hand pump equipped with ammonia 2/a tubes (for concentrations ranging from 2 to 30 ppm), ammonia 5/a tubes (for concentrations ranging from 5 to 700 ppm), and ammonia 0.5%/a tubes (for concentrations ranging from 0.05% to 10%). The tubes contained a yellow, a yellowish-orange, or a yellow indicating layer depending on the applicable concentration ranges. When air samples were sucked through the tubes, the indicating layer changed color from yellow to blue, yellowish-orange to blue, or yellow to violet, respectively. The entire length of the discoloration was then converted to the corresponding concentration.

Chemical Drips and Spills

As noted in Section 3, with a self-contained treatment plant layout, normal chemical drips and spills during CCA or ACQ operations would not create an immediate hazard to the

TABLE 15. DETECTION OF NH₃ USING DRÄGER TUBES

Source of Emissions	Monitoring Locations	Monitoring Time
Chemical concentrate storage	Around ACQ-C concentrate tank Around quat concentrate tote	Any time before treatment Any time before treatment
Chemical mixing and working solution storage	Around concentrate tanks and totes Around ACQ combo tank and work tank Vent Vent Vent Vent	During chemical mixing and storage During chemical mixing and storage During quat addition During ACQ-C addition During water addition During solution transfer from combo tank to work tank
Pressure treating process		
- Initial vacuum	Vent Around vacuum pump	During initial vacuuming During initial vacuuming
- Flooding	Vent Around vacuum pump	During flooding During flooding
- Pressure treating	Around cylinder door Around vacuum pump	During pressure treating During pressure treating
- Slow pressure release	Vent	During slow pressure release
- Blowback (initial draining)	Vent	During blowback
- Air pressure venting	Vent	During air pressure venting
- Final vacuum	Around cylinder door Vent Around vacuum pump	During final vacuuming During final vacuuming During final vacuuming
- Door opening	Around cylinder door Around cylinder door	Right after cylinder door opened 5 min afterward
Freshly treated wood on drip pad	Within 0.5 in of wood surface 3 ft away from wood surface	As soon as wood units were placed on drip pad. 10 min afterward After 0.5 in-from-wood-surface monitoring was complete 10 min afterward

environment. Therefore, no samples were collected to examine these effects. However, it is necessary for a treatment plant to maintain good housekeeping practice and to avoid any major chemical spills in and around the plant. During the on-site study, the plant operations were closely observed and any chemical drips and spills were recorded. As previously indicated in Table 5, the most likely sources of drips and spills occurred during chemical delivery, chemical storage, chemical mixing, working solution storage, pressure treating, and treated wood storage on drip pads.

Solid Waste on the Drip Pad

Dirt, dust, and debris on the drip pad were not collected after CCA or ACQ wood treatment as planned because little was accumulated on the drip pad after either treatment.

Stormwater Runoff

Test Layout

After the treated wood units had remained on the drip pad for 4 days, two 36 in × 42 in × 8 ft wood units from each treatment were subject to artificial rainfall on the drip pad. One untreated unit served as a control. Each wood unit consisted of 42 rough-cut timber pieces, each 6 in × 6 in × 8 ft. The wood units tested were stacked crosswise on top of three or four similar units spaced approximately 4 ft apart (see layout in Figure 6), with a sheet of heavy-duty polyethylene liner placed underneath each of the top units. The separating liners then were arranged as illustrated in Figure 7 to allow collection of runoff directly under each of the top units. A garden sprinkler placed about 6 ft above the floor and about 9 ft away from the units tested was used to produce artificial rainfall. The amount of the rainfall was measured by five rain gauges placed on top of the top units and at locations covering the entire test area. The runoff collected within the liner boundary flowed to a 32-gal plastic container. At different time intervals, the volume of the runoff collected in each plastic container was measured and runoff samples were taken for testing for heavy metals (including As, Cr, and Cu), total suspended solids (TSS), total dissolved solids (TDS), pH, total Kjeldahl nitrogen (TKN), and total organic carbon (TOC). After sampling, the water in the plastic containers was disposed of to the cylinder door pits.

Analytical Methods

Samples of stormwater runoff were collected in polyethylene bottles containing appropriate preservatives as specified in the respective EPA methods. After collection, the bottled samples were placed on ice in two large coolers and delivered in person to the analytical laboratory with the appropriate labels and chain-of-custody forms. The samples were analyzed in 5 to 19 days, which met all holding-time requirements. Concentrations of Cr and Cu were measured using EPA Method 6010. Arsenic concentrations were analyzed using EPA Method 7060. TSS and TDS were measured gravimetrically using EPA Methods 160.2 and 160.1, respectively. Acidity (pH) was measured using EPA Method 150.1. Concentrations of TKN and TOC were measured using EPA Methods 351.2 and 9060, respectively.

Estimation of Economics

Evaluating the economic worth of the new wood preservative was a comparative process. Costs associated with the old CCA wood-preserving practice were evaluated, identified, and compared with those associated with changing to and then maintaining the ACQ treatment process. In general, capital, operating, and waste disposal costs were included.

Costs associated with the CCA practice included capital equipment and CCA costs, as well as the total labor hours spent treating the wood. This total work time included practicing safety procedures, treating the wood in pressure cylinders, unloading the treated wood to drip pads, and handling liquid and/or solid wastes. Changing to the new ACQ process involved spending for capital equipment, materials, miscellaneous startup costs, and operation and maintenance (O&M) costs. The facilities were revamped to accommodate the ACQ treatment process.

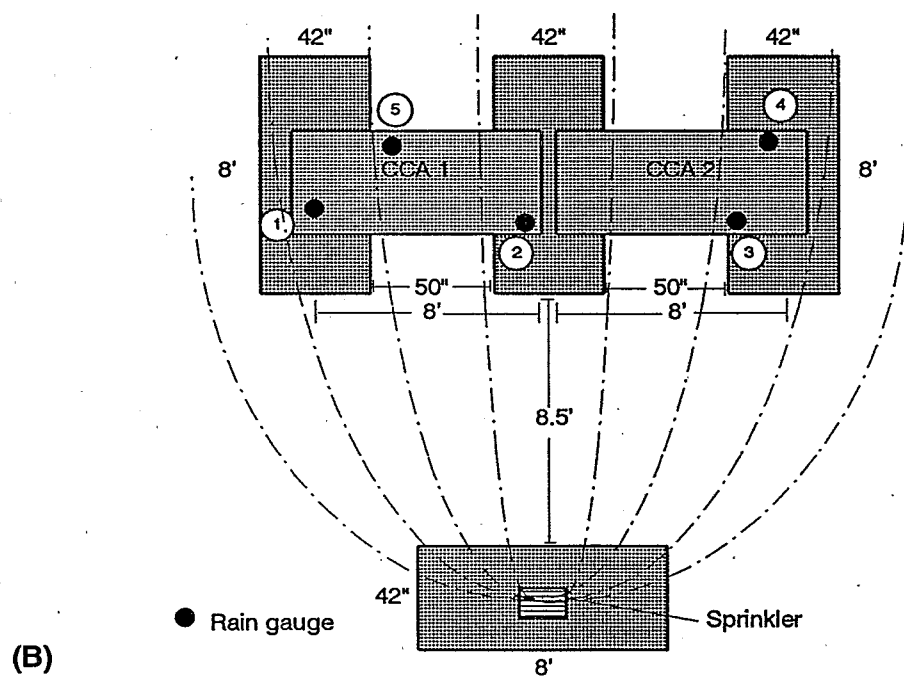
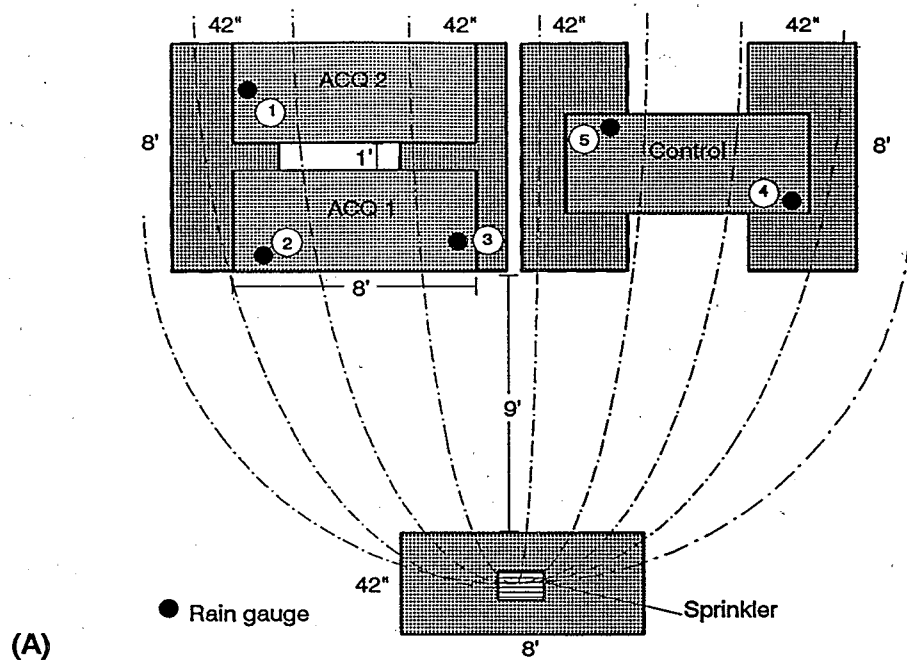


Figure 6. Leaching test layout for ACQ- and CCA-treated wood units (overhead view).
(A) ACQ and control; (B) CCA.

(A)



(B)

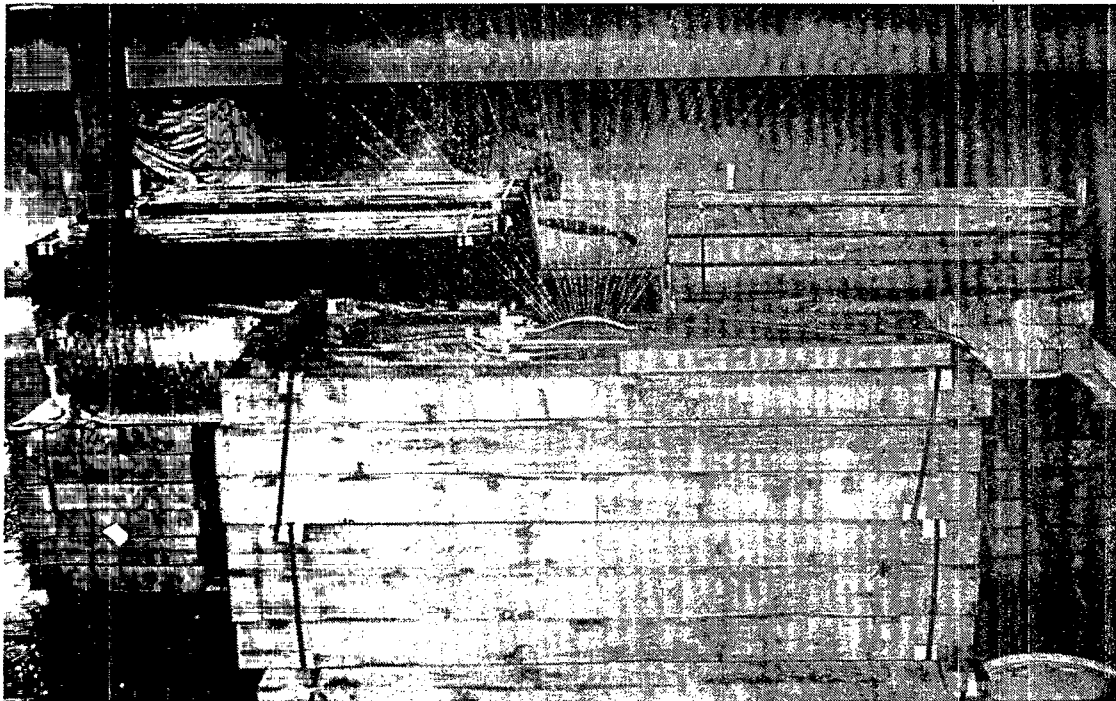


Figure 7. ACQ-treated and control wood units with plastic liners (A) and sprinkler setup (B).

SECTION 5

WASTE REDUCTION/POLLUTION PREVENTION POTENTIAL EVALUATION

Pollution prevention is achieved primarily by reduction of waste at the source. Pollution prevention considers all waste types, such as hazardous waste, solid waste, wastewater, air emissions, and utility consumption. Reductions must be true reductions in volume and/or toxicity of waste and not simply a transfer of waste from one medium to another.

The waste reduction potential was measured in terms of volume reduction and toxicity reduction. The reductions were quantified by comparing waste volumes and types from the CCA treatment process with those produced by the ACQ treatment process. Volume reduction addressed the gross wastestream, such as chemical spills, air emissions, and stormwater runoff. Toxicity reduction considered concentrations and types of contaminants, such as As, Cr(VI), and Cu in the CCA gross wastestream versus NH_3 , TOC, and TKN in the ACQ gross wastestream.

The pollution prevention potential also considered hazards that any toxic emissions might pose to workers. Air quality was measured in terms of airborne metal concentrations and NH_3 concentrations. The results of these measurements would determine the proper safety attire to be worn by the plant operators.

This section discusses contaminant emissions and worker exposures to these emissions during CCA and ACQ wood treatment. The contaminants could be emitted in a form of liquid, vapors, and/or aerosols. The results of a leaching study also are discussed, in which stormwater runoff was created by subjecting treated wood to artificial rainfall.

AIR EMISSIONS AND WORKER EXPOSURES

During CCA and ACQ wood treatment, As, Cr(VI), Cu, and NH_3 could be emitted to the air as toxic contaminants. Occupational Safety and Health Administration (OSHA), National Institute for Occupational Safety and Health (NIOSH), and American Conference of Governmental Industrial Hygienists (ACGIH) have established Permissible Exposure Limits (PELs), Recommended Exposure Limits (RELs), and Threshold Limit Values (TLVs), respectively, to regulate these toxic ambient air contaminants (NIOSH, 1990). The OSHA PELs are time-weighted average (TWA) concentrations that must not be exceeded during any 8-hr shift of a 40-hr workweek. The NIOSH RELs are TWA concentrations for up to a 10-hr workday during a 40-hr workweek. The ACGIH TLVs are 8-hr TWA concentrations and usually are more restrictive than the OSHA PELs or NIOSH RELs.

As listed in Table 16, the OSHA PEL for As is 0.010 mg/m^3 . The NIOSH REL for As is at a ceiling concentration of 0.002 mg/m^3 , as assessed during a 15-min exposure. This ceiling value should not be exceeded during any 15-min exposure. The OSHA PEL for chromic acid and chromates is at a ceiling concentration of $0.1 \text{ mg CrO}_3/\text{m}^3$, which must not be exceeded at any time. The NIOSH REL for all hexavalent chromium compounds is 0.001 mg/m^3 ; NIOSH considers all Cr(VI) compounds to be potential occupational carcinogens. The ACGIH 8-hr TWA TLV is 0.05 mg/m^3 for water-soluble Cr(VI) compounds, monochromate and dichromate salts, and certain water-insoluble Cr(VI) compounds that are designated as confirmed human carcinogens (NIOSH, 1990). The OSHA, NIOSH, and ACGIH limits for Cu are 0.1, 0.1, and 0.2 mg/m^3 , respectively.

**TABLE 20. RESULTS OF PERSONNEL AND AREA MONITORING FOR AMMONIA
DURING ACQ WOOD TREATMENT**

Personnel or Area Monitored	Sample Duration (min)	Flow Rate (L/min)	Sample Volume (L)	Analytical Result ^(a) ($\mu\text{g}/\text{sample}$)	Airborne Conc. ^(b) (mg/m^3)	8-hr TWA ^(c) (mg/m^3)
Drip pad ground man	462	0.106	49.0	220	6.5	7.5
	15	0.106	1.59	42	38	
Drip pad loader operator	482	0.107	51.6	8.9	0.25	0.97
	15	0.107	1.61	27	24	
Treatment plant operator	446	0.107	47.7	33	1.0	1.1
	15	0.107	1.61	6.0	5.4	
Location G	344	0.104	35.8	< 4.0 ^(d)	< 0.2	0.45
	15	0.104	1.56	9.2	8.5	
Location H	297	0.103	30.6	61	2.9	3.6
	15	0.103	1.55	19	18	
Location E	474	0.106	50.2	230	6.6	7.1
	15	0.106	1.59	25	23	
Location F	474	0.105	49.8	290	8.4	8.4
	15	0.105	1.58	11	10	
Location F (duplicate)	473	0.108	51.1	270	7.6	7.9
	15	0.108	1.62	19	17	

(a) Mass of analyte per sample as reported by the analytical laboratory.

(b) Milligrams of contaminant per cubic meter of air.

(c) 8-hour airborne concentration, calculated as the time-weighted average of the long-term and short-term sample results.

(d) Less than the analytical limit of quantitation.

surrounding the concentrate storage tanks, ACQ combo tank, and ACQ work tank. Ammonia concentrations ranging from 32 to 200 ppm were detected at the vent during addition of ACQ-C, quat, and water to the combo tank; 0.17% to 0.26% ammonia was detected at the vent during solution transfer from the combo tank to the work tank.

During pressure treatment, ammonia concentrations at the vent, in the areas surrounding the vacuum pump assembly (No. 23 in Figure 3), and at the door to the cylinder were monitored. Ammonia concentrations measured in the vacuum pump assembly area ranged from 1.5 to 41 ppm; two of 18 measurements exceeded the short-term exposure limit of 35 ppm recommended by OSHA, NIOSH, and ACGIH. Ammonia concentrations detected about 10 ft away from the vacuum pump ranged from 2 to 5 ppm. These monitoring results coincided with the short-term concentration (18 ppm) and 8-hour TWA concentration (3.6 ppm) measured at Location H (Table 20). The vacuum pump assembly was located in an annex west of the drip pad building with a ramp connecting the ground level and the basement. During air monitoring, the area was not ventilated; the water tank associated with the vacuum pump was not covered.

The monitoring results for ammonia at the door to the ACQ treating cylinder ranged from below the airborne quantitation limit to 75 ppm. Before the door was opened, only trace levels were detected. Right after the door was opened, three of the four measured concentrations

TABLE 21. NH₃ MONITORING USING DRÄGER TUBES

Source of Emissions	Monitoring Locations ^(a)	Monitoring Time	NH ₃ Concentration (ppm or %)					
			A9		A10		A11	
			1	2	1	2	1	2
Chemical concentrate storage	Around ACQ-C concentrate tank	Any time before treatment			<DL			
	Around quat concentrate tote	Any time before treatment			<DL			
Chemical mixing and working solution storage	Around concentrate tanks and totes	During chemical mixing and storage			<DL			
	Around ACQ combo tank and work tank	During chemical mixing and storage			<DL			
	Vent	During quat addition					35	50
	Vent	During ACQ-C addition					200	
Pressure-treating process	Vent	During water addition					32	
	Vent	During solution transfer ^(a)					0.17%	0.26%
	Vent	During initial vacuum	200	200	205	210	0.06%	0.07%
	Around vacuum pump	During initial vacuum	2	3	5	3		
- Flooding	Vent	During flooding	<DL	<DL	<DL	<DL	<DL	<DL
	Around vacuum pump	During flooding					10	15
- Pressure treating	Around vacuum pump	During pressure treating	1.5	3	38	9	3	5
	Around cylinder door	During pressure treating	Trace	1				
- Slow pressure release	Vent	During slow pressure release		0.15%	0.18%	0.18%	0.18%	0.12%
- Blowback (initial draining)	Vent	During blowback	0.25%	0.22%	0.20%	0.21%	0.21%	0.21%
- Air pressure venting	Vent	During air pressure venting	0.25%	0.27%	0.12%	0.14%	0.16%	0.18%

TABLE 21. NH₃ MONITORING USING DRÄGER TUBES (Continued)

Source of Emissions	Monitoring Locations ^(a)	Monitoring Time	NH ₃ Concentration (ppm or %)								
			A9			A10			A11		
			1	2	Trace	1	2	Trace	1	2	Trace
- Final vacuum	Around cylinder door	During final vacuum	Trace	Trace	Trace						
	Vent	During final vacuum	0.10%	0.11%	0.10%	0.10%	0.10%	0.18%	0.18%	0.11%	
	Around vacuum pump	During final vacuum	19	35	29(5 ^(b))	41(3 ^(b))	21(2 ^(b))	24(2 ^(b))			
- Door opening	Around cylinder door	Right before door opening				8					
	Around cylinder door	Right after door opening	50	9				75		35	
	Around cylinder door	About 5 min after opening	40	22				13 ^(c)		38 ^(c)	
	15 to 20 ft away from door	About 5 to 10 min after opening	11	19							
Freshly treated wood on drip pad	Within 0.5 in of wood surface	As soon as wood was placed on drip pad				200 ^(d)					
		10 min afterward	450	410	78 ^(d)	90 ^(d)	70 ^(d)				
	3 ft away from wood surface	10 min afterward	39	55	32	50					

(a) From combo tank to work tank.

(b) Measured about 10 ft away from the vacuum pump.

(c) Measured about 10 min afterward.

(d) Measured 1 to 3 ft away from wood surface.

<DL = lower than detection limit.

exceeded the short-term exposure limit of 35 ppm; the highest concentration was measured just inside the cylinder. Ammonia concentrations at the door dissipated to between 22 and 40 ppm and between 13 and 38 ppm after about 5 and 10 minutes, respectively. Meanwhile, the concentrations measured in the areas about 15 to 20 ft away from the door were 11 to 19 ppm.

The results of monitoring for ammonia at the vent ranged from 205 to 700 ppm during initial vacuum; from 0.12% to 0.18% during slow pressure release; from 0.20% to 0.25% during blowback; from 0.14% to 0.27% during air pressure venting; and from 0.10% to 0.18% during final vacuum. All airborne concentrations measured both upwind and downwind under the vent and at levels about 5 to 6 ft above the ground were below the quantitation limit of the Dräger tubes.

Ammonia concentrations measured within 3 ft of the freshly treated wood surface after unloading ranged from 32 to 450 ppm, with the highest concentration detected within 0.5 in of the wood surface. All airborne concentrations measured except one exceeded the short-term exposure limit of 35 ppm.

Total Ammonia Emissions

Using the ammonia concentrations measured at the vent during chemical mixing and pressure treating, the ammonia emission from each treatment charge was calculated and is presented in Table 22. The emission calculations are detailed in Appendix C. About 0.25 lb (or 114 g) to 0.35 lb (or 158 g) of ammonia was vented during each treatment charge; 0.015 lb (or 7.0 g) was emitted during chemical mixing. Assuming 2 mixes/day, 3 charges/day, and 240 working days/yr,

TABLE 22. NH₃ EMISSIONS DURING ACQ WOOD TREATMENT

Emission Source	NH ₃ Emissions (mg/m ³)	NH ₃ Mass Vented (g)			Total NH ₃ Venting (g)	Yearly NH ₃ Venting ^(b) (kg)
		Charge Number				
		A9	A10	A11		
<u>Mixing Process</u>						
Addition of ACQ-C	139			0.49 (mg)	0.98 ^(a) (mg)	
Addition of quat	35			1.4 (mg)	2.8 ^(a) (mg)	
Addition of water	22			75.5 (mg)	151.0 ^(a) (mg)	
Solution transfer	1,807			6.9	13.8 ^(a)	
Subtotal				7.0	14.0	3.4
<u>Treating Process</u>						
Initial vacuum	386	2.5	3.0	7.8	13.3	
Flooding	0	0	0	0	0	
Pressure treating	0	0	0	0	0	
Slow pressure release	1,182	17.3	11.3	25.5	54.1	
Blowback	1,552	44.7	41.7	33.9	120.3	
Air venting	1,367	79.5	43.3	49.8	172.6	
Final vacuum	904	13.8	14.3	20.0	48.1	
Subtotal		157.8	113.6	137.0	408.4	98.0
Total						101.4

(a) Assuming two mixes per day.

