COPPER DIMETHYLDITHIOCARBAMATE: AN EFFECTIVE WOOD PRESERVATIVE

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Summary

This paper reviews the efficacy, field trials, and *in situ* formation of copper dimethyldithiocarbamate (CDDC) in wood. Included in this discussion are chemical and physical characteristics of CDDC and CDDC preservative systems, the effect of CDDC preservative on wood treated, a review of the long-term efficacy trials, typical plant handling characteristics of CDDC and its diluted precursor solutions, and information relating to conversion of water-borne pressure treating plants to CDDC.

Background & History

Copper dimethydithiocarbamates (CDDC) are recognized fungitoxic compounds. This compound has been formed *in situ* in wood in long-term field trials by Arsenault, et al (1). Laboratory and field investigations of CDDC went largely unpublished until West (28) received U.S. Patent No. 4,937,143 for compositions and processing for preserving and coloring wood, wherein a copper source was reacted *in situ* with a dimethyldithiocarbamate source, producing a rich brown color in wood, giving long-term biocidal activity. It was discovered that long-term field trials had been installed by Arsenault (1) in Orange Park, Florida; Bainbridge, Georgia; Charleston, South Carolina. These trials documented 20-plus years of service data on CDDC formed *in situ* in wood with excellent, proven performance. Once the patent was issued to West, patent assignee to this invention was ISK Biotech Corporation. ISK Biotech Corporation then fulfilled the basic requirements necessary to bring CDDC to standardization within the AWPA. Included in this report are the chemical and physical properties of the precursor solutions as well as the CDDC chelate, environmental considerations, analytical methods for determining CDDC in solution and in wood, efficacy data relating to both laboratory, intermediate and long-term field tests, data relating to the preservative permanence when CDDC is leached by water, soil, or in field stakes, the effects on of CDDC on treated wood related to strength, corrosivity, and hygroscopicity, and treatment experience using this system to date.

Dithiocarbamates have long been recognized to be fungitoxic and effective preservative compounds. CDDC (CAS No. 137-29-1) has an extremely low water solubility, and tests of this compound in wood preservation for termite control had been conducted earlier (29) in solvent-based systems. Preparation of this chelate *in situ* in wood using the dual step process was first accomplished by Arsenault in 1967 and later patented by West in 1990. Today, after 24 years, CDDC continues to give excellent performance both at 0.1 pcf and 0.2 pcf copper (as metal) when compared to standard preservatives such as CCA and ACA in ground contact. Studies performed by

ISK Biotech and cooperating researchers (8, 9, 10, 11, 12, 13, 24) indicate that when Cu^{++} is the copper source, the formation of CDDC in wood is always the cupric bis (dimethyldithiocarbamate) in a 1:2 molar ratio (copper to dithiocarbamate).

Chemical and Physical Properties

Because CDDC is a water insoluble complex, this chelate is formed in wood using a solubilized form of copper (copper ethanolamine or copper sulfate) and sodium dimethyldithiocarbamate (SDDC). U.S. Patent No. 4,937,143 issued to M. West in 1990 covered many different sources of copper as well as many different sources of dithiocarbamates for this process. In 1992, U.S. Environmental Protection Agency (EPA) registrations were granted to ISK Biotech Corporation for two sources of copper, either copper sulfate or copper ethanolamine complex under the registered trademark of Kodiak System I. SDDC also received registration from the EPA for use as a wood preservative when used in conjunction with Kodiak System I to form CDDC in wood. SDDC is registered under the name Kodiak System II. Both solutions must be kept separate in the treating plant environment to prevent cross-contamination and formation of the CDDC chelate prior to wood treatment.

Physical and chemical properties of both preservative precursor systems are shown in Table 1. Both compounds are water soluble and are thus diluted with water to prepare a ready-to-use treating solution. Common construction materials (tanks, cylinders, piping, valves, etc.) similar to those used within the inorganic arsenical wood treating industry are compatible with either system component. Once prepared in wood, CDDC forms the 1:2 chelate regardless of ratio of copper to SDDC. X-ray diffraction patterns have indicated that there is no significant amount of copper (I) dimethyldithiocarbamate formed within wood (8, 9, 10). Further investigations into the formation of the chelate in wood revealed data from X-ray diffraction as well as wet chemistry analytical methods. Copper, nitrogen, sulfur and hydrogen formed in the wood were in the ratio of the cupric 1:2 dithiocarbamate chelate (11). These data were further confirmed when the analysis of stakes, either treated back-to-back or dried between treatments, yielded the same formation of the chelate as evidenced by SEM patterns (22) and the use of electron spin resonance (ESR) by Ruddick (24).

Environmental

Raw materials for the preparation of CDDC in wood are readily available and registered by the U.S. EPA. Registrations for the copper sources and the SDDC are being submitted to Agriculture Canada for registration under the Pest Control Products Act. Treated wood containing CDDC has been thoroughly evaluated and tested for environmental and toxicological concerns. Testing on CDDC treated wood has included extraction procedure (EP) testing, toxicity characteristic leaching procedure (TCLP) testing, emissions from treated wood, quantification and identification of gases from combusted treated wood and their respective LC_{50} values. The treated wood does not contain any *listed* hazardous waste constituents, and both EP testing and TCLP testing have shown that CDDC treated wood does not possess any hazardous waste *characteristics* according to U.S. EPA criteria.

An industrial hygiene survey during CDDC treating was conducted by Environmental Technologies of Magnolia, Texas, during commercial treatment trials in 1991. Results of tank, cylinder, and personnel monitoring indicated that no employees were placed at an increased risk of exposure to any of the contaminants monitored. Results showed that carbon disulfide and ethanolamine levels (breakdown products of dimethyldithiocarbamate under acidic conditions) were well below the limits of detection of the instrument (less than 0.09 ppm carbon disulfide and less than 0.75 ppm amine on a time weighted average basis). Constituents were generally at a 1 ppm level or less in monitoring airborne emissions from tanks and vents during the treatment trials.

