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SYNERGISTIC WOOD PRESERVATIVES FOR REPLACEMENT OF CCA

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NOTICE

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FOREWORD

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E. Timothy Oppelt, Director
National Risk Management Research Laboratory

ABSTRACT

The objective of this project was to evaluate the potential synergistic combinations of environmentally-safe biocides as wood preservatives. These wood preservatives could be potential replacements for the heavy-metal based CCA.

Didecyldimethylammonium chloride [DDAC] was combined with either chlorothalonil [CTN], tribromophenol [TBP] or sodium omadine [NaO] to provide the synergistic mixtures. A total of five systems were examined; one oil-borne [DDAC:CTN] and four water-borne [oil-in-water emulsions] mixtures, including DDAC:NaO with a water repellant. Wood treated with these preservatives was evaluated in both soil contact and above-ground exposures, with CCA and pentachlorophenol (penta) treated wood used as positive controls. The treated wood was evaluated for both biocide efficacy and depletion. Because of project deadlines, the outdoor exposure time was limited to two- to three-years exposure, which is insufficient to fully evaluate the efficacy of most systems.

The water-borne DDAC:TBP and DDAC:NaO formulations performed poorly in the field tests and, consequently, are not viable wood preservative systems. However, the addition of a water repellent to the DDAC:NaO system greatly improve the performance in above-ground tests, suggesting that this may be a good preservative for this application.

The oil-borne DDAC:CTN formulation is performing very well and may be a viable wood preservative system. The water-borne DDAC:CTN formulation is performing moderately well at this time but appears to suffer from excessive CTN leaching; this deficiency probably can be corrected with a modified formulation.

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CONTENTS

Appendices

BIOCIDE AND FORMULATION ABBREVIATIONS

Abbreviation	Full Name	Source
CCA	Chromated Copper Arsenate	Hickson Corporation
CTN	Chlorothalonil	ISK Biosciences
DDAC	Didecyldimethylammonium chloride	Lonza Company
KB-3	Ketone Still Bottoms (Biocide Carrier/Solvent)	Eastman Chemical Co.
NaO	Sodium Omadine	Olin Chemical Corporation
PABA	Mixture of: Palmitic Acid, Butyl Amine and Butyl Carbitol	Water-borne water repellent formulated at the Forest Products Laboratory, Mississippi State University
Penta	Pentachlorophenol	Vulcan Chemicals
TBP	Tribromophenol	Aldrich Chemical Company

SUMMARY OF PRESERVATIVE SYSTEMS/TESTS EXAMINED

Preservative System	Tests[1]					
	FC	FCD	FS	FSD	AG	AGD
Oil-borne DDAC:CTN	X	X	X	X		
Water-borne DDAC:TBP	X	X	X	X	X	X
Water-borne DDAC:CTN	X	X	X	X	X	X
Water-borne DDAC:NaO					X	X
Water-borne DDAC:NaO:PABA					X	X
Positive Controls						
Water-borne CCA	X	X	X	X	X	
Oil-borne Penta	X	X	X	X		

[1] FC = Fungus Cellar Exposure
FCD = Fungus Cellar Depletion
FS = Field Stake Exposure
FSD = Field Stake Depletion
AG = Above-ground Exposure
AGD = Above-ground Depletion

The field exposure and depletion tests were conducted at the Saucier, MS and Starkville (Dorman Lake), MS sites. The fungus cellar exposure and depletion tests were run using soil beds made with soil from Saucier, MS and Starkville (Dorman Lake), MS. Above-ground exposure and depletion tests were run at Saucier, MS and Hilo, HI.

1

INTRODUCTION: IS THERE A NEED TO DEVELOP A NEW WOOD PRESERVATIVE?

Wood, a natural product obtained from trees, is extensively used in residential construction, utility poles, railroad ties, decking, etc. As a natural organic material wood is degraded by many organisms, principally fungi and insects (Preston 1993). Consequently, in certain U.S. applications (ground contact or above-ground applications where the wood is wetted frequently) wood should be treated with biocides to protect it against wood-destroying organisms. The three major wood preservative systems currently used are the oil-borne, organic pentachlorophenol and creosote systems and the water-borne, inorganic chromated copper arsenic (CCA) preservative. Most of the treated wood products in the U.S., about 76%, are treated with CCA (Mickelwright 1992). Furthermore, CCA is the principle preservative used in residential construction (Preston 1993) while pentachlorophenol and creosote are mainly used in non-residential applications. Over 49.3 million lbs. of arsenic pentoxide and 68.2 million lbs. of chromium trioxide are consumed each year in formulating CCA (Mickelwright 1992).