(b) Assuming 240 working days.

the treatment plant would emit about 224 lb (or 102 kg) of ammonia when treating about 280,000 ft³ commodity.

Because of ammonia's volatility and the relatively high pH values in treated wood (e.g., about pH 8 to 9), a significant amount of ammonia would be discharged from the wood during air drying and storage. One experiment performed by CSI reported 40.57% ammonia loss after air drying for 14 days (Jin, 1993). The experiment evaluated ammonia loss of ten ¾ in × ¾ in × ¾ in ACQ-impregnated wood blocks based on the ammonia content both before and after air drying. The ammonia content in the wood blocks before air drying was calculated from the solution uptake; the ammonia content after air drying was obtained using TKN analysis. The 40.57% ammonia loss might represent a worst-case scenario because the wood blocks used for the experiment had much more available surface area per unit volume for volatilization than do the actual commodities produced. As a result, the ammonia discharge from the 280,000 ft³ of ACQ-treated wood would not exceed 24,860 lb/yr (or 11,300 kg/yr) (see Appendix C for a detailed calculation).

Based on the above discussion, treating 280,000 ft³ of commodities with ACQ would result in about 25,084 lb (or 11,400 kg) of ammonia emissions, of which 99.1% would be discharged from the treated wood. Therefore, converting to ACQ wood treatment would result in annual emissions of ammonia up to about 90,000 lb from the ACQ treatment operations and the ACQ-treated wood for a treatment plant with 1 million ft³ annual production, or up to about 450,000 lb for a plant with 5 million ft³ production.

Copper

Monitoring results for copper are presented in Table 23. Ranging from below the airborne quantitation limit of 0.0004 mg/m³ to 0.0035 mg/m³, these full-shift measurements were less than 4% of the OSHA PEL and NIOSH REL of 0.1 mg/m³ and less than 2% of the ACGIH TLV-TWA of 0.2 mg/m³.

TABLE 23. RESULTS OF PERSONNEL AND AREA MONITORING FOR COPPER DURING ACQ WOOD TREATMENT

Personnel or Area Monitored	Sample Duration (min)	Flow Rate (L/min)	Sample Volume (L)	Analytical Result ^(a) (µg/sample)	8-hr TWA ^(b,c) (mg/m ³)
Drip pad ground man	462	1.98	915	2.6	0.0028
Drip pad loader operator	482	2.08	1,003	3.4	0.0034
Treatment plant operator	461	2.12	977	0.9	0.0009
Location G	474	2.04	967	< 0.40 ^(d)	< 0.0004
Location H	475	2.12	1,007	1.2	0.0012
Location E	210	2.05	431	1.5	0.0035
Location F	474	2.07	981	1.2	0.0012
Location F (duplicate)	473	2.02	955	1.4	0.0015

(a) Mass of analyte per sample as reported by the analytical laboratory.

(b) Milligrams of contaminant per cubic meter of air.

(c) See Tables 17-20.

(d) Less than the analytical limit of quantitation.

Outdoor Concentrations

The exposures of the yard boss to arsenic and copper and of the yard loader operator to Cr(VI) and ammonia during ACQ wood treatment were measured to provide information on outdoor concentrations of these contaminants. The results are shown in Table 24. None of these contaminants were present in quantities above the analytical limit of quantitation; the resulting airborne concentrations were less than 2% of the applicable exposure limits.

CHEMICAL DRIPS AND SPILLS

During CCA wood treatment, no drips or spills were observed in the areas around the water storage tank, CCA combo tank, CCA work tanks, CCA process tank, and vacuum pump assembly, or in the areas under the bottom of the cylinder doors. After door opening and during unloading, some drips to the door pit and the drip pad were noticed. Drips intercepted by the drip pad flowed slowly onto the concrete floor (that slopes longitudinally toward each of the two CCA tracks) toward the door pit.

As noted earlier, sampling conducted on September 24, 1993 was halted following a spill of ACQ solution caused by an human error. The "blowback" of ACQ solution from the treating cylinder to the work tank was started before the system pressure was released (from 165 psi) to a safe level of 40 psi. Consequently, the ACQ solution was forced into the 6-in vent-pipe located on top of the work tank, and discharged to the yard outside of the treatment plant. In the meantime, a large quantity of the ACQ solution leaked through the 6-in vent-pipe to the areas surrounding the ACQ work tank and combo tank.

During the ACQ wood treatment on September 28, 1993, no major drips or spills were observed. Some drips or leaks were spotted under the cylinder door, around the vacuum pump assembly, and under a transfer line from the vacuum pump to the mixing tank area.

TABLE 24. RESULTS OF OUTDOOR PERSONNEL MONITORING FOR AMMONIA, COPPER, ARSENIC, AND HEXAVALENT CHROMIUM DURING ACQ WOOD TREATMENT

Personnel or Area Monitored	Analyte	Sample Duration (min)	Flow Rate (L/min)	Sample Volume (L)	Analytical Result ^(a) ($\mu\text{g}/\text{sample}$)	8-hr TWA ^(b,c) (mg/m^3)
Outside loader operator	NH ₃	58	0.110	6.38	< 4.0 ^(d)	< 0.9 ppm
Yard boss	Cu	478	2.10	1,004	< 0.40 ^(d)	< 0.0004
Yard boss	As	478	2.10	1,004	< 0.25 ^(d)	< 0.0002
Outside loader operator	Cr(VI)	478	2.12	1,013	< 0.60 ^(d)	< 0.0006

(a) Mass of analyte per sample as reported by the analytical laboratory.

(b) Milligrams of contaminant per cubic meter of air.

(c) See Tables 17-20.

(d) Less than the analytical limit of quantitation.

TABLE 25. ACTIVITIES ASSOCIATED WITH SHORT-TERM SAMPLES

Analyte	Personnel or Area Monitored	Activity	Lab Result ^(a) (mg/m ³)
As	Drip pad ground man	Open and unload CCA cylinder No. 8	0.033
	Drip pad loader operator	Open and unload CCA cylinder No. 8	< 0.002 ^(b)
	Treatment plant operator	Vent liquid from treatment cylinder to storage tank	0.14
	Location A	Vent liquid from treatment cylinder to storage tank	0.079
	Location A (duplicate)	Vent liquid from treatment cylinder to storage tank	0.075
	Location B	Open and unload CCA cylinder No. 8	0.021
	Location B (duplicate)	Open and unload CCA cylinder No. 8	0.017
	Location C	Open and unload CCA cylinder No. 8	0.0092
Cr(VI)	Drip pad ground man	Open and unload CCA cylinder No. 8	< 0.008 ^(b)
	Drip pad loader operator	Open and unload CCA cylinder No. 8	< 0.008 ^(b)
	Treatment plant operator	Vent liquid from treatment cylinder to storage tank	0.015
	Location A	Vent liquid from treatment cylinder to storage tank	< 0.008 ^(b)
	Location A (duplicate)	Vent liquid from treatment cylinder to storage tank	< 0.008 ^(b)
	Location B	Open and unload CCA cylinder No. 8	< 0.008 ^(b)
	Location B (duplicate)	Open and unload CCA cylinder No. 8	< 0.008 ^(b)
	Location C	Open and unload CCA cylinder No. 8	< 0.007 ^(b)
Cu	Drip pad ground man	Open and unload CCA cylinder No. 8	0.019
	Drip pad loader operator	Open and unload CCA cylinder No. 8	< 0.008 ^(b)
	Treatment plant operator	Vent liquid from treatment cylinder to storage tank	0.099
	Location A	Vent liquid from treatment cylinder to storage tank	0.044
	Location A (duplicate)	Vent liquid from treatment cylinder to storage tank	0.047
	Location B	Open and unload CCA cylinder No. 8	0.013
	Location B (duplicate)	Open and unload CCA cylinder No. 8	0.0092
	Location C	Open and unload CCA cylinder No. 8	< 0.008 ^(b)
NH ₃	Drip pad ground man	Open and unload CCA cylinder No. 10	38
	Drip pad loader operator	Open and unload CCA cylinder No. 10	24
	Treatment plant operator	Open and unload CCA cylinder No. 10	5.4
	Location G	Open and unload CCA cylinder No. 10	8.5
	Location H	Open and unload CCA cylinder No. 10	18
	Location E	Open and unload CCA cylinder No. 10	23
	Location F	Open and unload CCA cylinder No. 10	10
	Location F (duplicate)	Open and unload CCA cylinder No. 10	17

(a) Airborne concentration, averaged over 15 minutes, expressed in milligrams per cubic meter of air.

(b) Less than the analytical limit of quantitation.

STORMWATER RUNOFF

Amounts of Rainfall Applied

The amounts of rainfall measured during the leaching tests are summarized in Tables 27 and 28. The rainfall measured ranged from 0.6 in to 0.9 in per hour, equivalent to 10.5 to 15.7 gal of water falling onto the top of each wood unit (or a 3.5 ft × 8 ft area) per hour. The cumulative rainfall during the entire test period for both CCA- and ACQ-treated wood units (i.e., 21 and 20 hours for CCA- and ACQ-treated wood units, respectively) was 16.5 in and 14.4 in,

TABLE 26. RESULTS OF FIELD BLANK ANALYSES

Date Collected	Analyte	Result ^{(a),(b)} ($\mu\text{g}/\text{sample}$)
9/8/93	Cr(VI)	< 0.40
	Cr(VI)	< 0.40
	Cr(VI)	< 0.40
	Cu	< 0.40
	As	< 0.10
9/28/93	Cu	< 0.40
	As	< 0.25
	Cr(VI)	< 0.60
	NH ₃	< 4.0

(a) Mass of analyte per sample as reported by the analytical laboratory.

(b) Laboratory results were less than the analytical limit of quantitation.

respectively. The total amount of water falling onto the top of each CCA-treated wood unit was 288 gal. The total amount of water falling onto the top of each ACQ-treated wood unit and the control was 251.3 gal.

The amounts of runoff collected varied with time and with the position of the test units (Table 29). During the first 2 hours of leaching, only 57 to 67% of rainfall was recovered from the bottom of the CCA-treated wood units; 46 to 69% was recovered from that of the ACQ-treated wood units and the control. The water not accounted for (about 31 to 54%) was either absorbed by wood or entrapped in the gaps between wood pieces or between wood and the plastic liner. After the first few hours, the amounts of runoff collected from most wood units started to

TABLE 27. ARTIFICIAL RAINFALL APPLIED DURING CCA LEACHING TEST

Time (hr)	Rain Gauge (in)					Average Hourly Rainfall (in/hr)	Cumulative Rainfall (in)
	1	2	3	4	5		
0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1	0.5	0.8	0.8	1.0	1.2	0.9	0.9
2	0.6	0.8	0.9	1.0	1.1	0.9	1.8
3	0.5	0.4	0.6	0.8	0.9	0.6	2.4
4	0.4	0.6	0.7	0.8	0.8	0.6	3.0
5	0.6	1.0	0.9	0.7	0.9	0.8	3.8
6	0.5	0.9	0.8	0.6	0.8	0.7	4.5
7-20 ^(a)	N/A	N/A	N/A	N/A	N/A	0.8 ^(b)	15.7
21	0.5	1.0	1.1	0.8	0.4	0.8	16.5

(a) Overnight rainfall not measured.

(b) Average of hour 1 to hour 6 rainfall.

N/A = data not available.

TABLE 28. ARTIFICIAL RAINFALL APPLIED DURING ACQ LEACHING TEST

Time (hr)	Rain Gauge (in)					Average Hourly Rainfall (in/hr)	Cumulative Rainfall (in)
	1	2	3	4	5		
0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1	N/A	0.4	0.6	1.0	0.9	0.7	0.7
2	N/A	0.4	0.7	1.0	1.1	0.8	1.5
3	N/A	0.3	0.7	1.1	1.1	0.8	2.3
4	N/A	0.4	0.5	1.0	1.3	0.8	3.1
5	N/A	0.3	0.7	1.0	1.4	0.9	4.0
6	N/A	0.3	0.6	1.1	0.9	0.7	4.7
7	N/A	0.4	0.4	1.0	0.6	0.6	5.3
8-15	N/A	—	—	—	—	0.7 ^(a)	10.9
16	N/A	0.4	0.7	1.1	0.6	0.7	11.6
17	N/A	0.5	0.5	1.2	0.6	0.7	12.3
18	N/A	0.4	0.8	1.2	1.0	0.8	13.1
19	N/A	0.3	0.6	1.0	0.6	0.6	13.7
20	N/A	0.5	0.5	1.1	0.7	0.7	14.4

(a) Overnight rainfall measured using three 5-gal buckets.

N/A = data not available because the rain gauge was out of working order.

— = Rain gauges not used.

TABLE 29. VOLUME OF RUNOFF COLLECTED

Time	Volume of Runoff Collected (gal)				
	ACQ1	ACQ2	Control	CCA1	CCA2
0	0	0	0	0	0
1	6.5	9.5	6.0	9.0	10.5
2	6.5	9.5	6.0	9.0	10.5
3	8.0	12.0	10.3	12.0	13.0
4	8.0	12.0	10.3	12.0	13.0
5	8.0	12.0	10.3	13.0	14.0
6	8.5	12.0	10.5	13.0	14.0
7	8.5	12.0	10.5	—	—
7-17 ^(a)	—	—	—	13.3 ^(b)	14.5 ^(b)
8-15 ^(a)	8.5 ^(c)	12.3 ^(c)	11.3 ^(c)	—	—
16	8.5	12.5	12.0	—	—
17	8.5	12.5	12.0	—	—
18	N/A	N/A	N/A	13.5	15.0
19	N/A	N/A	N/A	13.5	15.0
20	N/A	N/A	N/A	N/A	N/A
21	—	—	—	N/A	N/A

(a) No measurements were made.

(b) Estimated value based on the average of hour 6's and hour 18's volume.

(c) Estimated value based on the average of hour 7's and hour 16's volume.

(d) Estimated value.

— = not applicable.

N/A = data not available.

approach the amounts of rainfall falling onto the wood units. The only exception was the wood unit ACQ1: runoff collected from this unit was consistently lower than the rainfall that would have been falling on the unit throughout the entire test duration. This discrepancy was due, most likely, to a localized variation resulting from an uneven distribution of water by the sprinkler.

Results of Leaching Tests

The results of the leaching tests are presented in Table 30. The results are presented in terms of analytes, i.e., pH, As, Cr, Cu, TDS, TSS, TOC, and TKN, and sampling time. Most samples were collected as composite samples. However, grab samples were collected at the end of 20 hr during the ACQ and control experiments and at the end of 21 hr during the CCA experiments. The samples collected during the 3rd to the 5th hour and at the end of the 20th hour for the ACQ and the control experiments were analyzed for Cu only. The samples collected during the 3rd to the 4th hour and at the end of the 21st hour for the CCA experiments were analyzed for As, Cr, and Cu only. A sample of tap water also was analyzed as a field blank. The tap water contained amounts below the quantitation limit of As, Cr, and TSS, and minute amounts of Cu, TOC, and TKN. The tap water also contained 276 mg/L of TDS. The pH of the tap water was 8.06.

Leaching of Active Ingredients from CCA-Treated Wood Units

The amounts of As, Cr, and Cu leached from the CCA-treated wood units under the above-mentioned test conditions during a 24-hour period were estimated and are presented in Table 31. The runoff volumes for most sampling periods were actually measured and are copied from Table 29. However, the volumes that could have been collected during the 7th to the 17th hour and the 20th to the 24th hour for the CCA experiments were estimated based on the actual volumes collected during the time intervals just before and/or after these time periods. Similarly, the runoff volumes during the 8th to the 15th hour and the 18th to the 24th hour for the control experiments also were estimated. Thus, the total runoff volumes collected during the 24-hour period would be 309 gal from CCA1, 340 gal from CCA2, and 262 gal from the control.

Significant amounts of As and Cr were leached from the treated wood units. Arsenic concentrations up to 8.84 mg/L were found in the runoff samples collected during the first 2 hours of leaching. Its concentrations slowly decreased to 3.89 to 6.07 mg/L after 4 hours and to 2.36 to 3.67 mg/L after 17 hours. Even after 21 hours, 2.85 to 4.11 mg/L of As was still detected in the runoff. Leaching of Cr was even more significant. Chromium concentrations ranging from 58.8 to 78.5 mg/L were found during the first 2 hours. Its concentrations remained at 33.3 to 49.7 mg/L after 4 hours and 16.1 to 20.5 mg/L after 17 hours. After 21 hours, its concentrations were still as high as 17.3 to 23.2 mg/L. The amounts of Cu leached were less significant. Only 3.05 to 3.84 mg/L Cu were analyzed during the first 2 hours. After 21 hours, Cu concentrations became as low as 0.78 mg/L. Trace amounts of As, Cr, and Cu (i.e., 0.003 to 0.08 mg/L for As; < 0.01 to 0.11 for Cr; and 0.05 to 0.12 mg/L for Cu) also were detected in the runoff samples collected from the untreated wood unit. A small amount of CCA might have inadvertently deposited on the surface of the untreated wood unit when being forklifted on the drip pad.

The mass of each active ingredient leached in 24 hours was calculated by adding together the products of the composite concentration of each sampling interval and the corresponding runoff volume. Some composite concentrations were estimated based on best-fit curves. For example, As concentrations of the runoff samples that would have been collected during the 7th to the 17th hour were estimated using the best-fit curves shown in Figure 8. Similarly, Cr and Cu concentrations of the same samples were estimated by the best-fit curves shown in Figures 9 and 10. As a result, the mass of active ingredients leached in 24 hours amounted to 0.0083 to 0.014 lb for As, 0.066 to 0.102 lb for Cr, and 0.0028 to 0.0044 lb for Cu.

TABLE 30. RESULTS OF LEACHING TESTS

Analyte	ACQ-Treated Wood Units												CCA-Treated Wood Units												Control (no treatment)						Grab sample collected at end of 20 hr	Tap Water ^(a)																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																															
	Composite Samples Collected During						Grab samples collected at end of 20 hr						Composite Samples Collected During						Grab samples collected at end of 21 hr						Composite Samples Collected During								Grab sample collected at end of 20 hr																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																														
	1-2 hr		3-5 hr		6-7 hr		16-17 hr		ACQ1		ACQ2		1-2 hr		3-4 hr		5-6 hr		18-19 hr		CCA1		CCA2		1-2 hr		3-5 hr		6-7 hr				16-17 hr		CCA1		CCA2		1-2 hr		3-5 hr		6-7 hr		16-17 hr																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																		
	ACQ1	ACQ2	ACQ1	ACQ2	ACQ1	ACQ2	ACQ1	ACQ2	ACQ1	ACQ2	CCA1	CCA2	CCA1	CCA2	CCA1	CCA2	CCA1	CCA2	CCA1	CCA2	CCA1	CCA2	CCA1	CCA2	CCA1	CCA2	CCA1	CCA2	CCA1	CCA2			CCA1	CCA2	CCA1	CCA2	CCA1	CCA2	CCA1	CCA2	CCA1	CCA2	CCA1	CCA2																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																			
pH	8.96	8.97			9.04	8.92	8.87	8.86			6.87	6.73			7.28	7.54	8.02	7.72							7.28				7.83	8.15																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																	</

(a) Field blank.

TABLE 31. LEACHING OF CCA ACTIVE INGREDIENTS IN 24 HOURS

Time Runoff Collected (hr)	As						Cr						Cu					
	CCA1			CCA2			Control			CCA1			CCA2			Control		
	CCA1	CCA2	Control	CCA1	CCA2	Control	CCA1	CCA2	Control	CCA1	CCA2	Control	CCA1	CCA2	Control	CCA1	CCA2	Control
	Conc. (mg/L)	Mass (lb)	Conc. (mg/L)	Mass (lb)	Conc. (mg/L)	Mass (lb)	Conc. (mg/L)	Mass (lb)	Conc. (mg/L)	Mass (lb)	Conc. (mg/L)	Mass (lb)	Conc. (mg/L)	Mass (lb)	Conc. (mg/L)	Mass (lb)	Conc. (mg/L)	Mass (lb)
1-2	18	21	12	5.53	8.3 x 10 ⁻⁴	8.84	1.5 x 10 ⁻³	8.0 x 10 ⁻⁶	58.8	8.8 x 10 ⁻³	78.5	1.4 x 10 ⁻²	0.11	1.1 x 10 ⁻⁶	3.05	4.6 x 10 ⁻⁴	3.84	6.7 x 10 ⁻⁴
3-4	24	26	31	4.48	9.0 x 10 ⁻⁴	7.35	1.6 x 10 ⁻³		40.2	8.1 x 10 ⁻³	60.4	1.3 x 10 ⁻²	0.11	1.1 x 10 ⁻⁶	2.07	4.1 x 10 ⁻⁴	2.59	5.6 x 10 ⁻⁴
5-6	26	28		3.89	8.4 x 10 ⁻⁴	6.07	1.4 x 10 ⁻³		33.3	7.2 x 10 ⁻³	49.7	1.2 x 10 ⁻²	0.01	1.8 x 10 ⁻⁶	1.36	3.0 x 10 ⁻⁴	2.26	5.3 x 10 ⁻⁴
6-7	148 ^(a)	160 ^(a)	21	2.95 ^(a)	3.6 x 10 ⁻³	4.55 ^(a)	6.1 x 10 ⁻³	1.9 x 10 ⁻⁶	23.0 ^(b)	2.8 x 10 ⁻²	33.0 ^(b)	4.4 x 10 ⁻²	0.01	1.8 x 10 ⁻⁶	0.82 ^(d)	1.0 x 10 ⁻³	1.45 ^(d)	1.9 x 10 ⁻³
8-15			90 ^(a)															
16-17			24															
18-19	27	30		2.36	5.3 x 10 ⁻⁴	3.67	9.2 x 10 ⁻⁴		16.1	3.6 x 10 ⁻³	20.5	5.1 x 10 ⁻³	<0.01	<1.8 x 10 ⁻⁶	0.70	1.6 x 10 ⁻⁴	0.81	2.0 x 10 ⁻⁴
18-24			84 ^(a)															
20-24	68 ^(a)	75 ^(a)		2.85 ^(a)	1.6 x 10 ⁻³	4.11 ^(a)	2.6 x 10 ⁻³		17.3 ^(b)	9.8 x 10 ⁻³	23.2 ^(b)	1.5 x 10 ⁻²			0.78 ^(d)	4.4 x 10 ⁻⁴	0.83 ^(d)	5.2 x 10 ⁻⁴
Total	309	340	262		8.3 x 10 ⁻³		1.4 x 10 ⁻²			6.6 x 10 ⁻²		1.02 x 10 ⁻¹				2.8 x 10 ⁻³		4.4 x 10 ⁻³

(a) See Table 29 for volume of runoff collected.

(b) Estimated value based on the runoff volume collected during hours 18 to 19.

(c) Estimated value based on the runoff volume collected during hours 16 to 17.

(d) Estimated value based on best fit curve (see Figure 8).

(e) Concentration of a grab sample taken at the end of 21 hr.

(f) Estimated value based on best fit curve (see Figure 9).

(g) Estimated value based on best fit curve (see Figure 10).