Weyerhaeuser Fire Technology Laboratory - Smoke and Toxic Gas Emissions Test

Tests were conducted at Weyerhaeuser's fire test laboratories in Longview, Washington, (25, 26) to determine combustion products of CDDC treated wood. Southern pine sapwood treated with amine-form (MEA) CDDC or sulfate-form CDDC at retentions of 0.48 pcf CDDC and 0.96 pcf CDDC were compared to untreated Southern pine sapwood in the BSS 7238, Test Method for Smoke Generation by Materials on Combustion, and BSS 7239, Test Method for Toxic Gas Generation by Materials on Combustion. Gases specifically covered are carbon monoxide (CO), hydrogen fluoride (HF), hydrogen chloride (HCl), hydrogen cyanide (HCN), nitrogen oxides ($NO_x = NO + NO_2$), and sulfur/sulfides ($SO_2 + H_2S$). Results of these tests (26) indicated no significant difference in total toxic gas formation over that of untreated wood controls.

The optical density of the smoke generated from CDDC treated wood was found to be 35-65% lower than the optical density for the untreated controls.

Analysis Of Combustion Products

In this test at the Weyerhaeuser fire test laboratories (25), Swiss-Webster mice were exposed to the thermal decomposition products of the CDDC treated wood specimen for 30 minutes to determine the LC_{50} value. The treatments evaluated were the same as for the Smoke and Toxic Gas Emissions Test (0.48 and 0.96 pcf CDDC).

Data generated in this series of tests using the U-Pitt Combustion Toxicity Test Method indicate that the smoke generated from CDDC-treated Southern pine lumber is no more toxic than smoke from untreated controls. The results of the tests are found in Table 2.

Analytical Methods

Analytical methods for the detection of penetration and retention in CDDC-treated wood are developed and available. The copper constituent may be determined by inductively coupled plasma spectroscopy (ICP), atomic absorption spectroscopy (AA), and X-ray fluorescence spectroscopy (XRF) using AWPA approved standard methods. Analysis of SDDC treating solutions may be performed by AA or XRF. A method for extracting the chelate directly from the treated wood and analyzing this by spectrophotometry was recently adopted by AWPA Sub-Committee P-5, "Chemical Methods of Analysis." The colorimetric methods closely resemble the U.S. EPA methods and Agriculture Canada methods for detection of dithiocarbamates using a simple extraction technique with a chlorinated solvent such as methylene chloride or chloroform and analyzing the resulting extract by at a wavelength of 435 nanometers (2, 6, 7).

Determination of penetration is obvious from the rich brown colored complex, CDDC, formed in the wood from the reaction products of copper and SDDC. In addition, penetration can be determined using classic copper indicators such as PAN indicator or chrome azurol S after the copper step.

EFFICACY

AWPA Standard E10 weathered and unweathered (1, 2, 7) soil block tests were conducted on CDDC (copper sulfate formulation) and test results were reported on *Postia placenta* (Madison 698 - also known as *Poria placenta*), *Lentinus lepideus* (Madison 534) and *Gloeophyllum trabeum* (Madison 617).

Weathered (leached) soil block tests were also conducted on CDDC (both the Cu-amine and copper sulfate formulas), CCA Type C, copper sulfate and Cu-ethanolamine complex by Michigan Technological University (2, 7, 23), using treated and untreated southern pine sapwood against the brown-rot fungi, *Gloeophyllum trabeum, Postia placenta* (ATTC 11538) and *Coniophora puteana,* and using treated and untreated birch sapwood against the white-rot fungi, *Trametes versicolor* (ATTC 12679), *Irpex lacteus* (ATTC 11245) and *Pleurotus ostreatus* (ATTC 32337).

Of the brown rot fungi tested, only *Postia placenta* resulted in a valid test because the weight losses on the untreated controls with the *Gloeophyllum trabeum* and the *Coniophora puteana* were very low or non-existent. The similarity in performance of the copper sulfate CDDC and copper ethanolamine complex CDDC is noteworthy. Also, the greater efficacy of the copper ethanolamine complex over the copper sulfate is demonstrated.

With the white rot fungi, CDDC made from copper sulfate or copper ethanolamine, resulted in excellent control, even at the lowest retentions tested.

Again, the greater efficacy of the copper ethanolamine complex over copper sulfate is noted. With *Irpex lacteus*, CDDC is more effective than CCA at all retentions tested.

Agar Block Decay Test

Miniaturized agar-block tests were conducted according to European Standard EN 113 by Timber Technology Research Group, Imperial College, London (2, 7, 14). Tests were completed with CDDC (both the Cu-amine and copper sulfate formulas), CCA, and Cu-ethanolamine complex, using Scots pine and beech against the fungi, *Postia placenta* (FPRL 280), *Coriolus versicolor* (FPRL 28A), and the soft rot fungus, *Chaetomium globosum* (FPRL S70K).

Results of these studies indicate that when tested in accordance with standards EN-113, EN-84, and EN-73 in miniaturized agar-block tests against the brown rot fungus, *Poria placenta*, the performance of the copper ethanolamine complex CDDC compared favorably with that of CCA. There was no measurable weight loss with CDDC at all retentions in weathered and unweathered blocks.

Also, with the white rot fungus, the performance of the copper ethanolamine complex, CDDC, was comparable with that of CCA when the CDDC was leached and evaporatively aged. The same increase in performance was seen in the copper complex alone. Possibly the increase in nitrogen from the excess amine provided nutrient which was lost on leaching and evaporative aging, thus improving performance.

With the soft rot fungus, both the copper sulfate CDDC and the copper ethanolamine CDDC gave the same level of protection. The performance of the copper ethanolamine CDDC compared favorably with that of CCA. As was previously noted, the performance of the copper ethanolamine improved after leaching and evaporative aging, probably indicating a loss of the nitrogen nutrient which had accumulated from the reaction of the copper ethanolamine complex with SDDC to form CDDC.

Fungal Cellar/Soft-Rot Test

Gray (14) indicated this test with *Chaetomium globosum* (FPRL S70K) to be very effective in predicting preservative failure when exposed to soft rot fungi. Of all products tested using this method, CDDC is one of the most favorable systems tested to date.

A fungal cellar study, which is intermediate between laboratory and field tests, is in progress at the Mississippi Forest Products Lab, where the soil is kept at high soil moisture content to drive the test toward soft-rot exposure. The 12 month inspection data are shown in Table 3. The amine and sulfate forms of CDDC are performing equally in this test.

Termite Test

Wolcott has shown CDDC to be effective at preventing termite attack when dissolved at 0.2% in acetone and used as a dip treatment (29).