Extensive testing and use has shown CCA to be highly effective at protecting wood against a variety of fungi and termites. CCA is also low-cost, water-borne, and has good weathering and leach-resistant properties. Since CCA is water-borne and thus has no petroleum odor or "oily" surface and is very cost effective, it is extensively used in residential applications such as home decks. Thus, CCA is a successful product which enjoys widespread consumer acceptance and market share. However, the presence of the perceived environmental hazards of chromium and arsenate will probably limit the use of CCA in the future. Indeed, the use of CCA-treated lumber has already been greatly reduced in the Hawaiian Islands and use of CCA in above-ground applications has been banned in Denmark, Germany, Sweden, and other countries. Also, while current U.S. regulations permit disposal of CCA-treated lumber by landfill burial, it is expected that discarding treated lumber will become more expensive and onerous in the future (Preston 1993; FPS Proceedings 1995). Consequently, a need exists for developing alternative environmentally-benign wood preservative(s), especially for use in residential applications. Creosote and pentachlorophenol will probably continue to be used for a long time in non-residential applications such as telephone poles, railroad ties, bridge pilings, etc.

In the intermediate term CCA replacements may be based on copper:organic biocide mixtures (Preston 1993; Nicholas and Schultz 1995). Wood products treated with copper:organic mixtures of ammoniacal copper quat (ACQ) and copper dimethyldithiocarbamate (CDDC) (Chen 1994; Nicholas and Schultz 1995) are already commercially available. Other copper-based systems such as copper citrate, copper:Na Omadine and copper azole have also been developed. However, toxicological concerns associated with copper will probably limit the long-term application of these "second-generation" wood preservatives in North America (Preston 1993). Consequently, it has been suggested (Preston 1993) that "third-generation" wood preservatives will be totally organic and may consist of combinations of two or more biocides to minimize cost and assure broad efficiency against the wide variety of wood-destroying organisms (Schultz and Nicholas 1995).

This study involved examining biocides which might be suitable CCA replacements. Since copper:organic mixtures are already commercially available - and also because of possible future restrictions on copper due to toxicological concerns - only organic [nonmetallic] biocide combinations were studied. The relatively low-cost biocide didecyldimethylammonium chloride [DDAC] (Walker 1995; Nicholas and Schultz 1995) was combined with a second organic biocide (Chlorothalonil [CTN], tribromophenol [TBP], or sodium omadine [NaO]), with these binary combinations selected since they may be synergistic (Schultz and Nicholas 1995). The DDAC:NaO system was examined both with and without a co-added water repellant. Due to economic and other advantages of water-borne formulations for treating lumber, especially in above-ground residential applications which is the major market for CCA-treated wood, most of the wood samples were treated using water-based (emulsion) formulations. One oil-borne system (DDAC:CTN), suitable for use in ground-contact applications, was also examined. Data collected included emulsion formulation studies, leaching under both laboratory and outdoor exposure conditions, and efficiency testing against wood-destroying organisms in both laboratory (principally fungal cellar) and actual field (ground-contact and/or above-ground) exposure conditions. For comparison, the positive controls were CCA- and/or Penta-treated samples.

2

PROBLEMS WITH DEVELOPING A NEW WOOD PRESERVATIVE

The purpose of this brief section is to introduce readers unfamiliar with wood preservation with the problems of developing a replacement for CCA. These challenges include costs, formulation of a water-borne system, need for the biocide(s) to be active against a wide-variety of fungi and insects and remain effective for a long period, and the long development time necessary.

Finding a biocide which protects wood is not difficult; developing a cost-effective preservative is. Essentially all potential wood preservatives (Nicholas and Schultz 1995) are more expensive than commercial biocides used today, with CCA selling for about $1.30/lb. Both the biocide cost ($/lb) and retention level required (pounds of biocide per cubic foot of wood [pcf]) will affect the final price of treated lumber/wood. In this study mixtures were selected which were believed synergistic, since this would permit lower biocide retentions and, thus, the costs would be reduced (Schultz and Nicholas 1995). A further consideration in the selection of replacement preservatives in the past decade is that the biocide(s) must be relatively environmentally benign.