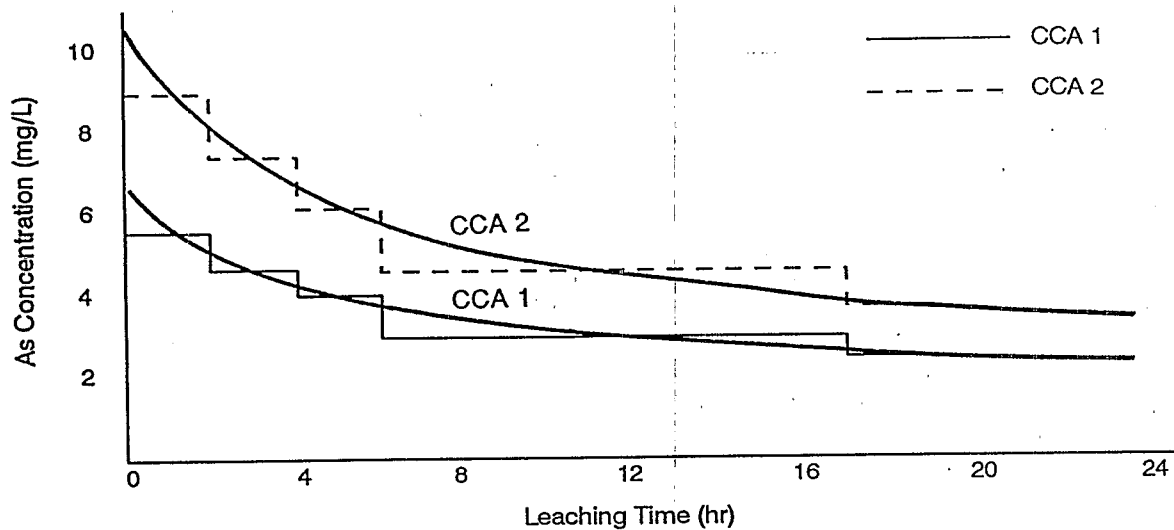


Figure 8. Best-fit curves for As concentration estimation — CCA leaching tests.

The percentage loss of each active ingredient in 24 hours was estimated and is presented in Table 32. The amounts of each active ingredient absorbed by the wood units were estimated by multiplying the specific retention of that ingredient by the wood volume having CCA penetration. The specific retention was the average of two retention analyses. The wood volume that had CCA penetration was estimated by assuming a uniform distribution of CCA only in the outer 1-in

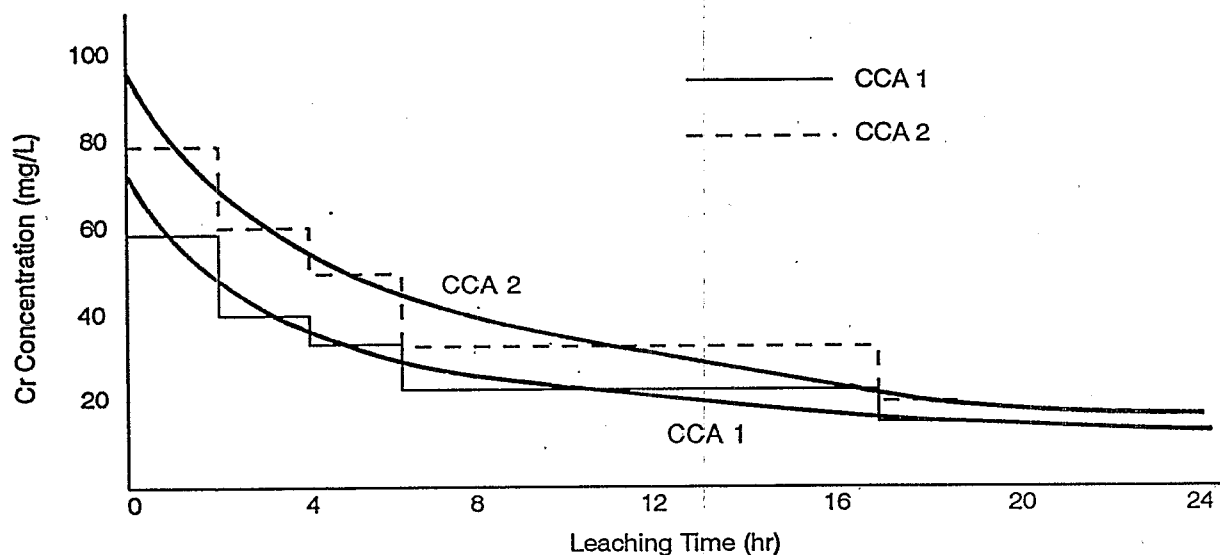


Figure 9. Best-fit curves for Cr concentration estimation — CCA leaching tests.

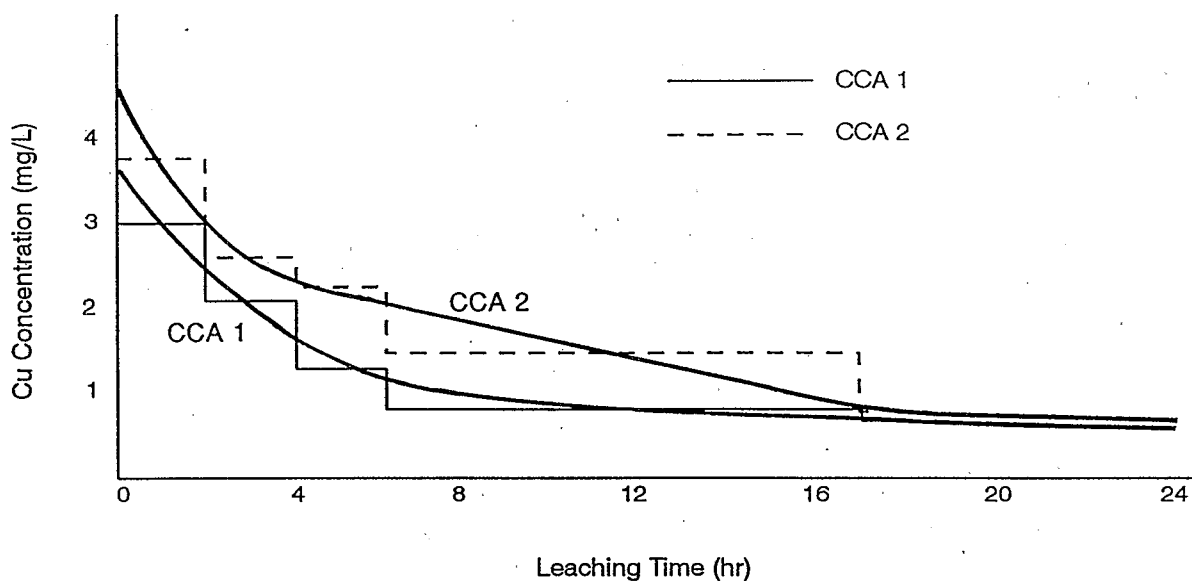


Figure 10. Best-fit curves for Cu concentration estimation — CCA leaching tests.

TABLE 32. LOSS OF CCA ACTIVE INGREDIENTS AS A RESULT OF LEACHING

	CCA1	CCA2	Average
Total wood volume (ft ³)	84.0	84.0	
Wood with CCA retention ^(a) (ft ³)	47.5	47.5	
Wood without CCA retention ^(a) (ft ³)	36.5	36.5	
Sapwood fraction ^(b) (%)	56.5	56.5	
Heartwood fraction ^(c) (%)	43.5	43.5	
As retention (lb/ft ³ as As ₂ O ₅)	0.17 ^(d)	0.17 ^(d)	
Total As absorbed (lb as As ₂ O ₅)	8.08	8.08	
" " " (lb as As)	5.27	5.27	
As loss in 24 hr (lb as As)	0.0083	0.014	0.0223
Percentage As loss (%)	0.16	0.27	0.22
Cr retention (lb/ft ³ as CrO ₃)	0.248 ^(d)	0.248 ^(d)	
Total Cr absorbed (lb as CrO ₃)	11.78	11.78	
" " " (lb as Cr)	6.13	6.13	
Cr loss in 24 hr (lb as Cr)	0.066	0.102	0.084
Percentage Cr loss (%)	1.08	1.67	1.38
Cu retention (lb/ft ³ as CuO)	0.092 ^(d)	0.092 ^(d)	
Total Cu absorbed (lb as CuO)	4.37	4.37	
" " " (lb as Cu)	3.49	3.49	
Cu loss in 24 hr (lb as Cu)	0.0028	0.0044	0.0036
Percentage Cu loss (%)	0.08	0.13	0.11

(a) Based on the assumption that CCA was uniformly retained in the outer 1-in thickness of each of the 42 6 in x 6 in x 8 ft timber pieces.

(b) Volume fraction with CCA retention.

(c) Volume fraction without CCA retention.

(d) Average of two retention analyses.

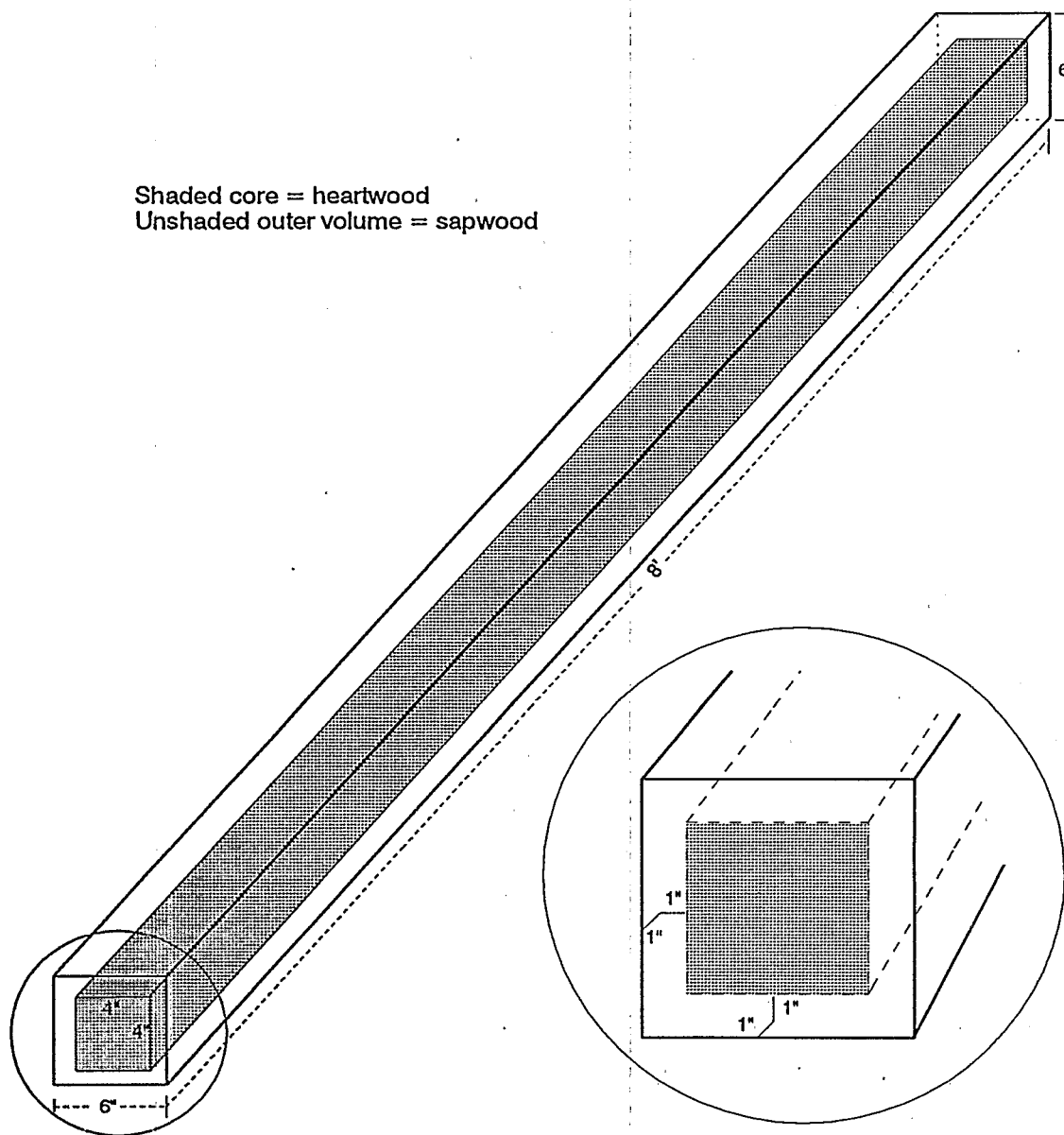


Figure 11. Assumed distribution of sapwood (with CCA retention) and heartwood (without CCA retention) in a timber piece.

thickness of each of the 42 6 in \times 6 in \times 8 ft timber pieces in a wood unit (see Figure 11). It also was assumed that only sapwood would have CCA penetration (and that heartwood would not have any CCA penetration). As a result, the volume fraction that had CCA retention (or sapwood fraction) would be 56.5%, and the volume fraction that did not have any CCA retention would be 43.5%. These volume fractions came out to be quite close to the estimate made by the treatment plant operator (i.e., 50%).

Using the above assumptions, the amounts of metal oxides absorbed by one wood unit would be 8.08 lb of As_2O_5 , 11.78 lb of CrO_3 , and 4.37 lb of CuO (or 5.27 lb of As, 6.13 lb of Cr, and 3.49 lb of Cu). Therefore, the percentage loss due to leaching in the first 24 hours would range from 0.16% to 0.27% for As, from 1.08% to 1.67% for Cr, and from 0.08% to 0.13% for Cu. In contrast, Jin and Preston (1993) reported 9.45% loss for As, 0.35% loss for Cr, and 2.42% loss for Cu when leaching treated-wood blocks using AWPA E11-87 standard laboratory procedures. Moreover, judging by their concentrations in the runoff collected at the end of 21 hr (Table 28), the rate of loss of these active ingredients would be a lot lower after the first 24 hours.

Also, when assuming a uniform distribution of CCA in the outer 1-in thickness of wood, fractions of CCA retained throughout that thickness may be described by the linear curve shown in Figure 12. For example, 55.36% of CCA would be retained in the outer 0.5 in thickness; 6.03% would be retained in the outer 0.05 in thickness; and 0.61% would be retained in the outer 0.005 in thickness. Because leaching of active ingredients required contact with water and because only 0.08% to 1.67% of As, Cr, and Cu was leached, the leaching might have occurred only from the wood surface to a depth of no more than 0.013 in. The bulk of the wood remained unleached.

Leaching of Other Substances from CCA-Treated Wood Units

Leaching of TOC from the CCA-treated wood units was analyzed and is presented in Table 33. TOC concentrations in the runoff collected from the treated wood units during three separate sampling periods (i.e., 1st to 2nd hour, 5th to 6th hour, and 18th to 19th hour) ranged from

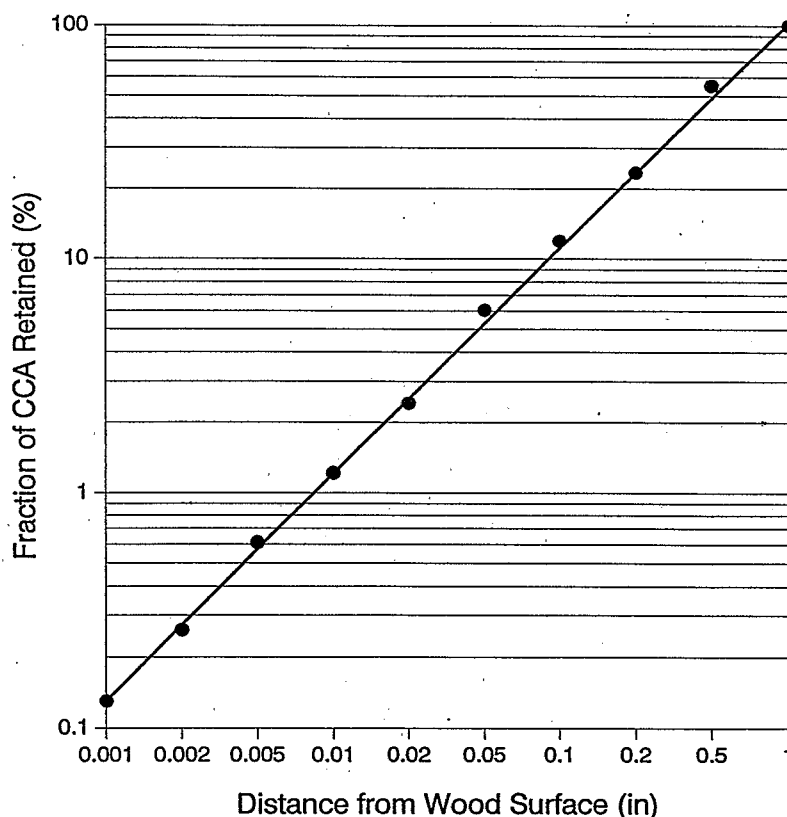


Figure 12. Fraction of chemical retained vs. distance from wood surface.

TABLE 33. TOC LEACHED FROM CCA-TREATED WOOD AND FROM WOOD WITHOUT TREATMENT

Time Runoff Collected (hr)	CCA1				CCA2				Control			
	Runoff Volume (gal)	Composite Conc. (mg/L)	Mass (lb)	Mass (lb)	Runoff Volume (gal)	Composite Conc. (mg/L)	Mass (lb)	Mass (lb)	Runoff Volume (gal)	Composite Conc. (mg/L)	Mass (lb)	Mass (lb)
1-2	18	279	0.042	0.042	21	153	0.027	0.027	12	176	0.018	0.018
5-6	26	148	0.032	0.032	28	104	0.024	0.024	21	120	0.021	0.021
6-7									24	92.5	0.019	0.019
16-17												
18-19	27	81	0.018	0.018	30	78.8	0.020	0.020				
TOC Leached in 24 Hours			0.300				0.263	0.263				0.227

78.8 to 279 mg/L. TOC concentrations in samples collected from the untreated wood unit also were high, ranging from 92.5 to 176 mg/L. It is well known that wood tissue not only is composed of naturally formed organic polymer substances but also contains organic extractives that are in admixture with the cell wall polymers or in the cell lumina (Panshin and Zeeuw, 1970). Some of these organic substances are water soluble and can be in the form of low-molecular-weight sugars, carbohydrates, and phenolic-containing lignin components, etc. The TOC in the runoff of the untreated wood unit was attributed primarily to these water-soluble wood organics. Similarly, most of the TOC leached from the CCA-treated wood units might also have come from the same sources. The wood organics leached are biodegradable and are not considered as environmental contaminants.

TOC mass-leached during each sampling period was calculated by multiplying the composite TOC concentration of that sampling period by the corresponding runoff volume. TOC mass-leached from each wood unit during a 24-hour period was estimated by an area bounded by a best-fit curve (Figure 13), x-axis, $x = 0$ hour, and $x = 24$ hour. The TOC mass thus estimated amounted to 0.3 lb for CCA1, 0.263 lb for CCA2, and 0.227 lb for the control.

As also shown in Table 30, a small amount of TKN was detected in the runoff of the CCA-treated (i.e., 1.8 to 7.0 mg/L) and the control (i.e., 1.75 to 9.8 mg/L) wood units, indicating leaching of some nitrogen-containing wood organics. Further, the substances leached from all wood units were mostly water soluble, as indicated by the TDS values (ranging from 508 to 826 mg/L, see Table 30) in all runoff samples. Few were present as insoluble (or suspended) forms (TSS ranging from 2 to 45 mg/L).

Leaching of Active Ingredients from ACQ-Treated Wood Units

The amounts of Cu, TKN, and TOC leached from the ACQ-treated wood units in 24 hours were estimated and are presented in Table 34. Cu concentrations in the runoff samples were high

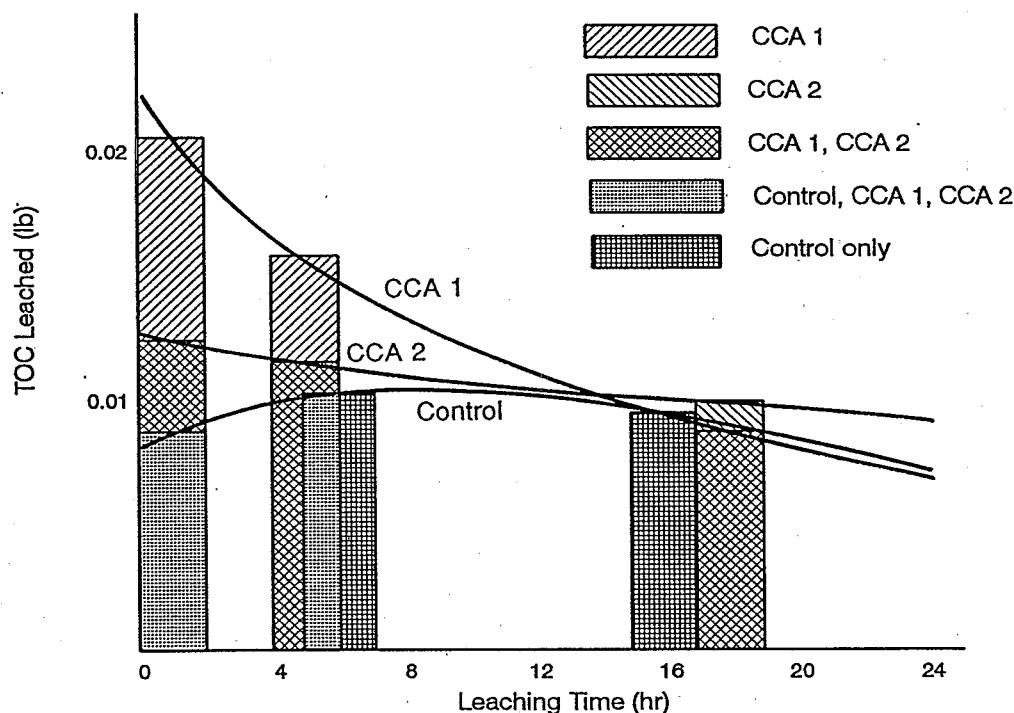


Figure 13. Best-fit curves for TOC mass estimation — CCA leaching tests.

TABLE 34. LEACHING OF ACQ ACTIVE INGREDIENTS IN 24 HOURS

Time Runoff Collected (hr)	Runoff Volume (gall)			Cu						TKN						TOC					
				ACQ1		ACQ2		Control		ACQ1		ACQ2		Control		ACQ1		ACQ2		Control	
	ACQ1	ACQ2	Control	Composite Conc. (mg/L)	Mass (lb)	Composite Conc. (mg/L)	Mass (lb)	Composite Conc. (mg/L)	Mass (lb)	Composite Conc. (mg/L)	Mass (lb)	Composite Conc. (mg/L)	Mass (lb)	Composite Conc. (mg/L)	Mass (lb)	Composite Conc. (mg/L)	Mass (lb)	Composite Conc. (mg/L)	Mass (lb)	Composite Conc. (mg/L)	Mass (lb)
1-2	13	19	12	288	0.031	146	0.023	0.11	1.1×10^{-4}	820	0.087	312	0.049	9.8	9.8×10^{-4}	890	0.097	624	0.099	176	0.018
3-5	24	36	31	283	0.057	117	0.035	0.10	2.6×10^{-4}												
6-7	17	24	21	180	0.023	74.1	0.015	0.12	2.1×10^{-4}	352	0.050	218	0.044	3.3	5.8×10^{-4}	518	0.073	334	0.067	120	0.021
8-15	88	98	90	110.0 ^(a)	0.062	55.4 ^(a)	0.045	0.07 ^(a)	5.3×10^{-4}												
16-17	17	25	24	84.8	0.012	45.9	0.010	0.05	1.0×10^{-4}	285	0.038	154	0.032	1.8	3.6×10^{-4}	382	0.054	170	0.035	92.5	0.019
18-24	60 ^(d)	88 ^(d)	84 ^(d)	72.2 ^(d)	0.036	28.7 ^(d)	0.021	0.05 ^(d)	3.5×10^{-4}												
	199	290	262		0.221		0.149		1.6×10^{-4}		0.534 ^(e)		0.447 ^(e)		0.013 ^(e)		0.767 ^(e)		0.605 ^(e)		0.232 ^(e)

(a) Estimated value based on a best-fit curve, as seen in Figure 14.