The long-term stake test performance reported by Arsenault, *et al*, in sites known to have significant termite activity proves the efficacy of CDDC in preventing termite destruction of the treated wood. Results from Arsenault's 1991 termite ratings for these stakes have previously been published (2, 7).

CDDC at 0.11 and 0.22 pcf copper is more effective against termites than pentachlorophenol at 0.43 pcf. CDDC at 0.22 pcf copper is more effective against termites than CCA at 0.41 pcf.

Stake Tests

Arsenault, *et al*, (1) reported on stake tests conducted with CDDC compared to CCA and ACA. Graphic results of the work by Arsenault, *et al*, are illustrated in Figures 1, 2, 3 and 4 (excerpted from AWPA Proceedings, 1991). Stakes were installed in tests plots in Charleston, SC, and Orange Park, FL. The Orange Park plot was discontinued at five years' exposure, and the highest retention CDDC and CCA stakes were transferred to a test plot in Bainbridge, GA, for the duration of the test.

Arsenault, *et al*, (1) reported "The copper dimethyldithiocarbamate is a very effective wood preservative, apparently better than ACA on an equivalent copper basis." Also, the paper states "It is evident that copper dimethyldithiocarbamate at 1.07 pcf performs about

the same as CCA-C at a retention of 0.4 pcf and performs significantly better than ACA at a retention of 0.54 pcf or 0.214 pcf copper." The aforementioned data were pertaining to the Orange Park , Florida/Bainbridge, Georgia test plots (Table 4), and the 1.07 pcf of CDDC is equivalent to 0.22 pcf copper. At the Charleston test plot (Table 5), the highest retention of CDDC, 0.22 pcf copper, performed about the same as CCA at the 0.4 pcf retention. Its performance was slightly superior to ACA, though the copper retention was about the same in both preservatives. At the Charleston test plot, the lowest retention of copper in CDDC was 0.11 pcf, and this appeared to be about equivalent in performance to CCA-A and ACA, though the results are better than CCA-A in test years 14 through 19. These same data in the Arsenault, *et al*, paper (1) were analyzed by Win Hartford (16) by the log probability method, and he came to the same conclusions as the conclusions in this paper - that the performance of CDDC (0.2 pcf copper) is very similar to the performance of CCA 0.4 pcf retention. The CDDC stakes (0.2 pcf Cu) were rated by Arsenault, averaging 95 in decay and 81 in termite ratings when the stakes were pulled for analytical analyses in 1991. The CCA stakes (0.6 pcf oxides) were given an average rating of 97 in decay and 92 in termites.
At the last published reading (2), the stakes had been exposed for approximately 23 years. The Charleston stakes are still in test.

PRESERVATIVE PERMANENCE

Water Leaching

Two AWPA E-11 water leach tests have been conducted on CDDC-treated wood. Morrell and Forsyth (21) found that copper in the leachate was not detectable at the instrument detection limits of 0.01% (w/w) using X-ray fluorescence spectroscopy. Cooper and Stokes (4) analyzed for copper in the leachate by atomic absorption spectroscopy and sent samples to Ricerca, Inc. for SDDC analysis by ion chromatography. It was found that very low levels of copper and SDDC leached from treated wood (Figures 5 and 6). The level of copper that leached from CDDC treatments was less than the amount of copper that leached from comparably treated CCA-C material.

Soil Leaching

In October of 1991, the remaining CDDC stakes and CCA stakes in the Bainbridge, GA, test plot were pulled for analysis after 23 years' exposure. Analysis of the above ground and below ground portions was performed, using either atomic absorption spectroscopy or X-ray fluorescence spectroscopy. This data had previously been presented (2, 7). It was found that after 23 years in ground contact, approximately 72% of the copper had leached from the base of the CCA Type C stakes and 77% of the copper had leached from the bottom of the CDDC stakes. New fungal cellar stakes were also evaluated after the end of 12 months, and data was compared to previously published data concerning both CCA and ACQ (ammoniacal copper quat).

Three-millimeter-thick stakes of Southern yellow pine (SYP) were used in the fungal cellar test at Mississippi State University. Copper loss from the CDDC stakes is minimal, whereas copper lost from CCA and ACA stakes is in the range of 40% to 50%. SDDC loss from stakes in the fungal cellar test decreased as the retention of CDDC increased and percent loss from the 3mm-thick stakes are comparable to SDDC loss from the 23-year-old 3/4 inch stakes. CDDC loss is similar for the copper MEA/SDDC complex as well as copper sulfate/SDDC stakes. The results are shown in Table 7.

EFFECTS ON TREATED WOOD

Strength

Southern pine treated with CDDC from either amine copper or copper sulfate was tested at New York State College of Environmental Science and Forestry at Syracuse University by Smith, *et al*, (2, 7, 27) and at Michigan Tech University by Laks, *et al* (2, 5, 7). No significant deleterious effects were found on Southern pine treated from either sulfate or amine when tested in small, clear specimens using standard ASTM tests for strength including modulus of elasticity, modulus of work rupture, and work to maximum load. In addition, strength tests were conducted on Southern pine clears using an elevated temperature dry kiln schedule at the end of the CDDC treatment. This additional heating caused no additional strength loss when tested in accordance with standard ASTM tests.

Wood Corrosivity

Treated wood corrosivity was tested (2, 7, 19) against metals, including mild steel, red brass, aluminum, galvanized steel, hot dipped and zinc phosphate coated mild steel. These same tests were run on CCA at ground contact retention and ACA treated wood. Results are as follows:

Mild steel	ACA was more corrosive than CDDC, CCA, or the control.
Red brass	CDDC and the control specimens have the same corrosion rate. ACA treated wood had a lower corrosion rate and CCA treated wood had a higher corrosion rate than either ACA or CDDC.
Aluminum	CDDC, CCA, and ACA have the same corrosion rate as the untreated control.
Steel	ACA treated wood was more corrosive than CDDC, CCA, or the untreated control.
Hot dipped zinc galvanized steel	CDDC-treated wood had a corrosion rate equivalent to that of the untreated control while CCA and ACA treated wood gave a negative corrosion rate due to build-up of corrosion products.
Zinc phosphate coated steel	CDDC, CCA, and ACA treated wood were all more corrosive than the control.