Essentially all organic biocides - which this study involved - are soluble in one or more organic [oil] solvents, and thus formulation of an oil-borne system is relatively easy. However, the relatively high cost of an oil solvent as compared to water, the problems in formulating a consumer-acceptable oil-borne system for residential use such as decking, and other considerations suggest that a wood preservative used predominately for residential construction should be water-borne. A few organic biocides such as DDAC are water soluble (Nicholas and Schultz 1995), and we concentrated on developing oil-in-water emulsion formulation systems for the other biocides. Some organic compounds are difficult to emulsify, however, and potential problems with emulsions might include poor penetration and subsequent leaching while in service.

A wide variety of wood-destroying organisms exist and, unfortunately, most biocides have weak activity against one or more types of organisms. This study employed biocide combinations since a weakness of one biocide against a particular class of organisms might be offset by the second biocide (Schultz and Nicholas 1995).

A large number of biocides can control organisms in the short term, but all organic biocides are subject to chemical, light and/or microorganism degradation over time. Furthermore, biocides can diffuse [leach] out of the wood during exposure. A successful preservative must remain in the wood product at a minimal level for an extended period of time.

Finally, treated wood products are expected to have a long service life and early failures can prove expensive in terms of product liability. Wood treating companies thus have a conservative outlook and require extensive field exposure testing of wood samples treated to different retentions and installed at multiple outdoor sites for 10 or so years. Consequently, commercial acceptance of a wood preservative requires many years. A good example of this is CCA, which was not fully commercialized until about 30 years after its development.

3

EXPERIMENTAL PROCEDURES

3.1 WOOD

The wood used for all wood-containing tests was kiln-dried southern yellow pine (SYP) sapwood (*Pinus spp.*). Defect-free, kiln dried boards were obtained from a local sawmill and machined to the desired size.

3.2 WOOD TREATMENT

Samples were treated by the full-cell method in a pressure treating cylinder. The process consisted of an initial vacuum cycle (27 in. Hg) for 30 minutes followed by adding the preservative formulation to a tray holding the wood samples in the treating cylinder while maintaining the vacuum and then the impregnation of biocides into the wood by a pressure cycle (150 psig for 60 minutes). Samples were weighed both before and after treatment to determine biocide retention in pounds [of biocide] per cubic foot [of wood] (pcf). After treating and weighing the samples were air-dried to remove the volatile solvent(s).

3.3 BIOCIDE EFFICACY AND DEPLETION TESTS

3.3.1 Agar Plate

***AWPA Test Name*:** No standard method available.

Brief Description: This test is used for an initial rapid determination, under laboratory conditions, of the relative activity of a biocide against one or more fungi. The agar medium consisted of 1.5% agar, 2.0% malt extract and 0.2% yeast extract. The biocides were dissolved in 1 ml of acetone and added to the hot autoclaved agar medium while stirring. Controls consisted of agar containing 1 ml of acetone. After the agar had cooled, a 5-mm agar disc with an actively growing fungus was added to the center of the plate and the plate was then incubated at 28°C for four to six days. The radial diameter of the fungal mycelium was measured and the growth relative to the solvent control determined (Archer et al. 1995). Four fungi were examined, two white-rot (*I. lacteus* and *T. versicolor*) and two brown-rot (*G. trabeum* and *P. placenta*) fungi, at levels of 1, 2, 5, 10, 25, 75 and 150 ppm biocide levels with five replicates per treatment level. Since the PI's have already conducted an extensive survey of biocides for synergistic action, and since most of the possible combinations have already been studied, only a few combinations were examined.

Sample Size: No wood was used in this test.

3.3.2 Leachability

AWPA Test Name: Standard Method of Determining the Leachability of Wood Preservatives; AWPA Standard E11-97.

Brief Description: This test is used to determine if a biocide will diffuse [deplete] from treated wood samples which are immersed in water over a relatively short period. Blocks of wood are vacuum impregnated with a particular formulation and then dried. After conditioning, the blocks are impregnated with water and kept in a beaker filled with water for 14 days, with the water being changed at periodic intervals. The relative depletion was determined by comparing the biocide retention of leached versus unleached matched blocks.

Sample Size: 19 mm cubes

3.3.3 Fungus Cellar (Soft-rot) Exposure

AWPA Test Name: Standard Method of Evaluating Wood Preservatives in a Soil Bed, AWPA Standard E14-94 (Modified).