(b) Estimated value based on a best-fit curve similar to that shown in Figure 14.

(c) Estimated value.

(d) Estimated value based on the volume of runoff collected during hours 16 to 17.

(e) Concentration of a grab sample taken at the end of 20 hr.

(f) TKN leached in 24 hr was estimated based on the area bounded by a best-fit curve, x-axis, x = 0 hr, and x = 24 hr (see Figure 13).

(g) TOC leached in 24 hr was estimated based on the area bounded by a best-fit curve, x-axis, x = 0 hr, and x = 24 hr (see Figure 14).

initially, ranging from 117 to 288 mg/L during the first 5 hours. The concentrations tapered down to 28.7 to 72.2 mg/L after 20 hours. The concentration in the sample that would have been collected during the 8th to the 15th hour was estimated using the best-fit curve as seen in Figure 14.

In order to save costs, both TKN and TOC were analyzed only for the samples collected during the three sampling periods specified in Table 34. Significant amounts of TKN and TOC were leached. TKN up to 620 mg/L was measured initially; its concentrations decreased to 154 to 265 mg/L after 15 hours. TOC as high as 890 mg/L was analyzed during the first sampling interval (the 1st to the 2nd hour); its concentrations were reduced to 170 to 382 mg/L after 15 hours. The TKN analyzed was attributed primarily to ammonium (NH_4^+) and didecyldimethylammonium (DDA) ions and, to a much lesser extent, to nitrogen-containing wood organics. The TOC analyzed comprised mainly the organic carbons of water-soluble wood organics and DDA (amounts not quantified). Because wood organics, e.g., low-molecular-weight acidic components, as well as partially acidic and phenolic components, are subjected to more severe leaching under alkaline conditions (Browning, 1987), they might account for more TOC than that analyzed in the CCA and control runoff samples.

The mass of Cu, TKN, and TOC leached in 24 hours was calculated/estimated using the same methods explained previously. The best-fit curves and the areas bounded by these curves, x-axis, $x = 0$, and $x = 24$ hours, used for estimating the TKN and TOC mass are presented in Figures 15 and 16, respectively. The mass of ACQ active ingredients leached in 24 hours amounted to 0.149 to 0.221 lb as Cu, 0.447 to 0.534 lb as TKN, and 0.605 to 0.767 lb as TOC.

The percentage loss of each active ingredient in 24 hours was estimated and is presented in Table 35. Using the same methods described previously for the CCA experiments, the amount of CuO absorbed by 1 ft^3 of sapwood would be 0.57 lb/ ft^3 . The total amount of copper absorbed, therefore, would be 27.05 lb as CuO or 21.61 lb as Cu. Consequently, the percentage copper loss due to leaching during the first 24 hours would be 1.02% for ACQ1 and 0.69% for ACQ2, or an average of 0.86%. These values were a lot lower than the 14.69% reported by Jin and Preston (1993).

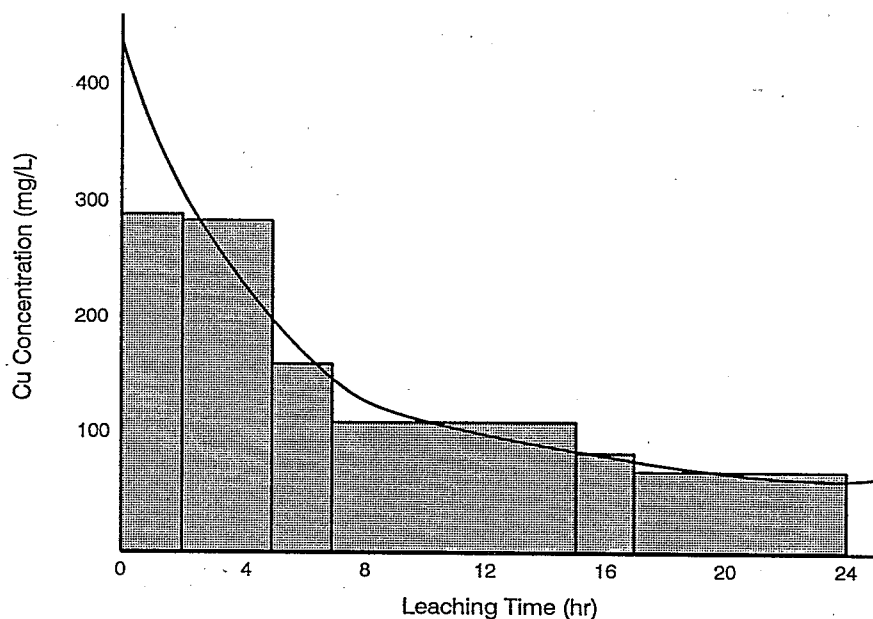


Figure 14. Best-fit curve for Cu concentration estimation — ACQ1.

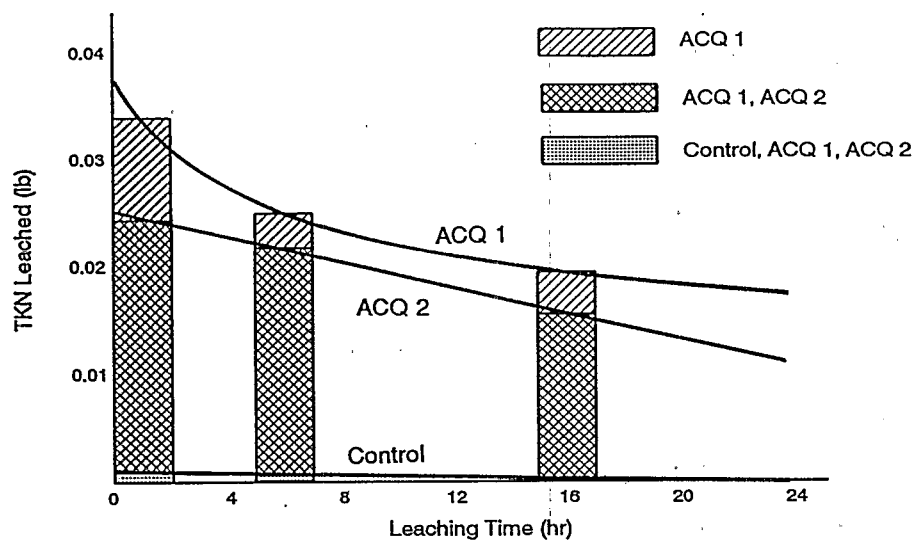


Figure 15. Best-fit curves for TKN mass estimation — ACQ leaching tests.

Similarly, the quat retention in 1 ft³ of sapwood was estimated to be 0.28 lb/ft³ as DDAC. The total quat absorbed would be 13.29 lb as DDAC, or 11.99 lb as DDA, or 0.62 lb as NH₃. Because the TOCs leached had been estimated to be 0.767 lb (as C) for ACQ1 and 0.605 lb

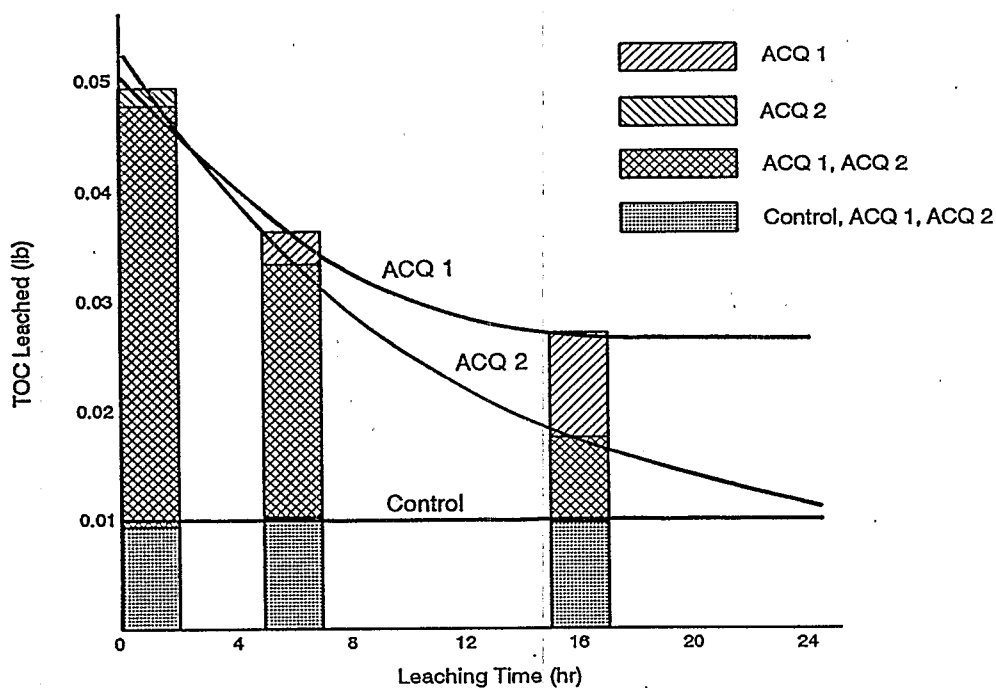


Figure 16. Best-fit curves for TOC mass estimation — ACQ leaching tests.

TABLE 35. LOSS OF ACQ ACTIVE INGREDIENTS AS A RESULT OF LEACHING

	ACQ1	ACQ2	Average
Total wood volume (ft ³)	84.0	84.0	
Wood with ACQ retention ^(a) (ft ³)	47.5	47.5	
Wood without ACQ retention ^(a) (ft ³)	36.5	36.5	
Sapwood fraction ^(b) (%)	56.5	56.5	
Heartwood fraction ^(c) (%)	43.5	43.5	
Cu retention (lb/ft ³ as CuO)	0.57	0.57	
Total Cu absorbed (lb as CuO)	27.05	27.05	
" " " (lb as Cu)	21.61	21.61	
Cu loss in 24 hr (lb as Cu)	0.221	0.149	0.185
Percentage Cu loss (%)	1.02	0.69	0.86
Quat retention (lb/ft ³ as DDAC)	0.28	0.28	
Total quat absorbed (lb as DDAC ^(d))	13.29	13.29	
" " " (lb as DDA ^(e))	11.99	11.99	
" " " (lb as NH ₃)	0.62	0.62	
TOC loss in 24 hr (lb as C)	0.535 ^(f)	0.373 ^(f)	0.454 ^(f)
" " " (lb as DDA)	0.662	0.461	0.562
" " " (lb as NH ₃)	0.034 ^(g)	0.024 ^(g)	0.029
Percentage of DDA loss (%)	5.52	3.84	4.68
NH ₃ retention (lb/ft ³ as NH ₃)	0.57 ^(h)	0.57 ^(h)	
Total NH ₃ absorbed	27.05	27.05	
NH ₃ loss during air drying (lb)	< 10.97 ⁽ⁱ⁾	< 10.97 ⁽ⁱ⁾	
NH ₃ remaining in wood (lb)	> 16.07	> 16.07	
TKN loss in 24 hr (lb as N)	0.534	0.447	0.491
" " " (lb as NH ₃)	0.648	0.543	0.586
TKN loss associated with DDA (lb as NH ₃)	0.034	0.024	0.029
TKN loss associated with NH ₄ ⁺ (lb as NH ₃)	0.614	0.519	0.567
Percentage NH ₃ loss (%)	3.82	3.23	3.53

(a) Based on an assumption that ACQ was uniformly retained in the outer 1" of each of the 42 6 in x 6 in x 8 ft timber pieces.

(b) Volume fraction with ACQ retention.

(c) Volume fraction without ACQ retention.

(d) DDAC = didecyltrimethylammonium chloride (formula wt. = 362.08)

(e) DDA = didecyltrimethylammonium ion (formula wt. = 326.63)

(f) Less TOC in control samples. (The TOC attributable to wood organics in ACQ samples most likely would be higher than the TOC in the control samples. Therefore, the percentage quat loss calculated most likely would be overestimated.)

(g) Amount of N (as NH₃) associated with DDA.

(h) NH₃ retention assumed to be identical to CuO retention.

(i) Assumed to be 40.57%.

(as C) for ACQ2 and because some of the TOCs were attributed to wood organics, the largest amounts of TOCs attributable to quat would be 0.535 lb (as C) for ACQ1 and 0.373 lb (as C) for ACQ2, respectively. These values also could be expressed as DDA (i.e., 0.662 lb and 0.461 lb).

Therefore, the percentage quat (as DDA) loss would be no more than 5.52% for ACQ1 and 3.84% for ACQ2, or an average of 4.68%. These values are higher than the value reported by Jin and Preston (1993), i.e., 3.27%. The discrepancy is explained by footnote (f) in Table 35.

The ammonia retention by 1 ft³ of sapwood was estimated to be 0.57 lb/ft³ (as NH₃). The total ammonia absorbed, thus, would be 27.05 lb (as NH₃). Because the CSI experiment discussed previously has reported up to 40.57% ammonia loss and because that level of loss might represent a worst-case scenario, the ammonia lost from the treated wood unit was assumed to be less than 40.57%. As a consequence, the ammonia remained in the sapwood would be more than 59.43% of that retained initially, or > 16.07 lb (as NH₃). As estimated earlier, the TKN loss due to leaching was 0.534 lb (as N) for ACQ1 and 0.447 lb (as N) for ACQ2, equivalent to 0.648 lb (as NH₃) for ACQ1 and 0.543 lb (as NH₃) for ACQ2, among which, 0.034 lb (ACQ1, as NH₃) to 0.024 lb (ACQ2, as NH₃) was associated with quat molecules (or DDA ions). Therefore, the TKN associated with NH₄⁺ ions would be 0.614 lb (as NH₃) for ACQ1 and 0.519 lb (as NH₃) for ACQ2. The percentage NH₃ loss would be 3.82% for ACQ1 and 3.23% for ACQ2, or an average of 3.53%.

As shown in Table 30, the pH values of the ACQ-treated wood unit runoff samples ranged from 8.86 to 9.04. It was speculated that the pH of the treated wood would be similar to or slightly higher than these values. According to the pC-pH diagram shown in Figure 17, ammonia would exist in about equal amounts as both NH₃ and NH₄⁺. The volatile NH₃ would be depleted during air drying and storage. (It is interesting to recall the CSI study [Jin, 1993] which reported 40.57% ammonia loss during air drying.) The water-soluble NH₄⁺ ions could be leached with water contact. The same CSI study reported up to 19% loss of ammonia due to leaching (vs. 3.2% to 3.8% by this study). Again, the results of the CSI study represented a worst-case scenario because a much more aggressive leaching method was used.

Using the linear curve shown in Figure 12, the extent of leaching was estimated to extend from the immediate wood surface to a depth of no more than 0.048 in.

Leaching of Other Substances from ACQ-Treated Wood Units

Some arsenic (0.17 to 2.53 mg/L) and chromium (lower than limit of quantitation to 0.18 mg/L) also were detected in the runoff samples of the ACQ-treated wood units. Cross-contamination of the treated wood units was the most plausible explanation that could be offered.

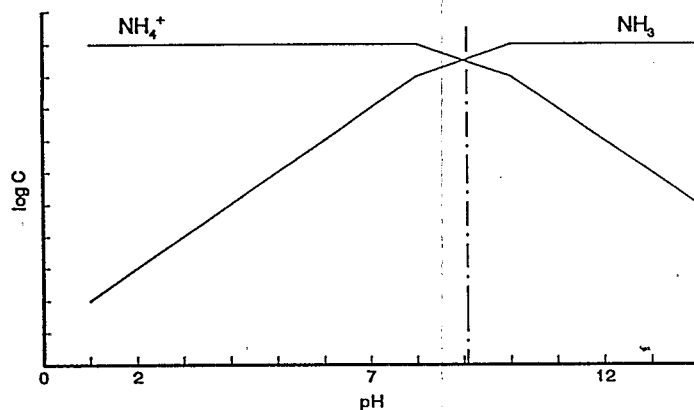


Figure 17. pC-pH diagram for ammonia.

TABLE 36. YEARLY CCA AND ACQ LOSSES DUE TO LEACHING^{(a),(b)}

	Yearly CCA and ACQ Loss (thousand lb/yr)				
	Plants with Annual Production (million ft ³)				
	1	2	3	4	5
CCA Ingredients					
As (as As ₂ O ₅)	0.157	0.314	0.471	0.627	0.784
Cr (as CrO ₃)	1.506	3.012	4.578	6.024	7.529
Cu (as CuO)	0.039	0.078	0.118	0.157	0.196
ACQ Ingredients					
Cu	1.299	2.598	3.896	5.195	6.494
TOC ^(c)	3.148	6.296	9.445	12.593	15.741
NH ₄ ⁺ (as NH ₃)	3.172	6.344	9.515	12.687	15.859

(a) Data prorated based on 0.4 lb/ft³ CCA and ACQ retention.

(b) Calculations based on exposure of all treated wood to about 18 in of rainfall 4 days after treatment.

(c) Including extractable wood organics and quat (as didecyldimethylammonium ion [DDA]).

In general, the substances leached from the treated units were mostly water soluble, as indicated by the TDS values (ranging from 655 to 1,632 mg/L) of all runoff samples. A very small amount of TSS (i.e., 8 to 24 mg/L) also was present in the same water samples.

Yearly CCA and ACQ Losses Due to Leaching

The yearly losses of the CCA and ACQ active ingredients through stormwater runoff to the environment were estimated and are presented in Table 36. For small-sized plants with annual production of 1 million ft³ (or about 20 million board feet), the CCA-treated materials at 0.4 lb/ft³ retention could result in the release of 157 lb of As₂O₅, 1,506 lb of CrO₃, and 39 lb of CuO to the environment every year. For medium-sized plants with annual production of 2 million ft³ (or about 40 million board feet), the annual release could amount to 314 lb of As₂O₅, 3,012 lb of CrO₃, and 78 lb of CuO. For large and very large plants with annual production of 3 to 5 million ft³ (or about 60 to 100 million board feet), the annual release could total 471 to 784 lb of As₂O₅, 4,578 to 7,529 lb of CrO₃, and 118 to 196 lb of CuO.

Converting from CCA to ACQ could significantly reduce the release of toxic metals (such as As and Cr) to the environment, but the release of other contaminants would be greatly increased. For example, a small-sized plant with an annual production of 1 million ft³ (or about 20 million board feet) of ACQ-treated materials (at 0.4 lb/ft³ retention) would not release any As or Cr, but could release 1,299 lb of CuO, 3,148 lb of TOC (inclusive of extractable wood organics and quat [as DDA]), and 3,172 lb of NH₄⁺ per year. A medium-sized plant with an annual production of 2 million ft³ (or about 40 million board feet) could release 2,598 lb of CuO, 6,296 lb of TOC, and 6,344 lb of NH₄⁺ per year. Further, a large to very large plant with annual production of 3 to 5 million ft³ (or about 60 to 100 million board feet) could release 3,896 to 6,494 lb of CuO, 9,445 to 15,741 lb of TOC, and 9,515 to 15,859 lb of NH₄⁺ annually. It must be noted that these releases were calculated based on exposure of all treated wood to about 18 in of rainfall 4 days after treatment. These conditions are very unlikely to occur naturally, however.

WASTE REDUCTION/POLLUTION PREVENTION ASSESSMENT

The pollution prevention benefit is represented by the net difference between the old system and the new. In this case, a CCA wood treatment facility was partially retrofitted to accommodate both CCA and ACQ treatment options. Because the types of wastestreams generated by each system vary in species, concentrations, amounts released, and the associated health and ecological impacts, a direct comparison of reductions of similar wastes is not easy. There is no common denominator to determine improvements on an absolute scale. However, we can list the two sets of data and draw relative significance, as shown in Table 37.

The most obvious pollution prevention benefit gained by using the ACQ system is the complete elimination of arsenic and chromium use, which eliminates the generation of hazardous wastes and the risk of contaminating the environment via chemical spills. (Converting from CCA to ACQ would not result in an immediate reduction of hazardous waste volume because the treatment equipment and the drip pads might still be contaminated with arsenic and chromium. This situation could be gradually improved, however.) Because most treatment plants are self-contained in that they recycle all wastewater produced within the plant and on the drip pads, no liquid waste problems need to be addressed for either the CCA or the ACQ system.

The ACQ system produces a greater amount of air emissions, mainly as NH_3 . For an annual production of 1 million ft^3 (or 20 million board feet), 90,000 lb of NH_3 per year would be released to the environment. In contrast, a CCA plant that produced four times as much commodities released only < 0.021 lb of As_2O_5 and trace amounts of CrO_3 and CuO annually. Currently, the McArthur plant does not have an ammonia scrubber installed, nor is it required to install such a system. During the air monitoring, however, airborne concentrations of inorganic arsenic were above the OSHA PEL of 0.01 mg/m^3 among all workers and in all monitoring locations. Therefore, appropriate respiratory protection should be used until engineering controls are in place to reduce exposures to acceptable levels. During ACQ treatment, full-shift exposures to ammonia were below applicable exposure limits. Ceiling exposures to ammonia during unloading of the ACQ treating cylinder were unacceptably high. Those working in the immediate areas must

TABLE 37. SUMMARY OF YEARLY POLLUTION PREVENTION POTENTIAL FOR ACQ WOOD PRESERVATIVE SYSTEMS^(a)

Environmental Media/Concern	CCA	ACQ
Liquid waste	None	None
Solid waste	75 to 100 lb hazardous waste/yr	None
Air emissions	< 0.021 lb As_2O_5 /yr ^(b) Trace CrO_3 Trace CuO	90,000 lb NH_3 /yr Trace CuO
Stormwater runoff	157 lb As_2O_5 1,506 lb CrO_3 39 lb CuO	1,299 lb CuO 3,148 lb quat (as DDA) 3,172 lb NH_4^+ (as NH_3)

(a) Assuming 1 million ft^3 annual production.

(b) Arsenic emission of a CCA treatment plant that treated four times as much wood as McArthur Lumber & Post in 1992.

use appropriate respiratory protection. Engineering controls also should be considered to reduce ceiling exposures.

The treated wood after being transferred from the drip pads to the outside storage yard could become a major source of contamination to the environment. For 1 million ft³ (or 20 million board feet) of CCA-treated wood, 157 lb of As₂O₅, 1,506 lb of CrO₃, and 39 lb of CuO could be washed away annually by the stormwater. For the same amount of ACQ-treated wood, 1,299 lb of CuO, 3,148 lb of TOC (inclusive of extractable wood organics and quat [as DDA]), and 3,172 lb of NH₄⁺ could be released into the stormwater runoff annually.

SECTION 6

ECONOMIC EVALUATION

The costs of treating wood with ACQ versus CCA were compared using vendor estimates and McArthur Lumber & Post's historical data. The capital investment and operating costs were calculated according to the worksheets provided in the Waste Minimization Opportunity Assessment Manual (U.S. EPA, 1988). The return on investment or payback period was not calculated because the use of ACQ would not result in any immediate monetary savings. It must be noted, however, that factors such as reduced long-term liability (because of eliminating the use of arsenic and hexavalent chromium), greater safety, and improved public relations were not incorporated into the economic analysis. These factors are intangible and estimation of their monetary benefits is not straightforward.