Hygroscopicity

Wood has been tested for hygroscopicity after treatment with CDDC (2,7). Although slightly higher than untreated controls, there was no statistically significant difference between hygroscopicity of either CCA or CDDC as compared to untreated controls when exposed at two relative humidity at constant temperatures to equilibrium moisture content. Results are in Figure 7.

Treatment Experience

CDDC treatment can be commercially implemented at existing CCA plants with minor plant conversions as long as a second cylinder is employed for the SDDC component. CDDC is not recommended for plants utilizing a single cylinder, due to the chelate formation in common lines and pipes due to cross-contamination of the copper component and the SDDC. Two large scale commercial pilot-plant scale-ups have been performed at Wood Protection, Inc. in Houston, Texas (17), and at Maine Wood Treaters in Mechanic Falls, Maine. Results of these treatments yielded a total production in excess of one million board feet of lumber which was uniformly penetrated, had excellent retention results which resulted in a warm, rich brown color throughout the treatable sapwood.

Acknowledgements

The author gratefully acknowledges the work of researchers in helping to prepare the data for this manuscript and especially appreciates the work of Bob Arsenault and Dr. Tom Woods in reviewing this paper prior to publication.

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Table 1. Physical properties

	Kodiak System I (Cu MEA)	Kodiak System II (SDDC)
Active Ingredient:	Copper Hydroxide	Sodium Dimethyldithiocarbamate
% AI (w/w):	10% Cu (as metal)	40%
Specific Gravity:	1.16	1.18
Lbs/gal. @ 60° F:	9.66	9.83
pH:	11.0	12.0
Appearance:	Dark blue liquid	Clear, slightly yellow liquid

Table 2. Inhalation LC_{50} for treated and untreated wood samples (25)

Sample ID	LC_{50} (gram)	95% Confidence Lower value (g)	Upper value (g)
0.48 CDDC (Amine)	14	11	17
0.96 CDDC (Amine)	28	22	35
0.48 CDDC (Sulfate)	28	25	33
0.96 CDDC (Sulfate)	11	10	13
Controls (untreated)	13	10	16

Table 3.
FUNGAL CELLAR DATA

ISK fungus cellar 12-month data summary
Installed 6/18/92 - MFPL

Treatment	Density	RETENTIONS** Cu (pcf)	SDDC (pcf)	Total (pcf)	Decay Ratings
CuMEA/SDDC (1:2)	37.9	0.021	0.114	0.135	9.6
CuMEA/SDDC (1:2)	34.4	0.067	0.247	0.314	9.8
CuMEA/SDDC (1:2)	34.8	0.108	0.513	0.621	9.9
CuMEA/SDDC (1:2)	33.9	0.197	1.256	1.453	9.9
CuSO4/SDDC (1:2)	36.8	0.028	0.129	0.157	9.2
CuSO4/SDDC (1:2)	33.2	0.045	0.286	0.331	9.7
CuSO4/SDDC (1:2)	37.9	0.081	0.562	0.643	9.8
CuSO4/SDDC (1:2)	35.3	0.156	1.123	1.279	9.9
		Total Oxides			
CCA-C	35.86	0.059			7.3
CCA-C	33.64	0.098			9.1
CCA-C	32.04	0.211			9.9
CCA-C	31.90	0.456			10
		ACA			
ACA	34.38	0.068			8.6
ACA	32.81	0.120			9.2
ACA	35.33	0.192			9.6
ACA	34.90	0.343			10
WATER CONTROL					4.2
AMMONIA CONTROL					3.6

*Ratings are mean values of 40 replicates
**Retentions - analytical assay results
Stake size: 19 mm x 3 mm x 154 mm (rtl)
Species: Southern pine

Table 4. - Index of Condition of Stakes Installed
at Orange Park, Florida and Bainbridge, Georgia Test Plots
Arsenault, et al (1)

	Months	10	27	46	59	82	105	115	130	141	160	245	273
	Test												
	CuDMDTC												
Avg. Combined	0.55 pcf	100	100	90	68	test terminated							
Avg. Combined	1.07	100	100	100	96	88	82	83	83	84	84	75	81
Avg. Decay	0.55	100	100	100	89	test terminated							
Avg. Decay	1.01	100	100	100	100	97	94	92	92	92	92	79	95
Avg. Termite	0.55	100	100	90	68	test terminated							
Avg. Termite	1.07	100	100	100	96	88	82	83	83	84	84	75	81
	CCA-C												
Avg. Combined	0.24	100	98	93	84	test terminated							
Avg. Combined	0.41	100	98	98	92	test terminated							
Avg. Combined	0.60	100	100	100	98	99	97	98	98	99	98	89	91
Avg. Decay	0.24	100	100	100	93	test terminated							
Avg. Decay	0.41	100	100	100	99	test terminated							
Avg. Decay	0.60	100	100	100	100	100	99	99	99	100	100	94	97
Avg. Termite	0.24	100	100	100	93	test terminated							
Avg. Termite	0.41	100	98	98	92	test terminated							
	ACA												
Avg. Combined	0.22	100	94	74	58	test terminated							
Avg. Combined	0.36	100	96	92	74	test terminated							
Avg. Combined	0.54	100	100	91	76	test terminated							
Avg. Decay	0.22	100	96	94	74	test terminated							
Avg. Decay	0.36	100	100	100	86	test terminated							
Avg. Decay	0.54	100	100	99	92	test terminated							
Avg. Termite	0.22	100	94	76	60	test terminated							
Avg. Termite	0.36	100	96	92	74	test terminated							
Avg. Termite	0.54	100	100	91	76	test terminated							
	Untreated Controls												
	0	48	10	0									
	Pentachlorophenol*												
Avg. Decay	0.43	100	100	98	91	test terminated							
Avg. Termite	0.43	99	98	95	84	test terminated							
Avg. Combined	0.43	99	98	94	84	test terminated							

*Pentachlorophenol in polypropylene glycol cosolvent and methylene chloride carrier
(glycol retention 60% of penta retention)

Scale: 0 = stake completely destroyed
100 = perfect condition

Index of Condition is defined as a measure of serviceability wherein
100 is a perfect condition and 0 is completely destroyed.