Brief Description: This test was used to determine the efficacy of wood samples exposed to soft-rot fungi with sets treated to various biocide retentions. Test specimens, treated with a particular formulation and retention, were positioned vertically in a soil bed maintained at a moisture content of approximately 100% of the soil-water holding capacity to promote soft-rot fungi and minimize basidiomycete activity (Nicholas and Archer 1995). The fungus cellar beds were maintained at a temperature of about 80°F and relative humidity of 90%. Stakes were removed periodically, water saturated, and the bending strength or stiffness (maximum load required to deflect [bend] the 3 mm dimension by 2 mm) determined. The AWPA test method has a visual inspection rating system, rather then a strength measurement, to determine extent of decay which is a deviation from the standard. The results are reported as % strength loss relative to the initial strength prior to exposure. Beds were made with soil obtained from the Starkville (Dorman Lake), MS and Saucier, MS sites, with soil from these sites chosen since these sites were used for the ground contact exposure and depletion tests described below.

Sample Size and Number: Four wood slats measuring 3 mm x 19 mm x 950 mm (t x r x l) [tangential x radial x longitudinal] were pressure treated as described above. After drying, these long pieces were cut into 6 stakelets, each 3 mm x 19 mm x 150 mm (t x r x l), with 3 samples from each board put into the Saucier soil and 3 into the Dorman Lake soil, to give a total of 12 sample stakelets for each soil type (four boards, 3 samples from each board for each soil type).

Treatments Studied: Oil-borne DDAC:CTN; water-borne DDAC:TBP; and water-borne DDAC:CTN formulations were used. Negative controls were untreated and solvent-treated samples, and positive controls were the commercial preservatives water-borne CCA and oil-borne penta.

3.3.4 Fungus Cellar Depletion

AWPA Test Name: No standard method available.

Brief Description: This test was used to determine biocide depletion from wood samples exposed to unsterile, wet soil [the fungal soft-rot beds above]. Test specimens were treated with selected formulations. After air drying, a 100-mm section was cut from the end of each test specimen and used to determine the initial (unexposed) biocide retention. Test specimens were then placed vertically in the soil beds described above, with the beds containing either Saucier or Dorman Lake soils. Samples were removed after 12 weeks, and a 12 mm segment removed from the bottom end of the sample and discarded. Following this, a 50 mm sample was cut off the bottom of the stakelet and chipped, ground, and analyzed along with the end-matched unexposed section. The remaining test sample was then placed back into the soil bed and left for an additional 24 weeks (36-weeks total exposure), at which time the above analysis procedure was repeated. Depletion was reported as percent biocide loss relative to the unexposed end section.

Sample Size and Number: Test specimens measuring 5 mm x 19 mm x 250 mm (t x r x l) were treated, air-dried, then cut into 5 mm x 19 mm x 154 mm (t x r x l) specimens. A total of 24 test specimens were treated for each retention level. The specimens were then divided into two groups for exposure in the Dorman Lake and Saucier soils.

Treatments Studied: Oil-borne DDAC:CTN; water-borne DDAC:TBP; and water-borne DDAC:CTN formulations were used. The positive control was commercial water-borne CCA. [One set of 19 mm x 19 mm x 150 mm (r x t x l), treated with four different water-borne emulsion formulations of DDAC:CTN, was also tested for extent of leaching by a 12-week exposure in the fungus cellar test; the positive control was an oil-borne DDAC:CTN formulation].

3.3.5 Field Stake (Ground Contact) Exposure

AWPA Test Name: Standard Method of Evaluating Wood Preservatives by Field Tests with Stakes, AWPA Standard E7-93.

Brief Description: This method determines the efficacy of biocides used to treat wood exposed to outdoor, ground-contact exposure. Several different retentions of the biocides were used so that the effective level required to inhibit wood decay fungi and termites could be determined. Wood stakes were impregnated with an appropriate series of retentions of the biocide, then air-dried and installed randomly at the field exposure site. The stakes were removed during each yearly inspection, cleaned and visually inspected for fungal and termite damage. Separate decay and termite ratings, based on a semi-log system, are given which are specified by the AWPA method above: [10 rating - sound to trace of degradation; 9 rating - trace to 3% degrade; 8 rating - 3 to 10% degrade; 7 rating - 10 to 30% degrade; 6 rating - 30 to 50% degrade; 4 rating - 50 to 75% degrade; and a 0 rating - failure]. Following inspection the stakes were returned to the original position at groundline mark. The average decay and termite rating for each treatment/retention was reported. Test sites used were Starkville (Dorman Lake), MS and Saucier, MS. Dorman Lake is located in Northeast Mississippi near Mississippi State University, and has a heavy clay soil. The Saucier test plot is located in the Harrison National Forest near the town of Saucier, and has a sandy loam soil. Since this site is near the Gulf Coast, it has a relatively mild winter and wet summer.