CAPITAL INVESTMENT

Table 38 presents the capital investment and capital cost inputs used in the economic analysis worksheet. The calculations were based on an annual production of 1 million ft³, or about 20 million board feet. The items listed in Table 38 are explained as follows:

- The equipment and material costs of retrofitting the existing facility for ACQ wood treatment were \$30,000. The only piece of equipment purchased was one 8,000-gal fiber glass tank for use as an ammoniacal copper concentrate tank. Black-iron, stainless steel, and/or polyvinylchloride (PVC) valves, fittings, and unions also were purchased to replace those made of brass, bronze, copper, and/or aluminum. Three new 2-in lines were installed to transfer quat and ammoniacal copper concentrates to the ACQ combo tank and from that combo tank to the ACQ work tank. The costs of retrofitting may vary depending on the extent of the job.
- Installation costs totaled \$21,900, including \$5,000 for hauling away CCA concentrate and or working solution and equipment (e.g., treating cylinder, mixing tank, and work tank) cleanup, \$9,400 for drip pad cleaning (mechanical or steam cleaning at \$1/ft²), and \$7,500 for equipment installation (i.e., 25% of the equipment and material costs).
- The plant engineering cost was \$7,790, i.e., 15% of the sum of the equipment, materials, and installation costs.
- Contingency costs totaled \$5,970, i.e., 10% of all of the above costs (or fixed capital investment).
- Working capital was based on a 1-month supply of ACQ chemicals and miscellaneous supplies, which was estimated to be \$112,400. The cost for chemicals quoted by CSI was \$58.44/1000 board feet, assuming 0.4% retention and 15%

TABLE 38. INPUTS AND OUTPUTS FOR CAPITAL COSTS

Input		Output Capital Requirement	
Capital cost		Construction year	1
Equipment and materials	\$30,000	Capital expenditures	
Installation	\$21,900	Equipment and materials	\$30,000
Plant engineering	\$7,790	Installation	\$21,900
Contractor/Engineering	\$0	Plant engineering	\$7,790
Permitting costs	\$0	Contractor/Engineering	\$0
Contingency	\$5,970	Permitting costs	\$0
Working capital	\$112,400	Contingency	\$5,970
Startup costs	\$5,970	Startup costs	\$5,970
		Depreciable capital	\$71,630
% Equity	60%	Working capital	\$112,400
% Debt	40%	Subtotal	\$184,030
Interest rate on debt, %	10%	Interest on debt	\$6,945
Debt repayment, years	5	Total capital	\$190,975
Escalation rate, %	5%	Equity investment	\$114,585
Cost of capital	15%	Debt principal	\$69,445
		Interest on debt	\$6,945
		Total financing	\$190,975

heartwood volume. Therefore, the monthly chemical cost for a plant of 1 million ft³, or about 20 million board feet annual production was \$97,400. Further, ACQ wood treatment required wood units to be stacked before treatment and capped after treatment. The cost for stacking and capping was \$9/1,000 board feet (including \$5 for stacker, \$3 for sticks, and \$1 for caps), or \$15,000/20 million board feet/month.

- The startup cost was \$5,970, i.e., 10% of the fixed capital investment.
- 60% equity, 40% debt, and 10% interest rate on debt were assumed. The debt was to be repaid in 5 years. The escalation rate and cost of capital were assumed to be 5% and 15%, respectively.

Based on the above inputs, the total capital requirement for converting to ACQ wood treatment would be \$190,975, including \$114,585 equity investment, \$69,445 debt principal, and \$6,945 interest on debt.

OPERATING COSTS

The operating costs for ACQ wood treatment were compared with those for CCA wood treatment. The differences in the operating costs are presented in Table 39. The items listed are discussed as follows:

- No marketable by-products were produced by either treatment method.

**TABLE 39. ANNUAL OPERATING COST OF ACQ WOOD TREATMENT
COMPARED WITH THAT OF CCA WOOD TREATMENT**

Operating Cost		Operating Savings ^(a)	
Marketable by-products		Raw materials	(\$966,210)
Rate	\$0		
Price	\$0	Disposal costs	\$2,100
Total \$/yr	\$0		
Utilities (per year)		Other production costs	(\$126,000)
Gas	\$0	Total operating savings	(\$1,090,110)
Electric	\$0		
Fuel oil	\$0		
Process water	\$0		
Total \$/yr	\$0		
Raw materials	\$740,200		
Chemicals	\$180,000		
Caps and misc. supplies	\$920,200		
Waste disposal savings			
No. of drums	4		
\$/drum	\$500		
Total disposal savings	\$2,000		
Other production costs	\$120,000		

(a) Operating year number is 1; escalation factor is 5%.

- No differences on utility consumption were assumed.
- Raw material costs were based on an annual supply of ACQ chemicals, CCA concentrate, and miscellaneous supplies. The chemical cost for CCA was \$21.43/1,000 board feet. Therefore, the additional chemical cost required for treating 20 million board feet of wood with ACQ would be \$740,200. The added cost for stacker, sticks, and caps for ACQ wood treatment was \$180,000. The total raw materials cost was \$920,000/yr.
- CCA wood treatment resulted in 1 drum/quarter hazardous waste, or 4 drums/yr; ACQ wood treatment produced no hazardous waste, assuming that the treating equipment, drip pad, and unloading equipment such as a forklift were well cleaned and did not create cross-contamination. The resulted savings from waste disposal, however, was minimum; only \$2,000 was saved based on a disposal cost of \$500/drum.
- Production of ACQ-treated wood cost additional \$6/1,000 board feet for an added labor (i.e., \$4/1,000 board feet) and a longer shed (or drip pad) turnaround (i.e., \$2/1,000 board feet). The total additional cost was \$120,000.

Based on the above information, the operating savings are presented in Table 39. Because of higher chemical costs and the costs needed for wood stacking and capping, a net expense of

\$966,210 resulted under the raw materials category. An additional net expense of \$126,000 also was incurred for production. The total operating net expense after being adjusted by a 5% escalation factor for the first year of operation would be \$1,090,110.

ECONOMIC ASSESSMENT

Converting from CCA to ACQ wood treatment, a plant of an annual production of about 20 million board feet would require a capital investment of about \$191,000. The operating costs for ACQ wood treatment were higher; a net expense of up to \$1,100,000 was required. Most of that net expense (i.e., 71.3%) would be used to purchase ACQ chemicals. Based on a CSI estimate, the selling price of ACQ-treated wood would be \$55/1,000 board feet more expensive than CCA-treated wood. Therefore, switching from CCA to ACQ would not produce any immediate quantifiable benefits. Because the economic analysis did not consider factors such as long-term liability, safety, and the company's public relations, the real benefit of using ACQ could be more than what it would appear.

SECTION 7

QUALITY ASSURANCE

A Quality Assurance Project Plan (QAPP) had been prepared and approved by the U.S. EPA before on-site testing began (Chen, 1993). The QAPP was designed to ensure that valid data were generated to meaningfully achieve the objectives of this study. The QAPP contained a detailed description of the experimental design and specific quality assurance objectives. The QAPP also included analytical procedures and calibration, as well as methods for internal quality control checks, performance and system audits, and corrective action.

QUALITY ASSURANCE OBJECTIVES

The four quantitative data quality indicators, i.e., precision, accuracy, minimum detection limit, and completeness, for the various measurements required for this study have been set at levels shown in Table 40. Precision for most of the measurements was estimated by calculating relative percent difference (RPD) of laboratory duplicates. Precision for pH was estimated by calculating the pH limit for duplicates. Accuracy for most of the measurements was estimated using percent recovery of laboratory matrix spikes. For pH measurements, bias was determined by analysis of standard reference materials. Completeness was presented as the percentage of valid data over the total number of measurements.

The precision and accuracy of airborne As, Cr(VI), Cu, and NH₃ were set at 25% and 75 to 125% recovery, respectively. The minimum detection limits for these analytes were 0.10 µg, 0.40 µg, 0.40 µg, and 1 ppm, respectively. The completeness of these measurements was set at 80%.

The precision of the semiquantitative on-site detection of NH₃ with Dräger tubes was set at 75% based on duplicate measurements in the field. There were no accuracy objectives set for these measurements because no matrix spikes could be added to the respective analytes. Further, because of their semiquantitative nature, the completeness of these measurements was set only at 25%.

Standard methods specified QA parameters for pH, total metal concentrations, TDS, TSS, TOC, and TKN; the QA data of these measurements were calculated according to their respective standard methods. The precision, accuracy, and completeness of most of these measurements were set at 25%, 75 to 125% recovery, and 80%, respectively. Because only laboratory duplicates were performed for TSS, there were no accuracy calculations for TSS measurements. The precision of pH measurements was ±0.1 pH unit. The bias of pH measurements was determined using a standard reference electrolyte solution. As indicated in Table 40, the method detection limit for As measurements was 0.001 mg/L when a more sensitive atomic absorption graphite furnace technique (i.e., EPA Method 7060) was used.

No independent on-site audits were performed during on-site testing and laboratory analyses. However, the Battelle Study Leader and QA Officer reviewed the analytical data for compliance with the QA objectives after completion of laboratory testing.

TABLE 40. QUANTITATIVE QA OBJECTIVES

Matrix Type	Analyte	Methods	Precision (%)	Accuracy (% Recovery)	Method Detection Limit	Completeness (%)
Aerosols and vapors	As	NIOSH 7029/OSHA ID 105	25	75-125	0.10 µg	80
	Cr(VI)	NIOSH 7600	25	75-125	0.40 µg	80
	Cu	NIOSH 7029/OSHA ID 105	25	75-125	0.40 µg	80
	NH ₃	NIOSH P&CAM 205	25	75-125	0.40 µg	80
		Dräger tubes	75	N/A	1 ppm	25
Simulated stormwater	As	EPA 7060 ^(a)	25	75-125	0.001 mg/L	80
	Cr	EPA 6010 ^(a)	25	75-125	0.01 mg/L	80
	Cu	EPA 6010 ^(a)	25	75-125	0.01 mg/L	80
	Zn	EPA 6010 ^(a)	25	75-125	0.01 mg/L	80
	TSS	EPA 160.2	25	N/A	1 mg/L	80
	TDS	EPA 160.1	25	75-125	1 mg/L	80
	pH	EPA 150.1	0.1 pH unit	— ^(b)	0.1 pH unit	80
	TKN	EPA 351.2	25	75-125	0.2 mg/L	80
	TOC	EPA 9060	25	75-125	0.8 mg/L	80

(a) Methods for sample preparation according to EPA Method 3010.

(b) The bias of pH measurements was determined using a standard reference electrolyte solution.

N/A = not applicable.

PRECISION

Precision quantifies the repeatability of a given measurement. Precision for laboratory and field measurements was estimated by calculating the relative percent difference (RPD) of duplicate measurements as shown by equation (1):

$$\text{RPD (\%)} = \frac{|\text{Regular} - \text{Duplicate}|}{(\text{Regular} + \text{Duplicate})/2} \times 100\% \quad (1)$$

The precision of laboratory and field Dräger tube measurements is shown in Tables 41 and 42, respectively. The RPDs for all laboratory analytes ranged from 0 to 28.6%. With the exception of one TSS duplicate measurement, the RPDs were well within the limits of 25% specified in the QAPP. The RPDs for field Dräger tube measurements ranged from 0% to 139%. Of the 35 duplicate measurements, three were beyond the limit (i.e., 25%) specified in the QAPP.

The precision limit for pH was estimated using the following equation (2):

$$\text{Precision Limit} = \text{pH (Regular Sample)} - \text{pH (Duplicate Sample)} \quad (2)$$

The precision limit was 0.02 pH unit which, again, was within the limit specified (i.e., 0.1 pH unit).

ACCURACY

Accuracy refers to the percentage of a known amount of analyte recovered from a given matrix. Percent recoveries for metals (including airborne and total metals in aqueous solution), airborne ammonia, TDS, TSS, TOC, and TKN measurements are estimated by equation (3) and presented in Table 43:

$$\text{Recovery (\%)} = \frac{(\text{Spiked Sample}) - (\text{Regular Sample})}{(\text{Spike Added})} \times 100\% \quad (3)$$

All data in Table 43 were within the specified limits of 75 to 125%. The bias of pH measurements has been determined using a standard reference electrolyte solution.

METHOD DETECTION LIMIT

The method detection limit (MDL) for most of the measurements was calculated according to equation (4):

$$\text{MDL} = 3 \times \text{Sb}/m \quad (4)$$

where Sb = standard deviation of the average noise level and m = slope of the calibration line. The MDLs of all measurements are listed in Table 41.

TABLE 41. PRECISION OF LABORATORY MEASUREMENTS

Sample Matrix	Analyte	Conc. Unit	MDL	Sampling Date	Duplicate 1	Duplicate 2	RPD (%)
Aerosols and vapors ^(a)	As	μg	0.1	9/8/93	2.00	1.95	2.5
				9/8/93	1.64	1.85	12.0
				9/28/93	1.88	1.91	1.6
				9/28/93	1.78	1.80	1.1
	Cr(VI)	μg	0.4	9/8/93	4.85	4.86	0.2
				9/8/93	4.78	4.78	0
				9/28/93	4.96	4.96	0
	Cu	μg	0.4	9/8/93	34.45	34.85	1.2
				9/8/93	34.90	35.05	0.4
				9/28/93	36.60	37.00	1.1
				9/28/93	36.20	36.30	0.3
	NH ₃	μg	0.4	9/28/93	242.1	242.1	0
Simulated stormwater	As	mg/L	0.001	9/29-30/93	2.53	1.97	24.9
				10/5-6/93	5.53	6.10	9.8
	Cr	mg/L	0.01	9/29-30/93	0.18	0.16	11.8
				10/5-6/93	16.00	16.00	0
	Cu	mg/L	0.01	9/29-30/93	288	318	9.9
				9/29-30/93	283	270	4.7
				10/5-6/93	3.05	3.02	1.0
	TDS	mg/L	1	9/29-30/93	856	870	1.6
				10/5-6/93	826	884	6.8
	TSS	mg/L	1	9/29-30/93	12	10	18.2
				10/5-6/93	6	8	28.6
	TOC	mg/L	0.08	9/29-30/93	176	180	2.2
				10/5-6/93	279	244	13.4
	TKN	mg/L	0.2	9/29-30/93	1.75	2.02	14.3
				10/5-6/93	6.30	6.28	0.3

(a) Matrix spike and matrix spike duplicate were used to calculate % RPD.

MDL = method detection limit.

RPD = relative percent difference.

N/A = data not available.

COMPLETENESS

Completeness refers to the percentage of valid data received from actual testing done in the laboratory. Completeness is calculated as follows:

$$\text{Completeness} = \frac{\text{Number of Measurements Judged Valid}}{\text{Total Number of Measurements}} \times 100\% \quad (5)$$

Completeness for all measurements is 100%.

TABLE 42. PRECISION OF NH₃ MONITORING USING DRÄGER TUBES

		NH ₃ Concentration (ppm or %)									
		A9					A10				
Source of Emissions	Monitoring Locations ^(a)	Duplicate		RPD (%)		RPD (%)	Duplicate		RPD (%)		RPD (%)
		1	2	1	2		1	2	1	2	
Chemical concentrate storage	Around ACQ-C concentrate tank						<DL				
	Around quat concentrate tote						<DL				
	Around concentrate tanks and totes						<DL				
	Around ACQ combo tank and work tank						<DL				
Chemical mixing and working solution storage	Vent								35	50	35.3
	Vent								200		
	Vent								32		
	Vent								0.17%	0.26%	41.9
Pressure-treating process - Initial vacuum	Vent										
	Around vacuum pump	200	100	66.7	205		210	2.4	0.06%	0.07%	15.4
		2	3	40.0	5		3	50.0			
		<DL	<DL		<DL		<DL		<DL	<DL	
- Flooding	Vent										
	Around vacuum pump								10	15	40.0
- Pressure treating	Around vacuum pump	1.5	3	66.7	38		9	123.4	3	5	50.0
	Around cylinder door	Trace	1								
- Slow pressure release	Vent						0.15%	0.18%	0	0.18%	40.0
- Blowback (initial draining)	Vent						0.25%	0.22%	12.8	0.21%	0
- Air pressure venting	Vent						0.25%	0.27%	7.7	0.16%	11.8

TABLE 42. PRECISION OF NH₃ MONITORING USING DRÄGER TUBES (Continued)

Source of Emissions	Monitoring Locations ^(a)	NH ₃ Concentration (ppm or %)									
		A9				A10				A11	
		Duplicate 1	Duplicate 2	RPD (%)	Duplicate 1	Duplicate 2	RPD (%)	Duplicate 1	Duplicate 2	RPD (%)	RPD (%)
- Final vacuum	Around cylinder door	Trace	Trace								
	Vent	0.10%	0.11%	9.5	0.10%	0.10%	0	0.18%	0.11%	48.3	
	Around vacuum pump	19	35	61.5	29	41	34.3	21	24	13.3	
- Door opening	Around cylinder door				8						
	Around cylinder door	50	9	139.0				75	35	72.7	
	Around cylinder door	40	22	59.1				13 ^(b)	38 ^(b)	98.0	
	15 to 20 ft away from door	11	19	53.3							
Freshly treated wood on drip pad	Within 0.5 in of wood surface	450	410	9.3	78 ^(a)	90 ^(a)	14.3	70 ^(a)	70 ^(a)	0	
	3 ft away from wood surface	39	55	34.0	32	50	43.9				

(a) See Table 21 for specific monitoring time.

(b) Measured about 10 min afterward.

(c) Measured 1 to 3 ft away from wood surface.

RPD = Relative percent difference.

<DL = lower than detection limit.

TABLE 43. ACCURACY OF LABORATORY MEASUREMENTS

Sample Matrix	Analyte	Conc. Unit	Sampling Date	Laboratory Blank	Spike Added	Spike Recovered	Recovery (%)
Aerosols and vapors	As	μg	9/8/93	<0.10	2.0	2.00	100
			9/8/93	<0.10	2.0	1.64	81.9
			9/28/93	<0.10	2.0	1.88	93.8
			9/28/93	<0.10	2.0	1.78	89.1
	Cr(VI)	μg	9/8/93	<0.40	5.0	4.85	97.0
			9/8/93	<0.40	5.0	4.78	95.6
			9/28/93	<0.40	5.0	4.96	99.2
	Cu	μg	9/8/93	<0.40	36.0	34.45	95.7
			9/8/93	<0.40	36.0	34.90	96.9
			9/28/93	<0.40	36.0	36.60	101.7
			9/28/93	<0.40	36.0	36.20	100.6
	NH ₃	μg	9/28/93	<0.40	250.0	242.1	96.8
Simulated stormwater ^(a)	As	$\mu\text{g/L}$	10/5-6/93	<1	1,000	991	99.1
	Cr	$\mu\text{g/L}$	9/29-30/93	<10	1,000.0	1,041	104.1
			10/5-6/93	<10	1,000.0 ^(b)	1,037	103.7
	Cu	$\mu\text{g/L}$	9/29-30/93	<10	1,000.0 ^(c)	1,105	110.5
			9/29-30/93	<10	1,000.0	1,078	107.8
			9/29-30/93	<10	1,000.0 ^(d)	1,034	103.4
	TDS ^(e)	mg	9/29-30/93	<1	500	483	96.6
			10/5-6/93	<1	500	499	99.9
	TOC	mg/L	9/29-30/93	<0.8	9.95	9.46	95.1
			10/5-6/93	<0.8	9.95 ^(f)	8.55	85.9
	TKN	mg/L	9/29-30/93	<0.2	1.0	0.95	95.4
			10/5-6/93	<0.2	1.0 ^(d)	1.07	107.0

(a) When dilutions were needed, they were made before the spike was added.

(b) Spike added to a sample diluted 500 times.

(c) Spike added to a sample diluted 1,000 times.

(d) Spike added to a sample diluted 10 times.

(e) Spike added in 50 mL solution.

(f) Spike added to sample diluted 50 times.

LIMITATIONS AND QUALIFICATIONS

Based on the above quality assurance data, the results from the laboratory and field analyses provided a good basis for drawing conclusions about waste reduction and pollution prevention.

SECTION 8

CONCLUSIONS AND RECOMMENDATIONS

This evaluation addresses the product quality, waste reduction/pollution prevention, and economic issues involved in replacing chromated copper arsenate (CCA) with ammoniacal copper/quaternary ammonium compound (ACQ) as a wood preservative for treatment of commodities. The most obvious benefit gained by using the ACQ system is the complete elimination of As and Cr use, which eliminates the generation of hazardous wastes and the risk of contaminating the environment via chemical spills. Because most treatment plants are self-contained in that they recycle all wastewater produced within the plant and on the drip pads, no liquid waste problems need to be addressed for either CCA or ACQ.

The ACQ system produces a greater amount of air emissions, mainly as NH_3 . For an annual production of 1 million ft^3 (or about 20 million board feet), 90,000 lb of NH_3 per year could be released from the ACQ treatment operations and the ACQ-treated wood. In contrast, a CCA plant that produced four times as much commodities released < 0.021 lb of As_2O_5 and only trace amounts of CrO_3 and CuO every year. During the air monitoring of the CCA system, however, airborne concentrations of inorganic arsenic were above the OSHA PEL of 0.01 mg/m^3 among all workers and in all monitoring locations. Therefore, appropriate respiratory protection should be used until engineering controls are in place to reduce exposures to acceptable levels. During ACQ treatment, full-shift personnel exposures to ammonia were below applicable exposure limits. Ceiling exposures to ammonia during unloading and stacking of ACQ-treated lumber on the drip pads exceeded the short-term exposure limit of 35 ppm. Those working in the immediate areas must use appropriate respiratory protection. Engineering controls also should be considered to reduce exposures.

The treated wood, after being transferred to the uncovered storage yard, could become a major source of contamination to the environment. For a CCA treating plant with 1 million ft^3 (or about 20 million board feet) of annual production, 157 lb of As_2O_5 , 1,506 lb of CrO_3 , and 39 lb of CuO could be washed away annually by stormwater. For an ACQ treating plant with the same amount of annual production, 1,299 lb of CuO , 3,148 lb of TOC (inclusive of extractable wood organics and quat [as DDA]), and 3,172 lb of NH_4^+ could be released annually. Converting from CCA to ACQ totally eliminates the release of As and Cr to the environment.

Although converting to ACQ requires a capital investment and higher operating costs, the benefits of reduced long-term liability, greater safety, increased morale, and improved public relations for the company as a result of using ACQ can be significant. Estimation of monetary benefits for these intangible factors is not straightforward.

SECTION 9

REFERENCES

- American Wood-Preservers' Association. 1992. *Book of Standards*. Woodstock, Maryland.
- American Wood-Preservers' Association. 1990. *Wood Preservative Statistics*. 1988 AWPA Proceedings, Woodstock, Maryland.
- Archer, K. J., L. Jin, A. F. Preston, N. G. Richardson, D. B. Thies, and A. R. Zahora. 1992. *ACQ: Proposal to the American Wood Preservers' Association Treatment Committee to Include Ammoniacal Copper Quat, ACQ Type B, in AWPA Standards under the Jurisdiction of the Treatments Committee*. Chemical Specialties, Inc., Charlotte, North Carolina.
- Arsenault, R. D. 1975. "CCA-Treated Wood Foundations: A Study of Permanence, Effectiveness, Durability, and Environmental Consideration." *Proc. Amer. Wood-Preservers' Assoc.*, 91:126-149.
- AWPA, *see* American Wood-Preservers' Association.
- Baldwin, W. J. 1992. "Reuse of Wood Preservative that Contains Arsenic." *Proc. Arsenic & Mercury: Workshop on Removal, Recovery, Treatment, and Disposal*. EPA/600/R-92/105, U.S. EPA Office of Research and Development, Washington, D.C.
- Barnes, H. M., and D. D. Nicholas. 1992. "Alternative Preservative Systems: Pros & Cons." *Proc. Arsenic & Mercury: Workshop on Removal, Recovery, Treatment, and Disposal*. EPA/600/R-92/105, U.S. EPA Office of Research and Development, Washington, D.C.
- Browning, B. L. 1987. *Methods of Wood Chemistry*, Vol. II. Interscience Publishers, a division of John Wiley & Sons, New York, New York.
- Butcher, J. A., A. F. Preston, and J. Drysdale. 1979. "Potential of Unmodified and Copper-Modified Alkylammonium Compounds as Groundline Preservatives." *N.Z. J. For. Sci.*, 9(3):348-358.
- Butcher, J. A., A. F. Preston, and J. Drysdale. 1977. "Initial Screening Trials of Some Quaternary Ammonium Compounds and Amine Salts as Wood Preservatives." *For. Prod. J.*, 27(7):19-22.
- Chemical Specialties, Inc. 1993. *Emission Compliance Survey Monitoring Report of a Canadian Treatment Plant*. CSI, Charlotte, North Carolina.
- Chemical Specialties, Inc. 1992. *ACQ 2100 Wood Preservative Operator's Manual*. CSI, Charlotte, North Carolina.