Table 5 - Index of Condition of Stakes
in Charleston S.C. Blessing Plantation Test Plot
Arsenault, et al (1)

Months in Test	14	28	45	59	74	82	94	106	118	130	142	154	166	178	189	201	213	225	237
CuDMDTC																			
0.55 pcf	100	100	100	100	100	100	100	100	100	98	81	79	74	61	54	55	48	43	30
1.07	100	100	100	100	100	100	100	100	100	99	100	99	95	91	91	91	88	86	89
CCA Type C																			
0.23 pcf	100	100	100	100	100	100	99	100	100	98	98	95	95	77	76	75	71	60	47
0.40	100	100	100	100	100	99	98	99	100	99	99	97	93	82	84	86	84	86	85
0.60	100	100	100	100	100	100	99	99	99	99	99	98	97	98	98	100	97	99	99
ACA																			
0.22pcf	100	100	100	100	100	99	100	100	100	96	95	91	87	58	58	57	52	49	32
0.36	100	100	100	100	100	100	100	100	100	98	99	97	92	70	70	75	72	69	55
0.54	100	100	100	100	100	100	100	100	100	89	90	87	87	86	84	85	83	83	75
Untreated Controls	39	14	0																

Scale: 0 = stake completely destroyed
100 = perfect condition

Index of Condition is defined as a measure of serviceability wherein 100 is a perfect condition and 0 is completely destroyed.

TABLE 6. Fungus Cellar CDDC 12-Month Depletion Data Summary
Stakes (3mm x 19mm x 154mm) Installed June 18, 1992.
(Results based on X-ray analysis)

Treatment		Retentions by Assay						% Depletion Based on Assay	
		Cu		SDDC				Cu	SDDC
		Init.	Final	Init.	Final				
CuMEA/		0.04	0.03	0.07	0.00			11.1	98.6
SDDC 1:2		0.07	0.07	0.19	0.11			-1.4	43.5
		0.11	0.11	0.54	0.25			-2.9	53.1
		0.17	0.20	1.33	0.59			-19.6	55.4
CuSO4/		0.03	0.03	0.08	0.01			13.8	92.4
SDDC 1:2		0.05	0.05	0.14	0.05			7.7	63.8
		0.09	0.09	0.38	0.16			3.3	57.1
		0.14	0.16	0.68	0.40			-16.1	41.3
	Wt. Gain	Cu Assay		Cr Assay		As Assay		Cu	As
CCA	0.06 pcf	0.02	0.01	0.03	0.09	0.02	0.01	20.0	47.1
	0.10 pcf	0.03	0.01	0.06	0.08	0.03	0.02	50.0	50.0
	0.20 pcf	0.04	0.02	0.12	0.15	0.06	0.05	42.5	27.4
	0.43 pcf	0.07	0.03	0.23	0.22	0.14	0.10	54.0	29.7
ACA	0.05 pcf	0.06	0.03			0.02	0.00	41.8	100.0
	0.10 pcf	0.09	0.05			0.04	0.00	42.2	97.3
	0.20 pcf	0.15	0.07			0.08	0.01	50.0	84.2
	0.39 pcf	0.28	0.14			0.19	0.06	51.4	68.6

Note: A negative % depletion represents a gain or zero depletion.