Sample Size and Number: Wood sticks measuring 3/4" x 3/4" x 44" (t x r x l) were treated, air-dried, and then a 6" center was cut from each stake and stored for possible future analysis for depletion measurement. Of the remaining two end pieces, 3/4" x 3/4" x 18" size, one sample was installed at Dorman Lake and the other sample at Saucier. The number of replicates per treatment/retention was 15 at each site.

Treatments Studied: Oil-borne DDAC:CTN; water-borne DDAC:TBP; and water-borne DDAC:CTN formulations were used. Negative controls were untreated and solvent-treated samples, and positive controls were water-borne CCA and oil-borne penta.

3.3.6 Field Stake Depletion

***AWPA Test Name*:** Part 10 of AWPA Standard E7-93 described above.

Brief Description: This test determines biocide depletion from wood treated with a specified retention of the biocide after ground contact exposure. Stakes were treated, dried, cut and installed as described for the field exposure samples above. After exposure for a specified time, five (5) of the 15 replicates [leaving 10 stakes for two (2) more depletion analyses] were removed from each site (Dorman Lake and Saucier). The samples were cleaned and a 25 mm section removed for analysis. The ground wood from all five depletion samples were combined and analyzed using the appropriate procedure described below. The biocide retention, relative to the biocide retention in the stored, unexposed 6" center cut, is reported.

Sample Size and Number: Fifteen samples, treated to a specified retention and of the size described above, were randomly installed with the exposure stakes described above at each site. Five samples were removed for analysis at each exposure period.

Treatments Studied: Oil-borne DDAC:CTN; water-borne DDAC:TBP; and water-borne DDAC:CTN formulations were used. The positive control was CCA.

3.3.7 Above-ground (L-joint) Exposure

AWPA Test Name: Standard Field Test for the Evaluation of Wood Preservatives to be used in Non-soil Contact, AWPA Standard E9-97.

Brief Description: This test method is designed to determine the efficacy of wood preservatives used in outdoor above-ground applications, with several different biocide retentions used for each biocide studied. Wood samples were cut with a mortise joint on one end and a tenon joint on the other end, treated with a specific biocide formulation and then dried. A 2" piece was cut from the center of the wood and stored for possible later depletion studies, then the two outside pieces were joined to form an L-shaped unit. These units were then installed on an above-ground rack set up at the outdoor testing sites. Saucier, MS and Hilo, HI were chosen because their weather conditions [warm winters and high rainfall] result in relatively rapid decay. These samples were pulled annually, and the joint, both the mortise and tenon, inspected for fungal attack and degradation. The rating system described above for the ground-contact samples was used, where a "10" rating indicates no attack, a "0" rating complete failure, etc. The test samples can be either painted or not painted prior to outdoor exposure. In this study, the samples treated with water-soluble formulations were painted while samples pressure-treated with oil-in-water emulsion or with water-repellant formulations were not painted.

Sample Size and Number: The initial machined size was 1 1/2" x 1 1/2" x 18" (r x t x l). After treatment and drying, the center 2" was cut out and the L-joint assembled. The number of replicates per biocide/retention was 20, with 10 samples installed at Saucier and 10 at Hilo.

Treatments Studied: Water-borne DDAC:NaO, painted; water-borne DDAC:TBP, unpainted; water-borne DDAC:CTN, unpainted; and water-borne DDAC:NaO:PABA, unpainted treatments were used. (PABA is a water-borne water repellent developed at the Forest Products Lab, Mississippi State University, in which the active components are **p**almitic **a**cid and **b**utyl **a**mine, with butyl carbitol added for water solubility). The negative controls consisted of untreated and solvent-treated samples, and the positive control was water-borne CCA.

3.3.8 Above-ground (L-joint) Depletion

AWPA Test Name: Based on Standard E9-97 described above.