Chen, A. S. C. 1993. "Quality Assurance Project Plan for Evaluating ACQ as an Alternative Wood Preservative System to CCA: A U.S. EPA RCRA Problem Wastes Technology Evaluation Study." Report submitted to U.S. Environmental Protection Agency, Risk Reduction Engineering Laboratory, Cincinnati, Ohio.

Chen, A. S. C., and L. S. Walters. 1979. "The Fate of Arsenic in Pressure-Treated Southern Pine Plywood Subjected to Heavy Artificial Rainfall." *J. Amer. Wood-Preservers' Assn.*, 75:118-161.

CSI, see Chemical Specialties, Inc.

Da Costa, E. W. B. 1967. "Laboratory Evaluation of Wood Preservatives: Part I. Effectiveness of Waterborne Preservatives against Decay Fungi after Sever Leaching." *Holzforschung*, 21:50-57.

Da Costa, E. W. B. 1972. "Laboratory Evaluations of Wood Preservatives: Part VIII. Protection of Plywood Against Decay Fungi by Incorporation of Fungicides in the Glueline." *Holzforschung*, 26:131-138.

Dahlgren, S. E. 1975. "Kinetics and Mechanism of Fixation of Preservatives: Part V. Effect of Wood Species and Preservative Composition on the Leaching during Storage." *Holzforschung*, 29:84-95.

Drysdale, J. 1983. "Performance of Unmodified and Copper-Modified Alkylammonium Treated Stakes in Ground Contact." *N.Z. J. For. Sci.*, 13(3):354-363.

EPA Method II-3 for Collection of Sludge or Sediment Samples with a Scoop.

EPA Method III-1 for Sampling Surface Waters Using a Dipper or Other Transfer Device.

EPA Method 150.1, (Electrometric) for pH, Storet No. 00403.

EPA Method 160.1, (Gravimetric, Dried at 180°C) for Filterable Residue, Storet No. 70300.

EPA Method 160.2, (Gravimetric, Dried at 103-105°C) for Non-filterable Residue, Storet No. 00530.

EPA Method 351.2, Nitrogen, Kjeldahl, Total (Colorimetric, Semi-automatic Block Digester, AA-s).

EPA Method 1311, Toxicity Characteristic Leaching Procedure (TCLP), 40 CFR Part 261, 1990.

EPA Method 3010, Acid Digestion of Aqueous Samples and Extracts for Total Metals for Analysis by Flame Atomic Absorption Spectroscopy or Inductively Coupled Plasma Spectroscopy.

EPA Method 6010, Inductively Coupled Plasma Atomic Emission Spectroscopy.

EPA Method 7060, Arsenic (Atomic Absorption, Furnace Technique).

EPA Method 9060, Total Organic Carbon.

Fahlstrom, G. B., P. E. Grunning, and J. A. Carlson. 1967. "Copper-Chrome-Arsenate Wood Preservatives: A Study of the Influence of Composition on Leachability." *For. Prod. J.*, 17:17-22.

- Findlay, D. M., and N. G. Richardson. 1983. "Wood Treatment Composition." *Canadian Patent* 1,146,704.
- Findlay, D. M., and N. G. Richardson. 1990. "Wood Treatment Composition." *U.S. Patent* 4,929,454.
- Fougerousse, M., and S. Lucas. 1976. "New Experiments on the Behavior of Wood Preservatives against Marine Organisms in Various Test Sites." *Beihefte zu Material und Organismen*, 3:555-568.
- Häger, B. 1969. "Leaching Tests on Copper-Chromium-Arsenic Preservatives." *For. Prod. J.*, 19:21-26.
- Henry, W. T., and E. B. Jeroski. 1967. "Relationship of Arsenic Concentration to the Leachability of Chromated Copper Arsenate Formulations." *J. Amer. Wood-Preservers' Assoc.*, 63:187-196.
- Hosli, J. P., and K. Mannion. 1991. "A Practical Method to Evaluate the Dimensional Stability of Wood and Wood Products." *For. Prod. J.*, 41(3):40-44.
- Jin, L. 1993. *Data on Ammonia Loss during Air Drying Process*. CSI Report, Harrisburg, North Carolina.
- Jin, L., and K. J. Archer. 1991. "Copper Based Wood Preservatives: Observations on Fixation, Distribution, and Performance." *Proc. Amer. Wood-Preservers' Assoc.*, 87:16.
- Jin, L., K. J. Archer, and A. F. Preston. 1992. "Depletion and Biodeterioration Studies with Developmental Wood Preservative Formulations." *Proc. Amer. Wood-Preservers' Assoc.*, 88:108-125.
- Jin, L., and A. F. Preston. 1993. "Depletion of Preservatives from Treated Wood: Results from Laboratory, Fungus Cellar, and Field Tests." Paper presented at 2nd International Symposium of Wood Preservation, Cannes-Mandelieu, France.
- Jin, L., and A. F. Preston. 1991. "The Interaction of Wood Preservatives with Lignocellulosic Substrates. I. Quaternary Ammonium Compounds." *Holzforschung*, 45(6):455-459.
- Johnson, B. R., L. R. Gjovik, and H. G. Roth. 1973. "Single- and Dual-Treated Panels in a Semi-Tropical Harbor: Preservative and Retention Variables and Performance: Progress Report No. 1." *Proc. Amer. Wood-Preservers' Assoc.*, 69:207-216.
- Loebenstein, J. R. 1991. "Arsenic." *Minerals Yearbook*. U.S. Department of Interior, Bureau of Mines, Washington, D.C.
- Loebenstein, J. R. 1992. "Arsenic: Supply, Demand, and the Environment." *Proc. Arsenic & Mercury: Workshop on Removal, Recovery, Treatment, and Disposal*. Alexandria, Virginia, August 17-20.
- New York State Department of Conservation. 1991. "Draft New York State Air Guide-1: Guidelines for the Control of Toxic Ambient Air Contaminants." Division of Air Resources, New York State Department of Conservation.

Nicholas, D. D. and A. F. Preston. 1980. "Evaluation of Alkyl Ammonium Compounds as Wood Preservatives." *Proc. Amer. Wood-Preservers' Assoc.*, 76:13-21.

Nicholas, D. D., A. D. Williams, A. F. Preston, and S. Zhang. 1991. "Distribution and Permanency of Didecyldimethylammonium chloride in Southern Pine Sapwood Treated by the Full-Cell Process." *For. Prod. J.*, 41(1):41-45.

NIOSH. 1990. *Pocket Guide to Chemical Hazards*. U.S. Department of Health and Human Services, Centers for Disease Control, National Institute for Occupational Safety and Health (NIOSH), Cincinnati, Ohio.

NIOSH Method 7900. 1985. "Arsenic Trioxide, as As." *NIOSH Manual of Analytical Methods*. U.S. Department of Health and Human Services, Centers for Disease Control, National Institute for Occupational Safety and Health (NIOSH), Cincinnati, Ohio.

NIOSH Method 7600. 1985. "Chromium, Hexavalent." *NIOSH Manual of Analytical Methods*. U.S. Department of Health and Human Services, Centers for Disease Control, National Institute for Occupational Safety and Health (NIOSH), Cincinnati, Ohio.

NIOSH Method 7029. 1985. "Copper (Dust and Fume)." *NIOSH Manual of Analytical Methods*. U.S. Department of Health and Human Services, Centers for Disease Control, National Institute for Occupational Safety and Health (NIOSH), Cincinnati, Ohio.

NIOSH Method 6701. 1985. "Ammonia." *NIOSH Manual of Analytical Methods*. U.S. Department of Health and Human Services, Centers for Disease Control, National Institute for Occupational Safety and Health (NIOSH), Cincinnati, Ohio.

NIOSH Method P&CAM 205. 1977. *NIOSH Manual of Analytical Methods*, 2nd ed. National Institute for Occupational Safety and Health, Cincinnati, Ohio.

OSHA ID 105. 1985. *OSHA Manual of Inorganic Analytical Methods*. Inorganic Methods Evaluation Branch, Occupational Safety and Health Administration Analytical Laboratory, Salt Lake City, Utah.

Panshin, A. J., and C. de Zeeuw. 1970. *Textbook of Wood Technology, Vol. 1. Structure, Identification, Uses, and Properties of the Commercial Woods of the United States and Canada*. McGraw-Hill Book Company, New York.

Purushotham, A., N. R. Das, H. S. Gahlot, S. Singh, I. V. Subrahmanyam, V. R. Shivaramakishnan, S. R. M. Pillai, and K. C. Badola. 1969. "Accelerated Testing of Wood Preservatives on Land (Part I)." *J. Timber Devel. Assoc. India*, 15:4-42.

Rak, J. 1976. "Leaching of Toxic Elements from Spruce Treated with Ammonical Solutions of Copper-Zinc-Arsenic Preservatives." *Wood Sci. and Tech.*, 10:47-56.

Sandstorm, S. 1948. "Wood Preservation with Boliden Salt Preservative." *S. Afr. Timber Treat. J.*, 2.

Science News. 1992. "Arsenic in Water: Bigger Cancer Threat." p. 253 (April 18).

Skolmen, R. G. 1973. *Pressure Treatment of Robusta and Ohio Posts: Final Report*. USDA Forest Services Research Note, Pacific Southwest Forest and Range Experimental Station, No. PSW-285.

Smith, D. N. R., and A. I. Williams. 1973. "The Effect of Composition on the Effectiveness and Fixation of Copper/Chrome/Arsenic and Copper/Chrome Preservatives: Part II: Selective Absorption and Fixation." *Wood Sci. and Tech.*, 7:142-150.

Teichman, T., and J. L. Monkman. 1966. "An Investigation of Inorganic Wood Preservatives: Part I. The Stability to Extraction of Arsenic Impregnated Hardwood." *Holzforschung*, 20:125-127.

Tillot, R. J., and C. R. Coggins. 1981. "Non-arsenical Waterborne Preservatives — A Review of Performance and Properties." *Rec. Ann. Conv. Brit. Wood Pres. Assoc.*, 32-46.

U.S. Department of Agriculture (USDA). 1987. *Wood Handbook: Wood as an Engineering Material. Agriculture Handbook Vol. 72*. U.S. Department of Agriculture, Forest Products Laboratory, Forest Service, Washington, D.C.

U.S. Environmental Protection Agency (EPA). 1993. *Waste Minimization Practices at Two CCA Wood-Treatment Plants*. EPA/600/R-93/168. U.S. EPA, Risk Reduction Engineering Laboratory, Office of Research and Development, Cincinnati, Ohio.

U.S. Environmental Protection Agency (EPA). 1992. *Contaminants and Remedial Options at Wood Preserving Sites*. EPA/600/R-92/182. U.S. EPA, Risk Reduction Engineering Laboratory, Office of Research and Development, Cincinnati, Ohio.

U.S. Environmental Protection Agency (EPA). 1991. *Inorganic Arsenicals: Technical Support Document*. U.S. EPA, Office of Pesticides and Toxic Substances, Office of Pesticide Programs, Washington, D.C.

U.S. Environmental Protection Agency (EPA). 1989. *Preparation Aid for RREL's Category III Quality Assurance Project Plans*. Office of Research and Development, Cincinnati, Ohio.

U.S. Environmental Protection Agency. 1988. *Waste Minimization Opportunity Assessment Manual*. EPA/625/7-88/003. U.S. Environmental Protection Agency, Cincinnati, Ohio.

Wallace, L. R. 1968. "Mathematical Modelling in Fungus Cellar Screening of Ammoniacal Copper/Quaternary Preservative Systems Efficacy." *Proc. Amer. Wood-Preservers' Assoc.*, 82:159-172.

APPENDIX A
MATERIAL SAFETY DATA SHEETS
FOR CCA, ACQ-C, AND ACQ-Q50

HAZARD AUTONARY STATEMENTS DANGER

Corrosive Causes irreversible eye damage, skin or mucous membrane irritation. Harmful or fatal if swallowed, inhaled or absorbed through skin. Handle in a well ventilated area. Do not get on skin, in eyes or on clothing. Keep container closed when not in use.

Individuals in the work area of an arsenical wood treatment plant must wear properly fitting, well-maintained, high efficiency respirators, MSHA/NIOSH approved for inorganic arsenic, if the level of inorganic arsenic in the plant is unknown or exceeds 10 micrograms per cubic meter of air (10 ug/m³) averaged over an 8-hour work period. Air monitoring programs, procedures, record retention and submission must be conducted in accordance with the instructions on the attached labeling material.

Refer to label attachment, "Permissible Exposure Limit (PEL) Monitoring Program" for additional information concerning the use of this product.

ENVIRONMENTAL HAZARDS

This product is toxic to fish and wildlife. Do not apply directly to water, do not contaminate water by cleaning of equipment or disposal of wastes.

PHYSICAL AND CHEMICAL HAZARDS

Do not use or store near heat or open flame.

DIRECTIONS FOR USE

It is a violation of Federal Law to use this product in a manner inconsistent with its labeling.

STORAGE AND DISPOSAL

Do not contaminate water, food or feed by storage or disposal. Open dumping is prohibited.

STORAGE

This product must be stored in closed tanks or drums which display a label properly identifying the product and its concentration.

PESTICIDE DISPOSAL

Pesticides wastes are acutely hazardous. Improper disposal of excess pesticide, spray mixture or rinsate is a violation of Federal Law. If this waste cannot be disposed of by use according to label instructions, contact your State Pesticide or Environmental Control Agency or the Hazardous Waste Representative at the nearest EPA Regional Office for guidance.

CONTAINER DISPOSAL

Triple rinse (or equivalent) and offer for recycling or reconditioning or dispose of in a sanitary landfill or by other approved State and local procedures.

SPILLS

- Avoid contact with eyes, skin or clothing.
- Dike to contain with sand or soil.
- Collect usable liquid and return to work tank or drum.
- Neutralize any uncollected liquid.

60% Concentrate
Apply 200 pounds of lime or 800 pounds of cement per 40 gallons of 60% concentrate.

Working Solutions (up to 10% solution)

- Apply 40 pounds of lime or 160 pounds of cement per 50 gallons of solution of 10% or less.
- Collect and enclose in steel drums, any contaminated soil, sand or absorbent and dispose in accordance with local, state and federal regulations for hazardous waste.
- Contact nearest manufacturer, state environmental agency or U.S. E.P.A. for assistance and instructions for control of spilled chemicals.

RESTRICTED USE PESTICIDE

For sale to and use by certified applicators only for those uses covered by this label.

CCA TYPE-C WOOD PRESERVATIVE

FOR INDUSTRIAL USE ONLY CHROMATED COPPER ARSENATE 60% CONCENTRATE

Guarantee:

ACTIVE INGREDIENTS	
Chromic Acid (CrO ₃)	28.50%
Cupric Oxide (CuO)	11.40%
Arsenic Pentoxide (As ₂ O ₅)	20.10%
INERT INGREDIENTS	40.00%
TOTAL	100.00%

Total arsenic, all in water soluble form, expressed as metallic - 13.32%.
This product contains 9.34 lbs. oxide per gallon.
This product weighs 15.56 lbs. per gallon.

KEEP OUT OF THE REACH OF CHILDREN DANGER POISON



STATEMENT OF PRACTICAL TREATMENT

IF SWALLOWED:

Contact a physician or Poison Control Center. Drink 1 or 2 glasses of water and induce vomiting by touching back of throat with finger. Do not induce vomiting or give anything by mouth to an unconscious person.

IF IN EYES:

Flush with plenty of water. Call a physician.

IF ON SKIN:

Wash with plenty of soap and water. Get medical attention.

Refer to additional precautionary statements elsewhere on the label under the heading, "Precautionary Statements: Hazards to Humans and Domestic Animals".



Manufactured By:

Chemical Specialties, Inc.
One Woodlawn Green
Charlotte, North Carolina 28217

Phone 704/455-5181 In case of emergency.

EPA Registration No. 10356-13

EPA Establishment No. 10465-NC-2

EPA Establishment No. 10356-GA-1

EPA Establishment No. 10356-T X-1

Net Contents _____ lbs

POST A COPY OF THIS LABEL IN WORK AREA

SPECIFIC USE INSTRUCTIONS

Contents for use only in pressure treating cylinder for forest products. Cannot be used in concentrated form. Do not attempt to use without implementing the necessary safety procedures and equipment. To be used only in impregnation of forest products utilizing water solutions having concentrations ranging from 0.5% to 10% by weight. Impregnation procedures must rigidly adhere to the current specifications of the American Wood Preservers Association. Treated wood is provided protection against termites, ascomycetes, brown rot, dry rot and white rot.

Applicators must wear gloves impervious to the wood treatment formulation in all situations where dermal contact is expected (e.g., handling freshly treated wood and manually opening cylinder doors).

Individuals who enter pressure treatment cylinders and other related equipment that is contaminated with the wood treatment solution (e.g., cylinders that are in operation or are not free of the treatment solution) must wear protective clothing, including overalls, jacket, gloves and boots, impervious to the wood treatment formulation. In addition, individuals who enter pressure-treatment cylinders must wear properly fitting, well-maintained, high efficiency respirators, MSHA/NIOSH approved for inorganic arsenic. If the level of inorganic arsenic in the plant is unknown or exceeds 10 micrograms per cubic meter of air (10ug/m³) averaged over an 8-hour work period. Air monitoring programs, procedures, record retention and submission must be conducted in accordance with the instructions on the attached labeling material.

Applicators must not eat, drink or use tobacco products during those parts of the application process that may expose them to the wood treatment formulation (e.g., manually opening/closing cylinder doors, moving tanks out of cylinders, mixing chemicals and handling freshly treated wood).

Protective clothing must be changed when it shows signs of contamination. Applicators must leave protective clothing and workshoes or boots and equipment at the plant. Worn out protective clothing and workshoes or boots must be left at the plant and disposed of in a manner approved for pesticide disposal and in accordance with local, state and federal regulations.

Processes used to apply inorganic and arsenical formulations shall leave no visible surface deposits on the wood, as defined by AWPB Standard C-1 and AWPB Standards LP2 and LP22. (visible surface deposits means a surface residue or crystallization on the treated wood. Small isolated or infrequent spots of chemical on otherwise clean wood shall be allowed).

NOTE TO USER: Examples of acceptable materials for protective clothing (e.g., gloves, overalls, jackets and boots) required during application and handling of inorganic arsenicals are vinyl, polyvinyl chloride (PVC), neoprene, NBR (Buna-N), rubber and polyethylene.

WARRANTY STATEMENT

Follow directions carefully. Buyer assumes all risks of use, storage or handling of this material not in strict accordance with directions given herewith.

12/90

IMPLEMENTATION OF THE PERMISSIBLE EXPOSURE LIMIT (PEL) MONITORING PROGRAM

Each arsenical wood treatment plant employer shall require all employees potentially exposed to airborne inorganic arsenic to wear properly fitting, well maintained, high efficiency filter respirators. MSHA/NIOSH-approved for inorganic arsenic for the entire period that the employees are in the treatment application work area or engaged in any activity associated with the treatment process. Alternatively, to potentially relieve employees from the burden of wearing respirators, the employer may implement a Permissible Exposure Limit (PEL) Monitoring Program. This requirement became effective on July 10, 1986. Any plant which begins operation after April 10, 1986 will have 3 months from the date of initial operation to implement this program.

All wood treatment plant employees who elect to implement the PEL monitoring program must determine the current levels of airborne arsenic, averaged over an 8-hour period, to which their employees are exposed. Monitoring data must be obtained in the same manner as described below under "Monitoring and Measured Procedures". If the initial or subsequent monitoring demonstrates that airborne inorganic arsenic in a work area is greater than $10\mu\text{g}/\text{m}^3$, all employees working in that area are required to wear properly fitting, well-maintained, high efficiency filter respirators, MSHA/NIOSH-approved for inorganic arsenic. If in subsequent monitoring, at least two consecutive measurements taken at least 7 days apart, the inorganic arsenic levels are below $10\mu\text{g}/\text{m}^3$, employees in those areas may discontinue wearing the respirators except as discussed in the PEL Checklist below. However, if the employee exposure is below $10\mu\text{g}/\text{m}^3$ but above $5\mu\text{g}/\text{m}^3$, the employer shall repeat monitoring at least every 6 months until at least two consecutive measurements, taken at least 7 days apart, are $5\mu\text{g}/\text{m}^3$. The employer may then discontinue monitoring except as discussed in the PEL Checklist below.

If the monitoring reveals employees are exposed to airborne arsenic levels below $5\mu\text{g}/\text{m}^3$, monitoring need not be repeated except as discussed in the PEL Checklist below.

PEL CHECKLIST

In all cases where there has been a change in production, process, control, or employee handling procedures, or if any events in the PEL Checklist occurred, or if, for any other reasons an employer should suspect new or additional airborne inorganic arsenic, additional monitoring that complies with the requirements for initial monitoring shall be completed. Responses to the Checklist will become part of the monitoring records. Monitoring is required within 3 months if any of the following events/questions on the Checklist can be answered in the affirmative with respect to any events which may have occurred since the last monitoring report submitted to the Agency.

1. After the wood has been treated, have you changed from hand stacking to mechanical stacking or from mechanical stacking to hand stacking? If yes, when?
2. Has your production capacity increased significantly? If yes, when?
3. Have you changed from a ready-to-use or dilute concentrate to a mix-it-

yourself formulation? Has the proportional amounts of arsenic in solution increased, e.g., have you shifted from CCA Type A or C to Type B? If yes, when?

4. Has a significant (i.e., reportable under the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (Superfund), 42 U.S.C. 960 et seq.) spill occurred? If yes, when?
5. Is treated wood being retained on the drip pad for less time? If yes, when?
6. Have there been any other production, process control or employee handling procedure changes which could result in new or additional airborne inorganic arsenic? Identify change and when it occurred.

MONITORING AND MEASUREMENT PROCEDURES

The Employer shall collect personal air samples, including at least one sample which is adequate to represent typical conditions for a full work shift (at least 7 hours) for each job classification in each work area. Sampling should be done using a personal sampling pump calibrated at a flow rate of 2 liters per minute. Samples should be collected on 0.8 micrometer pore size membrane filters (37 mm diameter). The method of sampling analysis should have an accuracy of not less than ± 25 percent (with a confidence limit of 95 percent) for 10 micrograms per cubic meter of air ($10\mu\text{g}/\text{m}^3$) and ± 35 percent (with a confidence limit of 95 percent) for concentrations of inorganic arsenic between 5 and $10\mu\text{g}/\text{m}^3$.