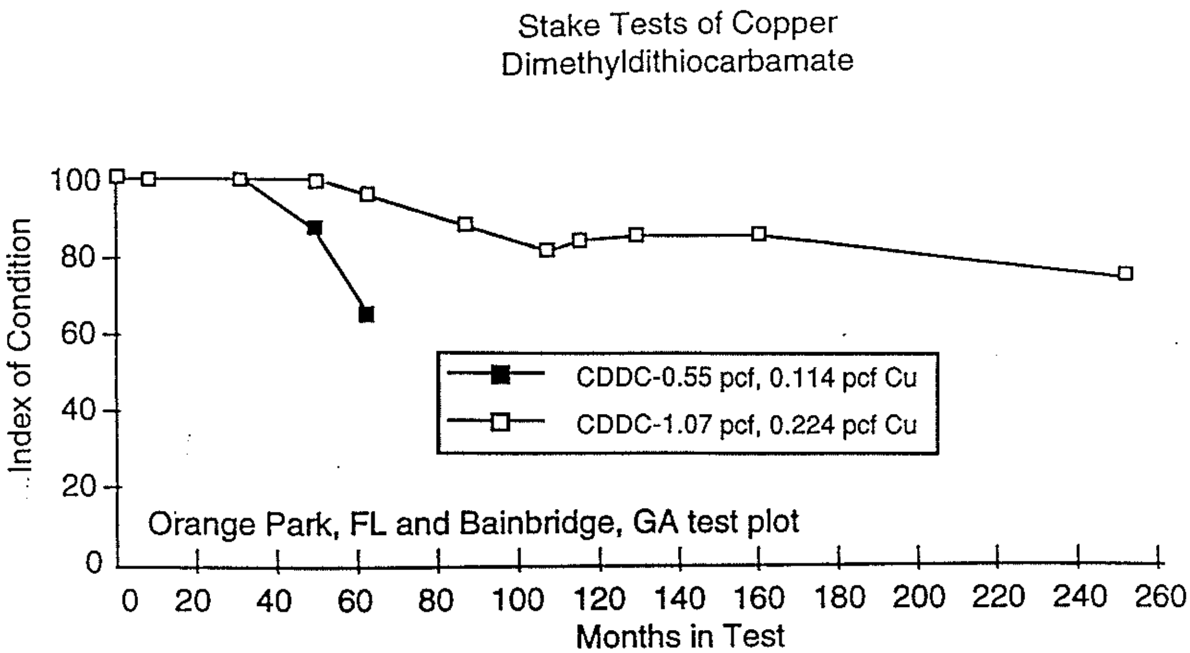


FIGURE 1

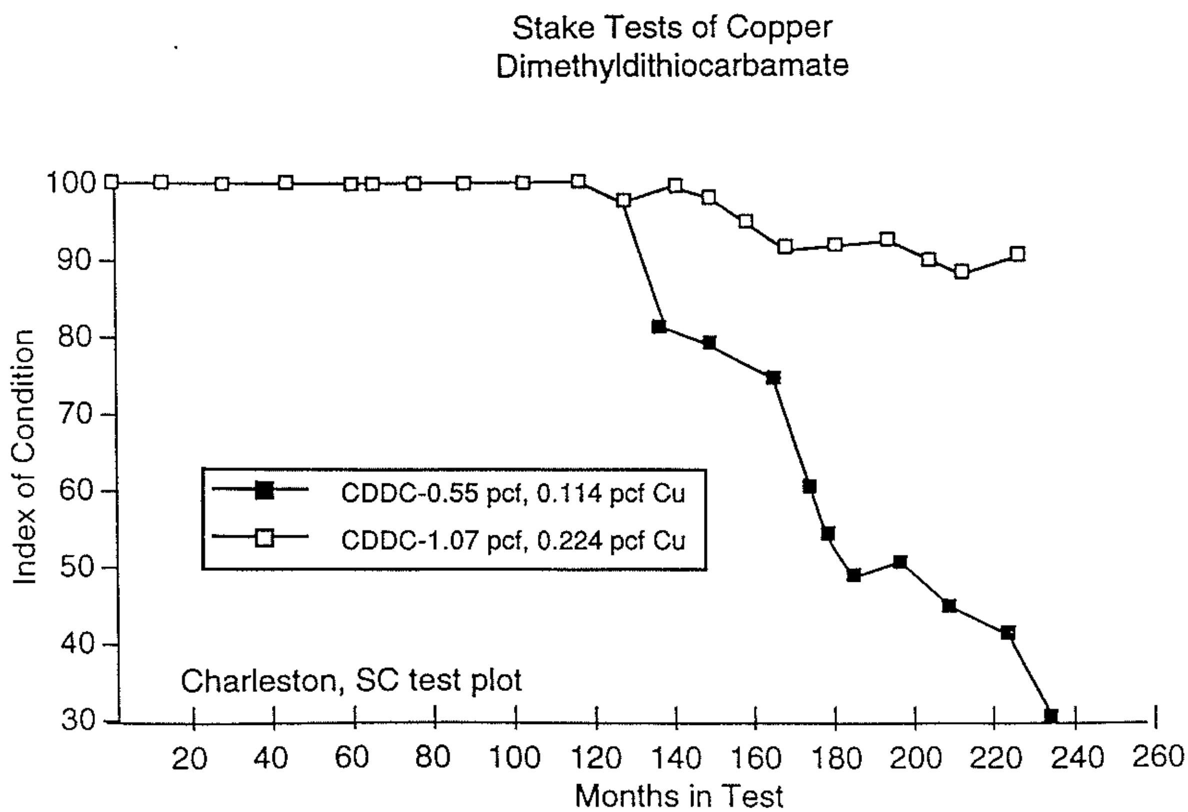


FIGURE 2

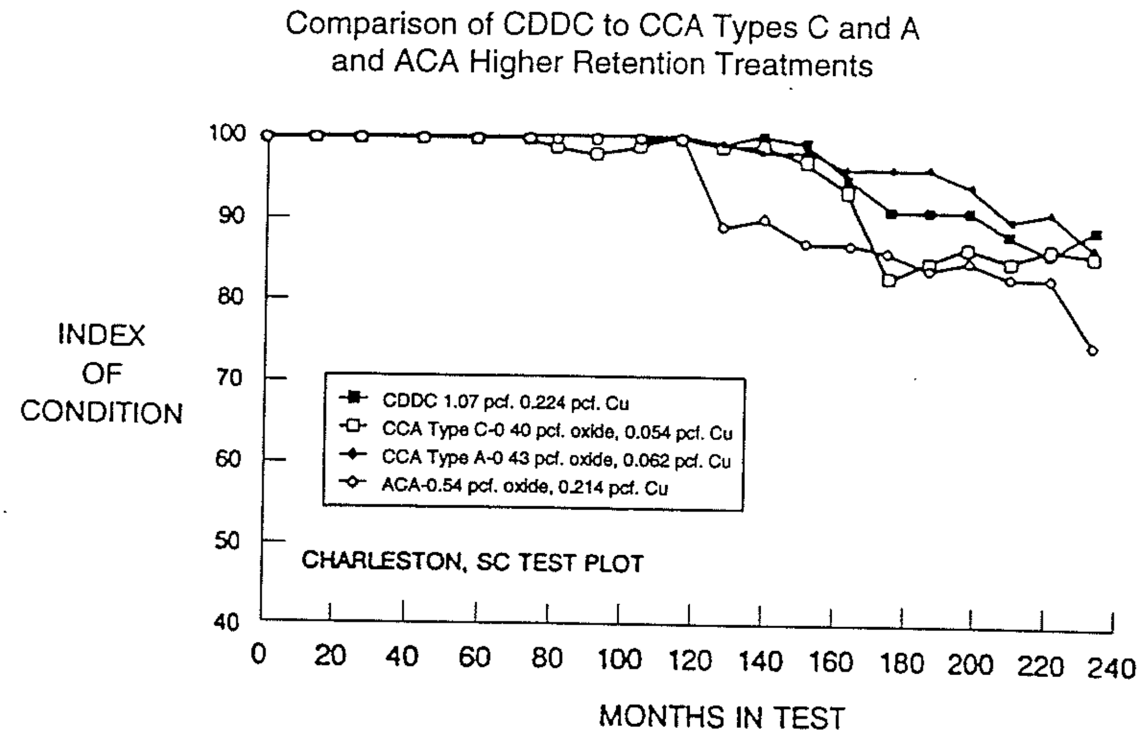