Brief Description: The purpose of this test is to obtain depletion data for treated wood samples exposed to actual field conditions in an above-ground test. Wood samples are prepared and treated as described above. The samples were installed at the same time as the exposure samples treated with the same biocide formulation. After a specified exposure period five (5) samples per site (Saucier, MS and Hilo, HI) were pulled. Biocide retention in the matched, unexposed 2" center- cut sample was compared to the biocide retention in the exposed joint. One problem encountered in this test was that the tenon and mortise joint have different dimensions than the center cut, and thus biocide penetration affected the results. To partially offset this unanticipated problem, biocide levels in the outer 6 mm of the center cut were determined. The outer 6 mm of the tenon joint was then cut off and discarded, and the next 12 mm cut off, ground, and the biocide level measured with this value compared to the biocide retention in the unexposed matched wood sample.

Sample Size and Number: The same size as described above was used. The number of replicates at each site was 10, with five (5) samples pulled at one time at each site.

Treatments Studied: Water-borne DDAC:NaO; water-borne DDAC:CTN; water-borne DDAC:TBP; and water-borne DDAC:NaO:PABA formulations were used.

3.4 FORMULATIONS

3.4.1 Initial Studies

Initial experiments to develop oil-in-water emulsion systems consisted of determining: the ease and ability to form an emulsion using selected additive(s); emulsion stability; penetration uniformity as measured by treatment of wood samples (end-coated with a water barrier) then analysis of biocide levels in inner versus outer sections of the treated wood; and biocide leaching by immersion of treated, dried wood in water for several days.

3.4.2 Oil-borne DDAC:CTN

Formulation: The biocides were DDAC and/or CTN, which were dissolved in a mixture consisting of 25% (by volume) of KB3:diesel fuel [9:1] and 75% toluene.

Concentrations:

- **Ground contact and fungus cellar efficacy stakes** DDAC at 0.50, 0.75, 1.00, and 1.50% [by weight]; CTN at 0.25, 0.50, and 1.00%; DDAC:CTN (3:1) at 0.252, 0.50, 0.667, 1.00 and 1.33%; DDAC:CTN (5:1) at 0.24, 0.48, 0.75, 0.90 and 1.20% were used. The positive control, CCA-type C, was treated at 0.37, 0.63 and 1.00%, and the positive control, penta, (treated with the toluene/diesel/KB3 mixture described above), was treated at 0.50, 1.0 and 1.50%. [Note: the highest level of CCA, 1.00%, was chosen in order to obtain an approximate retention of 0.40 pcf, the level specified for CCA in ground-contact use with SYP lumber per AWPA Standard C2-97. The highest level of penta, 1.50%, was chosen in order to obtain a retention of about 0.60 pcf, the level specified for penta in SYP poles per AWPA Standard C3-97.
- **Ground contact and fungus cellar depletion stakes** CTN at 0.25%; DDAC:CTN (3:1) at 1.00%; DDAC:CTN (5:1) at 0.90%; and CCA at 1.00, 0.63, and 0.37% were used.

Note: Actual formulations for all five systems examined in this study are listed in Appendix A.

3.4.3 DDAC:TBP

Formulation: The biocides were DDAC and/or TBP, which were formulated using an oil-in-water emulsion using the surfactant Tween 40, N-butanol and water. Since each system had different concentrations of DDAC and TBP, the concentration of Tween 40 and N-butanol varied accordingly. Appendix A lists the components and amounts for each formulation. DDAC was treated using both water and the emulsion system, so that the effect, if any, of the Tween 40 and N-butanol on efficacy could be measured.

Concentrations:

- **Ground contact and fungus cellar efficacy stakes -** DDAC at 0.50, 0.75, 1.00 and 1.50% [both water alone and with the emulsion system]; TBP at 0.25 and 0.50%; DDAC:TBP (1:1) at 0.50, 0.70, 1.00, 1.50, and 2.00%; DDAC:TBP (3:1) at 0.50, 0.667, 1.00, 1.33 and 2.00%. The positive control, CCA, was treated at 0.37, 0.63 and 1.00%.
- **Ground contact and fungus cellar depletion stakes -** DDAC with Tween 40 and N-butanol at 0.75%; DDAC:TBP (1:1) at 1.00%; and DDAC:TBP (1:1) at 1.00% were used. The positive control, CCA, was treated at 0.37, 0.63 and 1.00%.
- **Above-ground L-joint efficacy samples -** DDAC [both in water and with Tween 40 and N-butanol] at 0.25, 0.50, 0.75 and 1.00%; DDAC:TBP (1:1) at 0.25, 0.50, 0.70 and 1.00%; DDAC:TBP (3:1) at 0.252, 0.50, 0.667, and 1.00% were used. The CCA positive controls were treated at 0.19, 0.37 and 0.63%. [Note: The highest level of CCA, 0.63%, was chosen in order to obtain a retention of 0.25 pcf, the level specified for above-ground SYP lumber in AWPA Standard C2-97].
- **Above-ground (L-joint) depletion -** DDAC (with Tween 40 and N-butanol) at 0.50%; DDAC:TBP (1:1) at 0.70%; and DDAC:TBP (3:1) at 0.667% were used.