Monitoring may be conducted through a request made to the Occupational Safety and Health Administration (OSHA) for monitoring assistance, which may be provided free of charge under the terms of the OSHA consultation program as provided under section 7(c)(1) of the OSHA Act, or by the employees or contractors of the employer's choosing.

The Environmental Protection Agency (EPA) may direct that remonitoring take place at statistically selected establishments to assure that the checklist is effective in the identifying events which increase airborne arsenic. Selected employers will be notified by EPA/State enforcement representatives. The employer will be responsible for obtaining current air monitoring data within the time specified in the remonitoring notification and for submitting this data and report to the EPA as described below.

DATA SUBMISSION AND CERTIFICATION

The employer shall establish and maintain accurate records which include responses to the PEL Checklist and all monitoring reports. The annual record or copies thereof shall be submitted to the U.S. Environmental Protection Agency, Office of Pesticides and Toxic Substances, Office of Compliance Monitoring (EN-0342), 401 M Street, S.W., Washington, D.C. 20460. All records submitted will be certified by the employer as accurate and in compliance with all calibration analytical and sampling requirements outlined in this program. If the employer received assistance, from an OSHA 7(c)(1) consultant, that consultant's report to the employer will be an acceptable record of calibration, analysis, and monitoring requiring no additional certification.

CCA TYPE C 50-60%
WOOD PRESERVATIVE

CSI
One Woodlawn Green • Suite 250 • Charlotte, North Carolina 28217

VIII SPECIAL PROTECTION INFORMATION

VENTILATION REQUIREMENTS

Maintain adequate ventilation to keep air concentration below TLV-TWA in Section II in presence of solution spray or mist or dust.

SPECIFIC PERSONAL PROTECTIVE EQUIPMENT - When liquid contact potential exists, use impervious plastic or rubber clothing, shoes and gloves.

RESPIRATORY (SPECIFY IN DETAIL) - Use high efficiency particulate respiratory [HiEP while working with liquid. If high dust level, use HiEPF (See "Pocket Guide to Chemical Hazards" NIOSH/OSHA Pub. No. 78-210)]. TC21C-377 - Half Face; TC21C - Full Face

EYE Chemical Goggles or Face Shield.

GLOVES Plastic or rubber

OTHER CLOTHING AND EQUIPMENT

N/A

IX SPECIAL PRECAUTIONS

PRECAUTIONARY STATEMENTS

Store chemical in labeled containers. Keep closed. Empty containers, triple rinse before disposal. Wash hands before eating, drinking or smoking. Follow good industrial hygiene procedures. Do not handle this chemical until manufacturer's safety precautions on this sheet and on product label have been read and understood.

Emergency telephones: Harrisburg, NC Plant (704) 455-5181
Valdosta, GA Plant (912) 242-4813
CHEMTREC (800) 424-9300

OTHER HANDLING AND STORAGE REQUIREMENTS

Comply with 29 CFR 1910.1018. Launder contaminated clothing before reuse. Discard contaminated shoes. Discard gloves contaminated on interior.

Shipping Label: CCA Type C Wood Preservative EPA registered
Freight Classification: Arsenical Mixture, Liquid NOS
Class B Poison, Un 1556 Wood Preservative
Shipping Name: CCA Type C 50-60% Wood Preservative

PREPARED BY Zygmunt Towarnicki

ADDRESS CSI, One Woodlawn Green, Charlotte, NC 28217

DATE 12/20/89

Information contained in this MSDS refers only to the specific material designated and does not relate to any process or to use with any other materials. This information is furnished free of charge and is based on data believed to be reliable. It is intended for use by persons possessing technical knowledge at their own discretion and risk. Since actual use is beyond our control, no guarantee, expressed or implied, and no liability is assumed by CSI in connection with the use of this information. Nothing herein is to be construed as a recommendation to infringe any patents.

PRECAUTIONARY STATEMENTS

HAZARDS TO HUMANS AND DOMESTIC ANIMALS

Causes eye and skin irritation. Harmful if swallowed, absorbed through skin or inhaled. May cause skin sensitization reactions in certain individuals. Avoid contact with skin, eyes or clothing. Avoid breathing vapor or spray mist. Protective clothing, including goggles, should be worn. Wash thoroughly with soap and water after handling. Remove contaminated clothing and wash before reuse.

ENVIRONMENTAL HAZARDS

Do not apply directly to water. Do not contaminate water when disposing of equipment wash waters. This pesticide is toxic to fish. Do not discharge into lakes, streams, ponds, or public waters unless in accordance with a NPDES permit. Do not contaminate water by cleaning equipment or disposal of wastes. For guidance, contact your Regional Office of the Environmental Protection Agency.

STORAGE AND DISPOSAL

Do not contaminate water, food, or feed by storage or disposal.

Disposal: Wastes resulting from the use of this product may be disposed of on site or at an approved waste disposal facility. Pesticide, spray mixture or rinsate that cannot be used according to label instructions must be disposed of according to Federal, State, or local procedures under the Resource Conservation and Recovery Act.

Plastic Containers: Triple rinse (or equivalent). Then offer for recycling or reconditioning, or puncture and dispose of in a sanitary landfill, or incineration, or if allowed by state and local authorities, by burning. If burned, stay out of smoke.

DIRECTIONS FOR USE

It is a violation of Federal Law to use this product in a manner inconsistent with its labeling

FOR TREATMENT OF BURLAP

ACQ C is a copper based mildewicide specifically formulated to impart fungus resistance on burlap in accordance with Military Specification MIL-F-46032A. The operational procedure to obtain a treated product that will pass the product specifications requires the use of a treating tank that is not constructed of or contains any brass or bronze materials. Dilute the concentrate, ACQ-C 1:1 with water in the treatment tank and immerse the burlap to be treated. Keep the burlap submerged in the tank until the burlap has obtained an analysis of 1.5% to 2.0% metallic copper measured on a dry basis.

ACQ®-C

ACTIVE INGREDIENTS

*Copper ammonium carbonate
Inert Ingredients

TOTAL

BY WEIGHT

54.3%
45.7%
100.0%

*Metallic copper equivalent

Contains 0.784 lbs. copper per gallon.

KEEP OUT OF REACH OF CHILDREN

CAUTION

STATEMENT OF PRACTICAL TREATMENT

IF IN EYES: Flush with plenty of water. Call a physician.

IF ON SKIN: Wash with plenty of soap and water. Get medical attention if irritation persists.

IF SWALLOWED: Call a physician or Poison Control Center. Drink 1 or 2 glasses of water and induce vomiting by touching the back of throat with finger, or, if available, by administering Syrup of Ipecac. Do not induce vomiting or give anything by mouth to an unconscious person.

SEE ADDITIONAL PRECAUTIONARY STATEMENTS



Manufactured By:
CHEMICAL SPECIALTIES, INC.
One Woodlawn Green, Suite 250
Charlotte, NC 28217

In Case Of Emergency, Phone: 704-455-5181
EPA Reg. No. 10356-19
EPA Est. No. 10465-NC-1

Net Contents _____ Gallons

POST A COPY OF THIS LABEL IN WORK AREA

SPECIFIC USE INSTRUCTIONS

For ACQ Type A, Type B, and Type C Solutions

Contents for use only in pressure treating vessel for forest products. Cannot be used in concentrated form. Do not attempt to use without implementing the necessary safety equipment. To be used only in impregnation of forest product utilizing water solutions having concentrations ranging from 0.5% to 10% by weight. Impregnation procedures must rigidly adhere to applicable specifications of the American Wood Preservers' Association. Treated wood is provided protection against termites, ascomycetes, brown rot, and white rot.

Applicators must wear gloves impervious to the wood treatment formulation in all situations where dermal contact is expected (i.e. handling freshly treated wood and manually opening cylinder doors).

Individuals who enter pressure treatment cylinders and other related equipment that are contaminated with the wood treatment solution (e.g., cylinders that are in operation or are not free of the treatment solution) must wear protective clothing, including overalls, jacket, gloves, and boots, impervious to the wood treatment formulation. In addition, individuals who enter pressure-treatment cylinders must wear properly fitting, well-maintained, high-efficiency respirators, MSHA/NIOSH approved for ammonia. If level of ammonia in the plant is unknown or exceeds 35 ppm (STEL) or 25 ppm (ACGIH) of air averaged over an 8-hour work period, air monitoring programs, procedures, and record retention and submission must be conducted in accordance with OSHA standards.

Applicators must not eat, drink, or use tobacco products during those parts of the applications process that may expose them to the wood treatment formulation (e.g., manually opening/closing cylinder doors, moving tanks out of cylinders, mixing chemicals and handling freshly treated wood).

Wash thoroughly after skin contact and before eating, drinking, use of tobacco products, or using restroom.

Protective clothing must be changed when it shows signs of contamination. Applicators must leave protective clothing and workshoes or boots and equipment at the plant. Without protective clothing and workshoes or boots must be left at the plant and disposed of in a manner approved for pesticide disposal and in accordance with state and federal regulations.

FOR TREATMENT OF WOOD PRODUCTS

ACQ-C solution is used to formulate a 10% Ammoniacal Copper Quat (ACQ) Type A, Type B, or Type C solution for wood preservation that will be impregnated into lumber, millwork, poles, piles, using a vacuum pressure system.

Do not use in contact with brass, bronze, or copper.

MATERIAL SAFETY DATA SHEET

CHEMICAL SPECIALTIES, INC.
ONE WOODLAWN GREEN
CHARLOTTE, NC 28217

EMERGENCY TELEPHONE:
(CHEMTREC) 800-424-9300
(CSI) 704-455-5181

HEALTH: 3
FLAMMABILITY: 0
REACTIVITY: 0

ACQ - C

Page 1 of 4

MATERIAL:
ACQ - C

DATE ISSUED:
12/6/90

HAZARD CLASSIFICATION:
Chemicals, Not Liquid

CAS NO.:
See Section I

SUPERSEDES:
N/A

SHIPPING NAME(S):
Copper Ammonium Carbonate
Copper Ammonium Base
Copper Ammonium Solution

CHEMICAL NAME:
Copper Ammonium Carbonate

LABEL:
Hazard Label

***** I - INGREDIENTS *****

ACQ - C, WHICH COMPRISES:	WEIGHT %	TWA/TLV
Copper Ammonium Solution Complex	8.0	Unknown
Ammonium Hydroxide	12.0	
CAS No. 33113-08-5		

***** II - PHYSICAL AND CHEMICAL PROPERTIES *****

APPEARANCE: Dark Blue Liquid
VISCOSITY: N/A
BOILING POINT: N/A
VAPOR DENSITY (Air = 1): N/A
PERCENT VOLATILE (by weight): 91%
EVAPORATION RATE (Butyl Acetate = 1): N/A

pH: 9.9 @ 15°C
ODOR: Ammonia
MELTING OR FREEZING POINT: -5° C
VAPOR PRESSURE (mm Hg): N/A
SOLUBILITY IN WATER: 100%
SPECIFIC GRAVITY: 1.20 g/ml @ 25° C

***** III - FIRE AND EXPLOSION INFORMATION *****

FLASH POINT: N/A
LOWER EXPLOSION LIMIT: N/A
EXTINGUISHING MEDIA: Foam: ___ Alcohol Foam: ___

AUTO IGNITION TEMPERATURE: N/A
UPPER EXPLOSION LIMIT: N/A
CO₂: ___ Dry Chemical: ___ Water: ___ Other: X

* Non-flammable

SPECIAL FIRE FIGHTING PROCEDURES: Non-flammable

UNUSUAL FIRE AND EXPLOSION HAZARDS: When subjected to heat, will release choking, irritating ammonia fumes which can react with oxidizing materials. Cool container with water.

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MATERIAL SAFETY DATA SHEET

CHEMICAL SPECIALTIES, INC.
ONE WOODLAWN GREEN
CHARLOTTE, NC 28217

EMERGENCY TELEPHONE:
(CHEMTREC) 800-424-9300
(CSJ) 704-455-5181

HEALTH: 3
FLAMMABILITY: 0
REACTIVITY: 0

ACQ - C

Page 2 of 4

***** IV - HEALTH EFFECTS INFORMATION *****

ROUTES OF ENTRY: Skin Contact: X Eye Contact: X Inhalation: X Ingestion: X

EFFECTS OF OVEREXPOSURE:

Inhalation: Solvent vapors or mists of products can cause irritation and irreparable damage of mucous membranes, headache, breathing difficulty, bronchitis, and coughing.

Eye Contact: May cause irritation, ulceration, watering, and irreparable damage to mucous membrane.

Skin Contact: Skin burns.

Ingestion: Burning of mouth and throat, stomach cramps, diarrhea, possible blood passing, and possible stomach perforation.

OVEREXPOSURE MAY AGGRAVATE EXISTING CONDITIONS:

Risk of acute pulmonary edema, chemical bronchitis, skin ulceration and stomach perforation.

EMERGENCY AND FIRST AID PROCEDURES:

Eyes: Wash eyes for 15 minutes in running water, including inside eyelids. Seek medical attention.

Skin: Wash with soap and water.

Ingestion: Rinse mouth with water; if conscious, give milk with two raw eggs, or fruit juice, or 30% mixture of vinegar and water. This product may act as an emetic.

Inhalation: Remove to fresh air and give oxygen, if needed. Always inform physician of chemical and/or supply with MSDS.

CHEMICALS LISTED AS CARCINOGEN BY:

National Toxicology Program: Not Listed
I.A.R.C. Monographs: Not Listed
OSHA: Not Listed

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MATERIAL SAFETY DATA SHEET

CHEMICAL SPECIALTIES, INC.
ONE WOODLAWN GREEN
CHARLOTTE, NC 28217

EMERGENCY TELEPHONE:
(CHEMTREC) 800-424-9300
(CSD) 704-455-5181

HEALTH: 3
FLAMMABILITY: 0
REACTIVITY: 0

ACQ - C

Page 3 of 4

***** V - REACTIVITY INFORMATION *****

STABILITY: Stable: X Unstable: Conditions to Avoid: High heat and acids

Heat will cause release of ammonia and carbon dioxide gases. Acids will cause rapid formation of CO₂ gas, causing foaming.

HAZARDOUS DECOMPOSITION PRODUCTS: Ammonia

HAZARDOUS POLYMERIZATION: May Occur: Will Not Occur: X Conditions to Avoid: N/A

INCOMPATIBILITY (MATERIALS TO AVOID): Water: Other: X*

* Acids will cause CO₂ formation and foaming.

***** VI - SPILL AND DISPOSAL INFORMATION *****

STEPS TO BE TAKEN IN CASE MATERIAL IS RELEASED OR SPILLED: Avoid inhaling fumes. Avoid eye and skin contact. Contain and absorb with cat litter, clay or other non-acidic material, then place in metal container for subsequent disposal. 8,333 lbs. reportable quantity (based on 1,000 lbs. Ammonium Hydroxide RQ).

WASTE DISPOSAL METHODS: Liquid - flush to chemical waste disposal. Do not discharge to surface waters. Dispose of in compliance with all Federal, state and local laws and regulations.

CONTAINER DISPOSAL: Triple rinse (or equivalent). Puncture and dispose of in an ordinary landfill.

***** VII - PERSONAL PROTECTION INFORMATION *****

VENTILATION TYPE: Mechanical

RESPIRATORY PROTECTION: Use OSHA approved No. TC-23C-331 half-face dual cartridge respirator.

PROTECTIVE GLOVES: Rubber or plastic, when needed, to prevent skin contact.

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MATERIAL SAFETY DATA SHEET

CHEMICAL SPECIALTIES, INC.
ONE WOODLAWN GREEN
CHARLOTTE, NC 28217

EMERGENCY TELEPHONE:
(CHEMTREC) 800-424-9300
(CSI) 704-455-5181

HEALTH: 3
FLAMMABILITY: 0
REACTIVITY: 0

ACQ - C

Page 4 of 4

***** VII - PERSONAL PROTECTION INFORMATION (cont.) *****

EYE PROTECTION: Wear chemical splash goggles where there is a potential for eye contact. Use safety glasses with side shields under normal use conditions.

OTHER PROTECTIVE EQUIPMENT: Eye wash; safety shower; protective clothing (long sleeves, coveralls, rubber apron) when needed to prevent skin contact.

***** VIII - STORAGE AND HANDLING *****

PRECAUTIONS FOR STORAGE AND HANDLING: Keep away from heat. Keep containers tightly closed. Do not contaminate drinking water, food or feed by storage or disposal.

***** IX - TOXICOLOGY INFORMATION *****

Eye (rabbit): 44 mg, severe irritant
Oral: hmn LDLo: 43 mg/kg
ihl-hmn TCLo: 408 ppm

CAS# 7440-50-8
CAS# 7664-41-7

Chemical Name: Copper
Chemical Name: Ammonia

Maximum % by wt.: 8.1
Maximum % by wt.: 10.0

***** X - MISCELLANEOUS INFORMATION *****

NOTE TO PHYSICIAN: Published hazard data is not available on this product. Section IV comments apply only to concentrated ammonium hydroxide solution, the hazardous component. This product contains diluted ammonium hydroxide; therefore, health hazards tend to be less than indicated.

Product may act as an emetic.

SECTION 313 SUPPLIER NOTIFICATION: This product contains the following toxic chemicals subject to the reporting requirements of Section 313 of the Emergency Planning and Community Right-To-Know Act of 1986 and CFR 372:

CAS# 7440-50-8
CAS# 7664-41-7

Chemical Name: Copper
Chemical Name: Ammonia

Maximum % by wt.: 8.1
Maximum % by wt.: 10.0

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PRECAUTIONARY STATEMENTS

HAZARDS TO HUMANS AND DOMESTIC ANIMALS: CORROSIVE.

Causes severe eye and skin damage. Harmful or fatal if swallowed. Do not get in eyes, on skin, or on clothing. Wear safety glasses and rubber gloves. Wash thoroughly with soap and water after handling. Avoid contamination of food.

STATEMENT OF PRACTICAL TREATMENT:

For eyes and skin, flush with plenty of water for at least 15 minutes. (Eyelids must be held open). Call a physician immediately. Remove contaminated clothing and wash before reuse. If swallowed, immediately give 3-4 glasses of milk; if unavailable, give water. Do not induce vomiting. Call a physician. **NOTE TO PHYSICIAN:** Probable mucosal damage may contraindicate the use of gastric lavage. Measures against circulatory shock, respiratory depression, and convulsion may be needed.

ENVIRONMENTAL HAZARDS:

This pesticide is toxic to fish. Do not discharge effluent containing this active ingredient into lakes, streams, ponds, estuaries, oceans, or public waters unless this product is specifically identified and addressed in NPDES permit. Do not discharge effluent containing this product to sewer systems without previously notifying the sewage treatment plant authority. For guidance, contact your State Water Board or Regional Office of the EPA.

PHYSICAL OR CHEMICAL HAZARDS:

Do not use or store near heat or flame!

**FOR HELP IN A CHEMICAL EMERGENCY,
CALL CHEMTREC: 800-424-9300**

**BEFORE USING, CONSULT MATERIAL
SAFETY DATA SHEET**

ACQ - Q50 FOR THE FORMULATION OF WOOD PRESERVATIVES

ACTIVE INGREDIENTSBY WEIGHT
Didecyl dimethyl ammonium chloride.....50.0%
INERT INGREDIENTS50.0%
TOTAL100.0%

CAS No.: Mixture
Net Weight: 7.73 lbs./gal.

**KEEP OUT OF REACH OF CHILDREN
DANGER**



Manufactured By:

Chemical Specialties, Inc.
One Woodlawn Green, Suite 250
Charlotte, North Carolina 28217

EPA Registration No. 6836-51-10356
EPA Establishment No. 6836-IL-1

POST A COPY OF THIS LABEL IN WORK AREA

DIRECTIONS FOR USE

It is a violation of Federal Law to use this product in a manner inconsistent with its labeling.

ACQ-Q50 is a concentrate for formulating purposes only. Use only in accordance with the directions in the Technical Bulletin from Chemical Specialties, Inc.

NOTE: This product should not be used or compounded with any reducing or oxidizing agents (such as calcium hypochlorite, solid perchlorate or nitric acid) since such mixtures may be explosive. Do not use in conjunction with soap or any anionic wetting agent.

STORAGE AND DISPOSAL

Do not contaminate water, food, or feed by storage or disposal. Do not store on side.

'CONTAINER DISPOSAL

Triple rinse (or equivalent). Then offer for recycling or reconditioning, or puncture and dispose of in a sanitary landfill, or incineration, or, if allowed by state and local authorities, by burning. If burned, stay out of smoke.

PESTICIDE DISPOSAL

Pesticide wastes are acutely hazardous. Improper disposal of excess pesticide, spray mixture, or rinse is a violation of Federal Law. If these wastes cannot be disposed of by use according to label instructions, contact your State Pesticide or Environmental Control Agency, or the Hazardous Waste representative at the nearest EPA Regional Office for guidance.

HEALTH	3
FLAMMABILITY	2
REACTIVITY	0

MATERIAL SAFETY DATA SHEET

CHEMICAL SPECIALTIES, INC.
ONE WOODLAWN GREEN
CHARLOTTE, NC 28217

EMERGENCY TELEPHONE:
(CHEMTREC) 800-424-9300
(CSI) 704-455-5181

HEALTH: 3
FLAMMABILITY: 2
REACTIVITY: 0

ACQ - Q50

Page 1 of 4

MATERIAL:
ACQ - Q50

DATE ISSUED:
11/23/88 Rev.

HAZARD CLASSIFICATION:
Corrosive Material, UN1760

CAS NO.:
See Section I

SUPERSEDES:
06/25/87

SHIPPING NAME(S):
Corrosive Liquid N.O.S.

CHEMICAL NAME: (Active) Didecyl dimethyl ammonium chloride

LABEL: Corrosive

FORMULA: Mixture (See Section I)

*****I-INGREDIENTS*****

ACQ - Q50, WHICH COMPRISES:	WEIGHT %	TWA/TLV
Didecyl dimethyl ammonium chloride [(C ₁₀ H ₂₁) ₂ N ⁺ (CH ₃) ₂ Cl ⁻ (CAS# 7173-51-5)	50.0	None established
Ethyl alcohol (CAS# 64-17-5)	10.0	1000 ppm (ACGIH-TLV) 1000 ppm (OSHA-PEL)
Water	40.0	None established

*****II - PHYSICAL AND CHEMICAL PROPERTIES*****

APPEARANCE: Colorless to Pale Yellow Liquid	pH: 6.5 to 9.0 (10% active solution)
VISCOSITY: < 100 cps @ 25°C	ODOR: Ethanolic
BOILING POINT: Not known	MELTING OR FREEZING POINT: Not known
VAPOR DENSITY (Air = 1): Not known	VAPOR PRESSURE (mm Hg): Not known
PERCENT VOLATILE (by weight): 50.0	SOLUBILITY IN WATER: Soluble
EVAPORATION RATE (Butyl Acetate = 1): Not known	SPECIFIC GRAVITY: 0.927 g/ml @ 25° C

*****III - FIRE AND EXPLOSION INFORMATION*****

FLASH POINT: 109°F (Setaflash)	AUTO IGNITION TEMPERATURE: Not known
LOWER EXPLOSION LIMIT (%): Not known	UPPER EXPLOSION LIMIT (%): Not known
EXTINGUISHING MEDIA: Foam: ___ Alcohol Foam: <u>X</u> CO ₂ : <u>X</u> Dry Chemical: <u>X</u> Water: <u>X</u> Other: ___	

SPECIAL FIRE FIGHTING PROCEDURES: Must wear MSHA/NIOSH approved self-contained breathing apparatus and protective clothing. Cool fire-exposed containers with water spray.