FIGURE 3

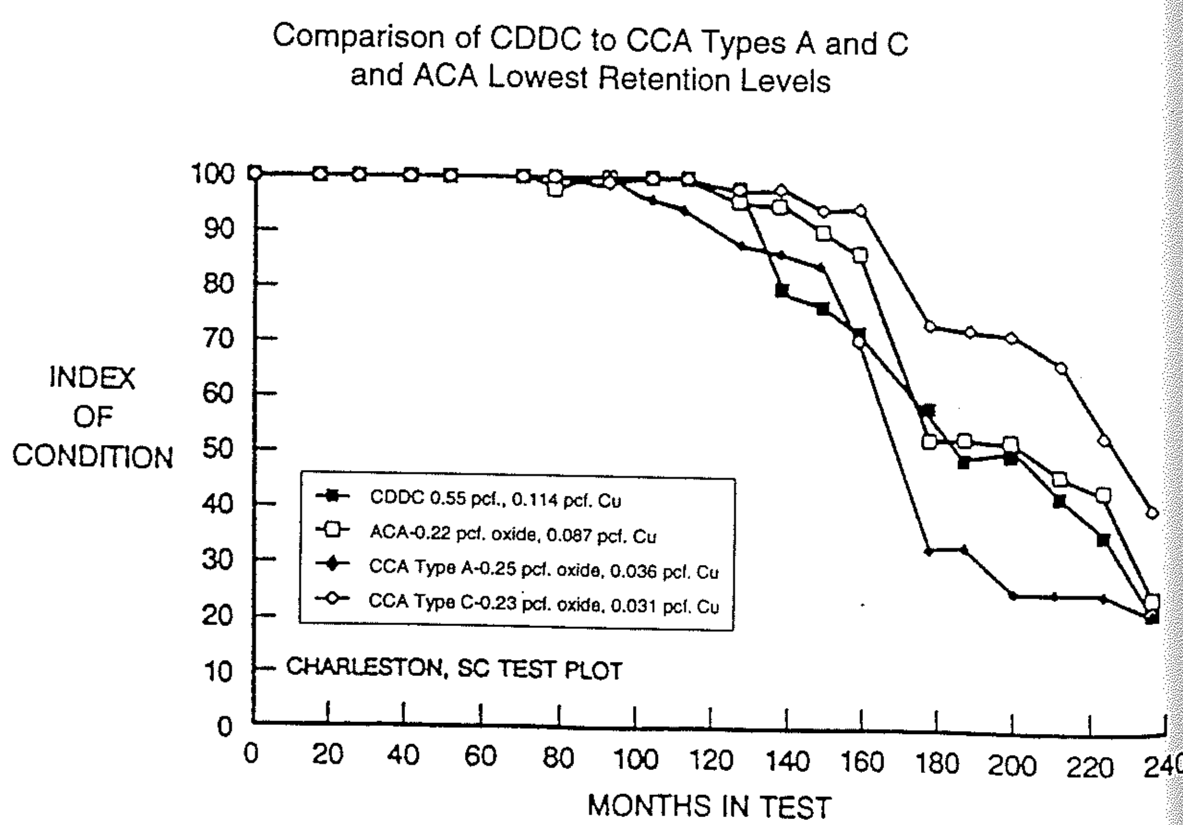


FIGURE 4

Figure 5: AWPA E-11 Water Leaching Test

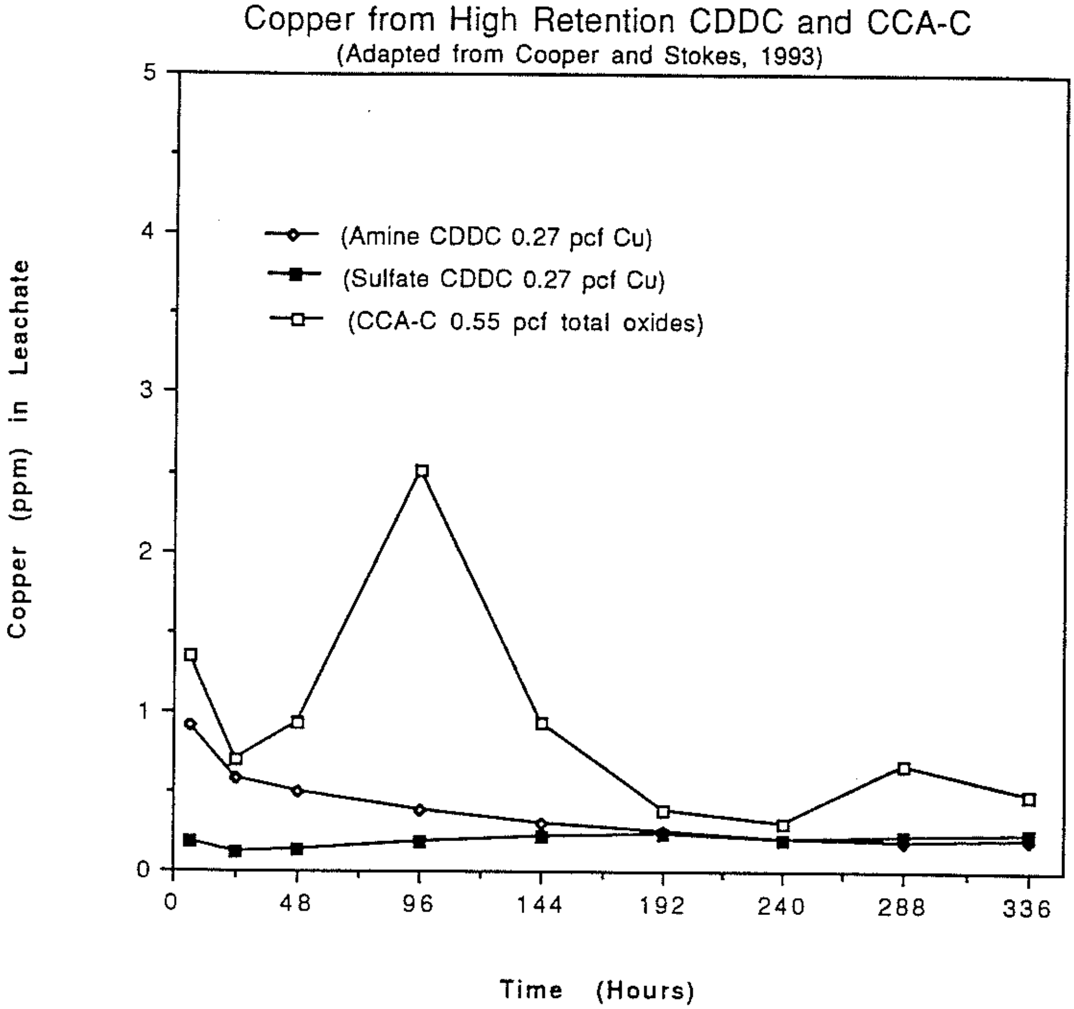


Figure 6:

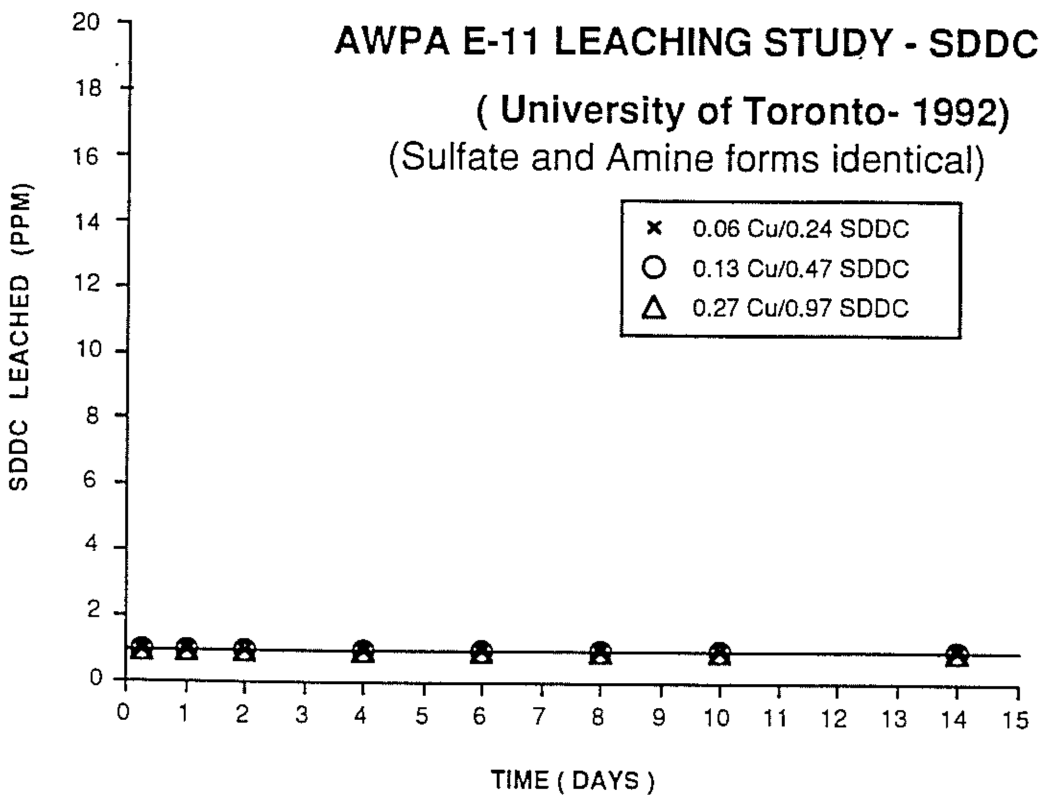
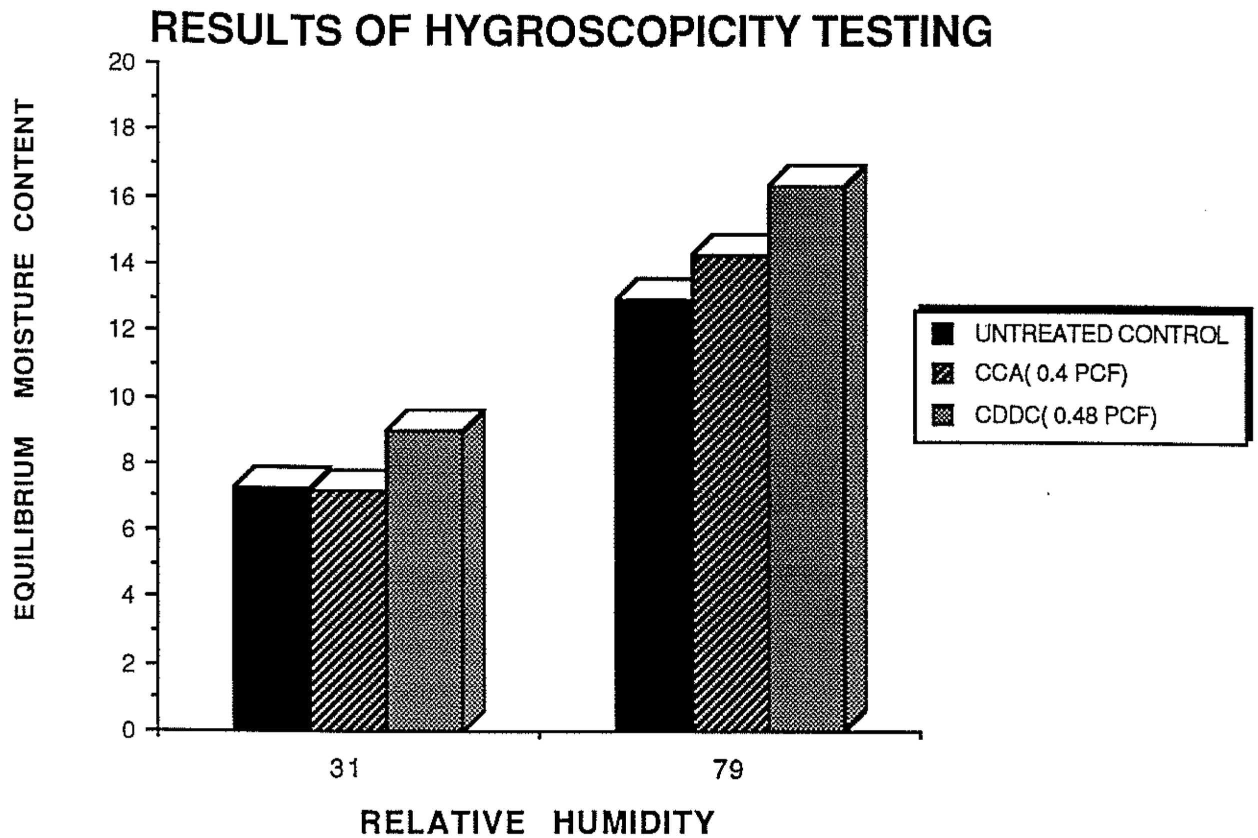

AWPA E-11 LEACHING STUDY - SDDC
(University of Toronto- 1992)
(Sulfate and Amine forms identical)
0.06 Cu/0.24 SDDC
0.13 Cu/0.47 SDDC
0.27 Cu/0.97 SDDC
SDDC LEACHED (PPM)
20
18
16
14
12
10
8
6
4
2
0
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
TIME (DAYS)

Figure 7.



RESULTS OF HYGROSCOPICITY TESTING
EQUILIBRIUM MOISTURE CONTENT
20
18
16
14
12
10
8
6
4
2
0
31
79
RELATIVE HUMIDITY
UNTREATED CONTROL
CCA(0.4 PCF)
CDDC(0.48 PCF)