3.4.4 Water-borne DDAC:CTN

Formulation: The biocides were DDAC and CTN, formulated using an oil-in-water emulsion with xylene. DDAC, which is also a surfactant, is a necessary component of this emulsion and therefore CTN alone could not be prepared. Appendix A gives the exact formulation for each treatment, with the amount of xylene dependant on the biocide(s) concentration(s).

Concentrations:

- **Ground contact and fungus cellar efficacy stakes -** DDAC at 0.50, 0.75, 1.00 and 1.50%; DDAC:CTN (3:1) at 0.252, 0.50, 0.667, 1.00 and 1.33%; DDAC:CTN (5:1) at 0.24, 0.48, 0.75, 0.90 and 1.20% were used. The water-borne positive control CCA was treated at 0.37, 0.63 and 1.00%, and oil-borne penta [toluene/KB3/Diesel] was treated at 0.50, 1.0 and 1.50%.

- **Ground contact and fungus cellar depletion samples -** DDAC:CTN (3:1) at 1.00%; DDAC:CTN (5:1) at 0.90%, and CCA water-borne positive controls treated at 0.19, 0.63 and 1.00% were used.
- **Above-ground L-joint efficacy samples -** DDAC (water/xylene) at 0.25, 0.50, 0.75 and 1.00%; DDAC:CTN (3:1) at 0.124, 0.252, 0.50, 0.667 and 1.00%; DDAC:CTN (5:1) at 0.126, 0.240, 0.48, 0.75 and 0.90% were used. [Note: The DDAC:TBP above-ground L-joint samples were installed at both locations at the same time as these DDAC:CTN water-borne samples, and thus the CCA positive controls for the DDAC:TBP sample set were used for both treatments].
- **Above-ground L-joint depletion samples -** DDAC:CTN (3:1) at 0.50%; DDAC:CTN (5:1) at 0.48% were used.

3.4.5 Water-borne DDAC:NaO, Above-ground L-joint Samples Only

Formulations: DDAC and/or NaO were/was dissolved in water. Since both components are water soluble and would be presumably quickly leached out in soil contact, no ground-contact field stakes or fungus cellar samples were tested.

Concentrations:
- **Above-ground L-joint Efficacy Samples -** DDAC at 0.25, 0.50, 0.75 and 1.00%; NaO at 0.05; 0.10; 0.20 and 0.40%; DDAC:NaO (4:1) at 0.12, 0.25, 0.50, 0.75 and 1.00%; DDAC:NaO (7:1) at 0.17, 0.23, 0.46, 0.69, 0.91% were used. The positive controls were water-borne CCA at 0.19, 0.37 and 0.63%.
- **Above-ground L-joint Depletion Samples -** DDAC at 0.50%; DDAC:NaO (4:1) at 0.50%; DDAC:NaO (7:1) at 0.46% were used.

3.4.6 Water-borne DDAC:NaO:PABA, Above-ground L-joint Samples Only

Formulations: The biocides were DDAC and/or NaO, dissolved in water. The water-borne water repellent, PABA, was co-dissolved with the biocides in all formulations. PABA consisted of 5.0% palmitic acid, 3.0% butyl amine and 3.0% butyl carbitol dissolved in water, with these concentrations based on the final formulation used [with the co-added biocide(s)].

Concentrations:
- **Above-ground L-joint Efficacy Samples -** DDAC at 0.25, 0.50, 0.75 and 1.00%; NaO at 0.05, 0.10, 0.20 and 0.40%; DDAC:NaO (4:1) at 0.12, 0.25, 0.50, 0.75 and 1.00%; DDAC:NaO (7:1) at 0.17, 0.23, 0.46, 0.69 and 0.91% were used. Since these samples were installed at the same time as the DDAC:TBP, the positive controls of the DDAC:TBP were used for this set.
- **Above-ground L-joint Depletion Samples -** DDAC at 0.50%; DDAC:NaO (4:1) at 0.50%; and DDAC:NaO (7:1) at 0.46% were used.