UNUSUAL FIRE AND EXPLOSION HAZARDS: Products of combustion are toxic. Heated solvent vapors can travel to an ignition source and flash back. Explosive mixtures can form with air.

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MATERIAL SAFETY DATA SHEET

CHEMICAL SPECIALTIES, INC.
ONE WOODLAWN GREEN
CHARLOTTE, NC 28217

EMERGENCY TELEPHONE:
(CHEMTREC) 800-424-9300
(CST) 704-455-5181

HEALTH: 3
FLAMMABILITY: 2
REACTIVITY: 0

ACQ - Q50

Page 2 of 4

***** IV - HEALTH EFFECTS INFORMATION *****

ROUTES OF ENTRY: Skin Contact: X Eye Contact: X Inhalation: X Ingestion: X

EFFECTS OF OVEREXPOSURE:

Inhalation: Solvent vapors or mists of products can cause irritation of mucous membranes. Exposure to ethyl alcohol concentrations of over 1,000 ppm may cause headache, irritation of the eyes, nose and throat, and, if long continued, drowsiness and lassitude, loss of appetite and inability to concentrate.

Eye Contact: Direct contact can cause severe eye damage. Corrosive.

Skin Contact: Direct or prolonged contact can cause severe irritation. Corrosive.

Ingestion: Immediate burning pain in the mouth, throat, and abdomen; severe swelling of the larynx; skeletal muscle paralysis affecting the ability to breathe; circulatory shock; convulsions. May be fatal.

OVEREXPOSURE MAY AGGRAVATE EXISTING CONDITIONS: No effects indicated.

EMERGENCY AND FIRST AID PROCEDURES:

Eyes: Flush eyes with large amounts of running water for at least 15 minutes. Hold eyelids apart to ensure rinsing of the entire surface of the eye and lids with water. If physician not available, flush for additional 15 minutes. Get immediate medical attention.

Skin: Wash with large amounts of running water, and soap if available, for 15 minutes. Remove contaminated clothing and shoes. Get immediate medical attention. Wash clothing and decontaminate shoes before reuse.

Ingestion: If swallowed, immediately give 3-4 glasses of milk (if unavailable, give water). DO NOT induce vomiting. If vomiting occurs, give fluids again. Have physician determine if patient's condition allows for induction of vomiting or evacuation of the stomach. Do not give anything by mouth to a convulsing or unconscious person. Get immediate medical attention. (See "NOTE TO PHYSICIAN" in Section X).

Inhalation: Remove from area to fresh air. If not breathing, clear airway and start mouth-to-mouth artificial respiration or use a bag-mask respirator. Get immediate medical attention. If victim is having trouble breathing, transport to medical care and, if available, give supplemental oxygen.

CHEMICALS LISTED AS CARCINOGEN BY:

National Toxicology Program: Not Listed
I.A.R.C. Monographs: Not Listed
OSHA: Not Listed

The information provided herein is compiled from internal reports and data from professional publications. IT IS FURNISHED WITHOUT WARRANTY OF ANY KIND EXPRESS OR IMPLIED. It is intended to assist in evaluating the suitability and proper use of the material in manufacturing and in the development and implementation of safety precautions and procedures.

MATERIAL SAFETY DATA SHEET

CHEMICAL SPECIALTIES, INC.
ONE WOODLAWN GREEN
CHARLOTTE, NC 28217

EMERGENCY TELEPHONE:
(CHEMTREC) 800-424-9300
(CSI) 704-455-5181

HEALTH: 3
FLAMMABILITY: 2
REACTIVITY: 0

ACQ - Q50

Page 3 of 4

***** V - REACTIVITY INFORMATION *****

STABILITY: Stable: X Unstable: Conditions to Avoid: None known

HAZARDOUS DECOMPOSITION PRODUCTS: Thermal decomposition may produce toxic fumes of organic chlorides, amines, hydrogen chloride, ammonia and oxides of carbon and nitrogen.

HAZARDOUS POLYMERIZATION: May Occur: Will Not Occur: X Conditions to Avoid: None known

INCOMPATIBILITY (MATERIALS TO AVOID): Water: Other: X*

* Strong oxidizing or reducing agents.

***** VI - SPILL AND DISPOSAL INFORMATION *****

STEPS TO BE TAKEN IN CASE MATERIAL IS RELEASED OR SPILLED: Danger! Corrosive material. Product is combustible. Remove all sources of ignition and ground all equipment before use. Floors may become slippery. Wear appropriate protective gear and respiratory protection where mist or vapors of unknown concentrations may be generated (self-contained breathing apparatus preferred).

Dike and contain spill with inert material (sand, earth, etc.) and transfer the liquid and solid separately to containers for recovery or disposal. Keep spill out of sewers and open bodies of water.

WASTE DISPOSAL METHODS: Dispose of in compliance with all Federal, state and local laws and regulations. Incineration is the preferred method.

CONTAINER DISPOSAL: Triple rinse (or equivalent). Then offer for recycling or reconditioning, or puncture and dispose of in a sanitary landfill, or incineration, or, if allowed by state and local authorities, by burning. If burned, stay out of smoke.

***** VII - PERSONAL PROTECTION INFORMATION *****

VENTILATION TYPE: In processes where TLV for ethyl alcohol may be exceeded, or mists and/or vapors may be generated, proper ventilation must be provided in accordance with good ventilation practices.

RESPIRATORY PROTECTION: A NIOSH/MSHA jointly approved respirator is advised in the absence of proper environmental controls or if TLV for ethyl alcohol is exceeded.

PROTECTIVE GLOVES: Rubber or neoprene, when needed, to prevent skin contact.

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ACQ - Q50

Page 4 of 4

***** VII - PERSONAL PROTECTION INFORMATION (cont.) *****

EYE PROTECTION: Wear chemical splash goggles where there is a potential for eye contact. Use safety glasses with side shields under normal use conditions.

OTHER PROTECTIVE EQUIPMENT: Eye wash; safety shower; protective clothing (long sleeves, coveralls, rubber apron) when needed to prevent skin contact.

***** VIII - STORAGE AND HANDLING *****

PRECAUTIONS FOR STORAGE AND HANDLING: Store containers in compliance with the most recent National Fire Protection Association's "Flammable and Combustible Liquids Code" (NFPA 30). Ground all containers prior to pouring. Keep containers closed until used.

Maximum storage temperature: 140°F. Do not contaminate drinking water, food or feed by storage or disposal.

***** IX - TOXICOLOGY INFORMATION *****

- oral LD₅₀ (rat): 450 mg/kg (80% active)
- dermal LD₅₀ (rabbit): 3342 mg/kg (80% active)
- skin irritation (rabbit): application of 0.5 ml to abraded and non-abraded skin resulted in severe redness and swelling, as well as scabbing and blanching of the skin that did not clear by day 7, post-dose
- corrosive via DOT test for skin corrosivity in rabbits
- eye irritation (rabbit): instillation of 0.1 ml to the eye with or without washing resulted in extreme irritation that did not clear by day 7, post-dose
- not teratogenic in rats treated with 10 to 50 mg/kg on days 6 to 15 gestation
- not mutagenic in Ames *Salmonella* test with or without metabolic activation
- not clastogenic in Chinese hamster ovary cells with or without metabolic activation
- no evidence of chromosomal damage in the bone marrow of rats treated with 600 mg/kg

***** X - MISCELLANEOUS INFORMATION *****

NOTE TO PHYSICIAN: Probable mucosal damage may contraindicate the use of gastric lavage. Measures against circulatory shock, as well as oxygen and measures to support breathing manually or mechanically may be needed. If persistent, convulsions may be controlled by the cautious intravenous injection of a short acting barbiturate drug.

Found on U.S. EPA TSCA inventory.

This is an EPA registered pesticide (EPA Registration No. 6836-51-10356).

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APPENDIX B

**LITERATURE SEARCH FOR NON-CCA, NON-PCP, AND NONCREOSOTE
WOOD PRESERVATIVES**

TABLE B-1. NON-CCA, NON-PCP, NON-CREOSOTE WOOD PRESERVATIVES MENTIONED IN THE LITERATURE

Chemical Class	Chemical/Formula/Mixture	Relative Performance		Wood Tested ^(c)	References
		I ^(a)	II ^(b)		
Inorganic	acid copper chromate (ACC)			9	12
	ammoniacal copper arsenate (ACA)		3	2	3
	boric acid & mixture or borate	-2	1,1	3,4,7	2,10,11
	chromated zinc chloride (CZC)	0		3,4	21
	fluoroborate	1		11	17
	fluorosilicate	1		11	17
	ZnCl ₂	0		4	21
	ZnSO ₄	0		3,4	4
	alkyl or acrylic resin mixture		2	7	16
	Amical 48	0		1	1
Organic	ammonium bifluoride (ABF)	2	3,3,3	3,4,7	7,10,11
	Basilit BFB	1		11	17
	bis-(tributyltin)oxide (TBTO) (or tri- <i>n</i> -butyltin oxide)	0,2,2		1,4,9,10	1,9,12,14,19
	Blue 7	1		11	17
	Captafol (or Difolatan™, N-(1,1,2,2-tetrachloroethylthio) tetrahydrophthalimid)	1	3	10	18,20
	chlordane (1,2,4,5,6,7,8-octachloro-2,3,3a,4,7,7a-hexahydro-4,7-methanoindene)	0		3,4	4
	Cunap	-1		1	1
	3-iodo-2-propynyl butylcarbamate (IPBC)		2	2	3,9
	Kathon 930 (or 2-octyl-4-isothiazolin-3-one)	0		1	1
	methylene bithiocyanate (ComCor)	1		1	15
	NW 100SS	0		1	1
	quaternary NH ₄ compounds (QAC)	1,-2,0	1,3	1,3,7,8,10	1,10,13,20
	sodium tribromophenolate (NaTBP)	1		15	15
	Tachigaren (or hydroxyisoxazole, C ₄ H ₅ NO ₂)	1		11	17
	2-(thiocyanomethylthio)benzothiazole (TCMTB)	-1,-1,0		1,5	1,5,9
	water repellent			9	12

TABLE B-1. NON-CCA, NON-PCP, NON-CREOSOTE WOOD PRESERVATIVES MENTIONED IN THE LITERATURE (Continued)

Chemical Class	Chemical/Formula/Mixture	Relative Performance		Wood Tested ^(c)	References
		I ^(a)	II ^(b)		
Organometallic	ammoniacal copper borate	0	3,3	3,4,7	9,10,11
	ammoniacal copper/quaternary ammonium compound systems (ACQ)	0	1	3,4	22
	Cu-F-wax (CFW)	-1,1,-1	2	2	3
	copper naphthenate	-2		1,3,4,9	4,6,9,12,14
	copper nonanoate	-1		4	14
	copper oxinate in xylene	-1		3,4	4
	Cu-8-quinolinolate (Cu-8) and mixture	-1,-1,0,1,-2	2,2,3,1,1,3	1,2,3,4,5,6,7,9,10	1,3,5,6,7,8,9,10,11,12,14,18,19
	fluor-chrome-arsenic phenol (FCAP)	0	3	3	7
	zinc naphthenate			5	5,9

(a) Performance Comparison I

- +2 = much better than the performance of CCA, PCP, and creosote
- +1 = better than the performance of CCA, PCP, and creosote
- 0 = similar to the performance of CCA, PCP, and creosote
- 1 = poorer than the performance of CCA, PCP, and creosote
- 2 = much poorer than the performance of CCA, PCP, and creosote

(b) Performance Comparison II

- 1 = Good
- 2 = Fair
- 3 = Poor

(c) Wood/Material Tested

- 1. Western red cedar sapwood
- 2. Aspen waferboard panels bonded with phenol-formaldehyde resin
- 3. Douglas fir
- 4. Southern pine wood
- 5. Alderwood
- 6. Scotch pine wood
- 7. Gurger maple
- 8. Red oak
- 9. Beehives
- 10. *Pinus radiata* sapwood
- 11. *Eucalyptus maculata*

TABLE B-1 REFERENCES

1. Newbill, M. A., and J. J. Morrell. 1990. "Protection of Western Redcedar Sapwood from Decay." *For. Prod. J.*, 40(6):29-32.
2. Evans, D. L. 1988. "Boron-containing Wood Preservative and Thickeners." *Eur. Pat. Appl.*
3. Gertjeansen, R. O., E. L. Schmidt, and D. Ritter. 1989. "Assessment of Preservative-treated Aspen Waferboard after 5 Years of Field Exposure." *For. Prod. J.*, 39(4):15-19.
4. Pendleton, D. E. 1988. "Inspections of Experimental Piling at Pearl Harbor, Hawaii." *Proc. Annual Meet. Amer. Wood-Preserv. Assoc.*, 84:267-274.
5. Mitchoff, M. E., and J. J. Morrell. 1988. "Laboratory Decay Resistance of Preservative-treated Red Alder." *Wood Fiber Sci.*, 20(3):370-377.
6. Scheffer, T. C., J. J. Morrell, and M. A. Newbill. 1987. "Shellrot Control in Western Red Cedar: Potential Replacements for Pentachlorophenol Spray." *For. Prod. J.*, 37(7-8):51-54.
7. Morrell, J. J., M. A. Newbill, G. G. Helsing, and R. D. Graham. 1987. "Preventing Decay in Piers of Nonpressure-Treated Douglas-Fir." *For. Prod. J.*, 37(7-8):31-34.
8. Bentsen, A. T. 1985. "Wood Preservative." *Brit. UK Pat. Appl.*
9. Dacre, J. C. 1984. "Preliminary Toxicological Evaluation of Eight Chemicals Used as Wood Preservatives." *Report, USAMBRDL-TR-8405: Order No. AD-A144526, NTIS*, 84(24):46.
10. Highley, T. L. 1984. "In-place Treatments with Waterborne Preservatives for Control of Decay in Hardwoods and Softwoods Above Ground." *Mater. Org.*, 19(2):95-104.
11. Highley, T. L. 1983. "Protecting Piles from Decay: End Treatments." *Int. J. Wood Preserv.*, 3(2):73-76.
12. Kalnins, M. A., and B. F. Detroy. 1984. "The Effect of Wood Preservative Treatment of Beehives on Honey Bees and Hive Products." *J. Agric. Food Chem.*, 32(5):1176-1180.
13. Drysdale, J. A., and A. F. Preston. 1982. "Laboratory Screening Trials with Chemicals for the Protection of Green Timber Against Fungi." *N.Z. J. For. Sci.*, 12(3), 456-466.
14. Greaves, H., M. A. Tighe, and D. F. McCarthy. 1982. "Laboratory Tests on Light Organic Solvent Preservatives for Use in Australia. a. Evaluation of Candidate Fungicides, Including Some Commercial Formulations." *Int. J. Wood Preserv.*, 2(1):21-27.
15. Cserjesi, A. J., and E. L. Johnson. 1982. "Mold and Sapstain Control: Laboratory and Field Tests of 44 Fungicidal Formulations." *For. Prod. J.*, 32(10):59-8.
16. Vasishth, R. C., and D. P. Desilva. 1981. "Wood Treatment to Enhance Wood Properties." *Cont.-in-part of U.S. Ser. No. 23,051*.
17. Da Costa, E. W. B., and O. Collett. 1979. "Potential Toxicants for Controlling Soft Rot in Preservative Treated Hardwoods. IV. Evaluation of Combined Diffusion and Toxicity." *Mater. Org.*, 14(2):131-140.
18. Henningsson, B. O. 1979. "Thermotolerant Moulds on Timber during Kiln Drying." *Int. J. Wood Preserv.*, 1(3):131-135.
19. Da Costa, E. W. B. 1979. "Comparison of Three Organic Fungicides as Light Oil Solvent Preservatives." *Holzforschung*, 33(3):65-67.
20. Butcher, J. A., and J. Drysdale. 1978. Laboratory Screen Trials with Chemicals for Protection of Sawn Timber Against Mold, Sapstain, and Decay." *Int. Biodeterior. Bull.*, 14(1):11-19.
21. Gjovik, L., and H. L. Davidson. 1972. "Comparison of Wood Preservatives in Stake Tests." *U.S. For. Serv., Res. Note, FPL-02*.
22. Archer, K. J., L. Jin, A. F. Preston, N. G. Richardson, D. B. Thies, and A. R. Zahora. 1992. "ACQ." *Proposal to the American Wood Preservers' Assoc. Treatment Committee to Include Ammoniacal Copper Quat, ACQ Type B in AWP Standards under the Jurisdiction of the Treatments Committee*. Chemical Specialties, Inc. (CSI).

APPENDIX C

CALCULATIONS OF NH₃ EMISSIONS

DATA CONVERSION

Conversion from ppm or percent to mg/m³ was made as follows:

$$\text{ppm} = \text{mg/m}^3 \times \frac{24.46}{\text{molecular weight (MW) of NH}_3}$$

where the MW of NH₃ = 17. Therefore,

$$\frac{\text{ppm} \times 17}{24.46} = \text{ppm (0.695)}$$

RAW DATA

	NH ₃ Concentration ^(a) (mg/m ³)			Average
	Charge A9	Charge A10	Charge A11	
<u>Pressure treating</u>				
Initial vacuum	139	146	487	257
Flooding	0	0	0	0
Pressure	0	0	0	0
Slow pressure release	1,043	1,251	1,251	1,182
Blowback (initial drain)	1,738	1,460	1,460	1,552
Air venting	1,877	973	1,251	1,367
Final vacuum	765	695	1,251	904
Vacuum venting	0	0	0	0
Door opening	35	—	52	44
<u>Mixing</u>				
Addition of copper	—	—	139	
Addition of quat	—	—	35	
Addition of H ₂ O	—	—	22	
Draining of combo tank to work tank	—	—	1,807	

(a) Data obtained using Dräger tubes.

CALCULATIONS

Initial Vacuum

Most of the ammonia detected from the vent would be attributed to the remaining residues in the cylinder and vent pipe, and the ammonia concentration of the recycled vacuum coolant supply (analyzed at 0.017%). The vacuum pump used is a liquid ring type manufactured by SIHI (model #65320) and operated at 1760 rpm by a 30-horsepower motor. The vacuum level achieved (before flooding) was 25 in Hg or 2.44 psia.

Example Charge A8: volume of cylinder = 6 in dia. \times 40 in cylinder = 1,157 ft = 32.8 m³.

	<u>Charge A9</u>	<u>Charge A10</u>	<u>Charge A11</u>
Volume of wood (m ³)	11.1	8.2	13.6
Volume of void (m ³)	21.7	24.6	19.2
Total volume (m ³)	32.8	32.8	32.8

The ammonia removed during vacuum was equal to:

$$\frac{14.7 \text{ psia} - 2.44 \text{ psia}}{14.7 \text{ psia}} \times (\text{void space in m}^3) \times (\text{mg of ammonia/m}^3) = \text{mass of ammonia vented}$$

	<u>Charge A9</u>	<u>Charge A10</u>	<u>Charge A11</u>
Volume of air (m ³)	18.1	20.5	16.0
Mass of ammonia (g)	2.5	3.0	7.8

Flooding

No ammonia was detected, which was expected because the work tank vent and vacuum exhaust are tied in together. The vacuum exhaust at the time of flooding was almost zero at 25 in Hg while air was moving from the vent to the work tank to replace the displaced liquid that was flooding the cylinder.

Pressure

No vents were opened during the pressure period.

Slow Pressure Release

The cylinder and combo tank were vented from 150 psig to 20 psig before the drain was completed. The volume was assumed to be equal to the uptake.

$$\text{mass of ammonia vented} = \frac{164.7 \text{ psia}}{34.7 \text{ psia}} \times (\text{uptake in m}^3) \times (\text{mg of ammonia/m}^3)$$

	<u>Charge A9</u>	<u>Charge A10</u>	<u>Charge A11</u>
Uptake (m ³)	3.5	1.9	4.5
Volume of air (m ³)	16.6	9.0	17.5 ^(a)
Mass of ammonia (g)	17.3	11.3	21.9

(a) Charge A10 was only at 120 psig when pressure was released.

Blowback (Initial Drain)

The cylinder was drained to the work tank at a relatively constant pressure. Therefore, the volume of air discharged was equal to the air displaced in the work tank by the liquid.

$$\begin{aligned} &\text{mass of ammonia removed} = \\ &(\text{volume of air displaced in work tank}) \times (\text{mg of ammonia/m}^3) \end{aligned}$$

	<u>Charge A9</u>	<u>Charge A10</u>	<u>Charge A11</u>
Volume of liquid to work tank — gal (m ³)	6,795 (25.7)	7,551 (28.6)	6,122 (23.2)
Mass of ammonia removed (g)	44.7	41.7	33.9

Air Venting

The venting of the remaining air (approximately 10 psig) to atmospheric was assumed to be the volume of the cylinder and combo tank (or uptake).

$$\begin{aligned} &\text{mass of ammonia vented} = \\ &\frac{24.7 \text{ psia}}{14.7 \text{ psia}} \times (\text{volume of cylinder void and uptake}) = (\text{mg of ammonia/m}^3) \end{aligned}$$

	<u>Charge A9</u>	<u>Charge A10</u>	<u>Charge A11</u>
Volume of air removed (m ³)	25.2	26.5	23.7
Mass of ammonia removed (g)	79.5	43.3	49.8

Final Vacuum

The majority of the ammonia detected at this stage was from the wood itself and the drippage off the wood surface. At 25 in Hg, this is the same calculation as the initial vacuum.

	<u>Charge A9</u>	<u>Charge A10</u>	<u>Charge A11</u>
Volume of void (m ³)	21.7	24.6	19.2
Mass of ammonia vented (g)	13.8	14.3	20.0

Door Opening

The door opening was assumed to be part of the ammonia loss by the wood. It does affect the operators, who must wear full-face respirators for the first few minutes after the door has been opened.

Mixing Process

A 1,000-gallon mix of ACO[®] was performed at the beginning of the third charge. This included the addition of 89 gallons of copper, 11 gallons of quat, and 900 gallons of water. The air displaced by the liquid can be assumed to be the volume; however, one must also include the air evacuated (or add 3.2 m³) to achieve a vacuum with the copper analysis.

$$\text{mass of ammonia vented} = (\text{volume of air displaced by liquid}) \times (\text{mg of ammonia per m}^3)$$

	<u>Copper</u>	<u>Quat</u>	<u>Water</u>	<u>Drain</u>
Volume (m ³)	3.5	0.04	3.4	3.8
Mass of ammonia (g)	0.49	1.4	75.5	6.9

Therefore, the total per mix equals 7.0 g. Assuming two mixes/day and 240 days/yr, one can expect 3.3 kg of ammonia emissions per year from mixing.

Total Venting of Plant Operation

The vent sampled was a 6-in sch 80 PVC line exhausted horizontally 10 ft off the ground. It includes the vacuum exhaust, work tank vent, and header.

	<u>Charge A9</u>	<u>Charge A10</u>	<u>Charge A11</u>	<u>Average</u>
Mass of ammonia vented (g)	157.8	113.6	133.4	134.9

Assuming 240 days of production per year, one can estimate that the plant discharges 97.1 kg of ammonia from the vent during operation and 3.3 kg of ammonia during mixing.

Ammonia Discharge from Treated Wood

A 40.57% loss of ammonia (includes liquid and gas forms) was assumed.

mass of ammonia lost =

$$\frac{(40.57\%)}{100} (\text{uptake}) (\text{mass concentration of ammonia}) (\text{density of solution})$$

	<u>Charge A9</u>	<u>Charge A10</u>	<u>Charge A11</u>
Uptake (gal)	915	495	1,200
Ammonia concentration (%)	1.127	1.077	1.225
Mass of ammonia lost (kg)	16.0	8.3	22.8

Assuming 240 days of production per year, one can estimate an ammonia loss of 11,300 kg per year.