3.5 ANALYSIS METHODS

3.5.1 Treatment Retentions by Weight Gain Following Treatment

Biocide retentions in treated wood are based on the dimensions of the wood prior to treatment, the % active ingredients of the biocide, and the weight gain following treatment (weight of the wood just after pressure treatment - weight of the wood sample just before pressure treatment). From this data, the pounds of biocide(s) per cubic foot of wood (pcf) were calculated for each sample.

3.5.2 Biocide Retentions in Depletion Samples

Wood samples were obtained from the depletion samples and their matched unexposed mates. Both the exposed and unexposed piece cut from one wood sample after treating and drying the wood sample as described in **Section 3.2**, were ground in a Wiley Mill. Generally, unless otherwise noted, the individual replicates were combined into a composite sample. Biocide depletion was calculated as biocide level in the exposed sample relative to biocide level in the matched, unexposed sample.

CCA

AWPA Standard: Standard Method for Analysis of Treated Wood and Treating Solutions by X-Ray Spectroscopy, AWPA Standard A9-97.

Brief Description: This method is a non-destructive procedure for determining the amount of CCA (as the specified oxides of chromium, copper and arsenic) in a given mass of ground wood which has been compacted and mounted in a sample holder prior to irradiation. A bench-top X-ray fluorescence instrument (model 8620), specifically designed for the wood treating industry by ASOMA Instruments, Inc., was used. This instrument has built-in software to calculate the biocide retention, expressed as pcf.

Chlorothalonil

AWPA Standard: Standard Method for Analysis of Treated Wood and Treating Solutions by X-ray Spectroscopy, AWPA Standard A9-97.

Brief Description: The same X-ray fluorescence instrument and method described above for ground wood samples were used.

DDAC

AWPA Standard: Standard for HPLC Method for Didecyldimethylammonium Chloride Determination in Treated Wood, AWPA Standard A16-97.

Brief Description: This method involves overnight extraction of DDAC from the ground wood samples with ethanol using an ultrasonic bath, then analyzing the DDAC concentration using a high performance liquid chromatographic system. The DDAC elution was monitored using indirect UV detection, where a UV-adsorbing compound was put into the solvent system so that the UV detector is continuously detecting a constant signal. When the DDAC or some other compound goes through the detector cell, some of the UV adsorbing compound is excluded and thus the UV signal is reduced. A Spectra Physics SP 8800 HPLC was used, with the Whatman Partisile SCX cation exchange column with 5 μm particle size. Each sample was run in triplicate, with 3 recovery controls [ground wood samples in which a known amount of DDAC had been added] and one blank [solvent control] samples were run for all 36 samples.

TBP

AWPA Standard: No Standard Test Method available.

Brief Description: Ground wood samples were extracted using methanol solvent and an ultrasonic bath, as described above. The samples were then analyzed by HPLC, using a Hewlett Packard HP 1090, with a UV detector set at 280 nm. An Alltech C-18 reversed-phase column was used, with an isocratic solvent system consisting of 80% acetonitrile and 20% water. The water had 1% acetic acid added to prevent peak broadening. Each wood sample was run in triplicate, with three recoveries (ground wood in which a known amount of TBP had been added) and one blank (solvent control) being run per 36 samples.

NaO

AWPA Standard: No Standard Test Method available.

Brief Description: Based on discussions with the manufacturer, Olin Chemical Corporation, extraction of the treated wood followed by HPLC analysis was attempted. Unfortunately, it appears that NaO quickly undergoes an oxidative polymerization and thus the HPLC analysis was unsuccessful. Some samples were submitted for elemental analysis of sulfur (Galbraith Laboratories, Inc, Knoxville, TN). However, the relatively low level of sulfur present in wood treated with NaO and the difficulty in obtaining very precise values limited the usefulness of this method.

4

RESULTS AND DISCUSSION

4.1 AGAR-PLATE SYNERGISM

Biocide mixtures (DDAC plus tetradecylamine, hexadecylamine, Irgastab 2002, and zinc omadine) were examined for possible synergism using the agar plate test with the wood destroying fungi *Trametes versicolor* (ATCC 12679), *Gloeophyllum trabeum* (ATCC 11539), *Postia placenta* (ATCC 11538) and *Chaetomium globosum* (ATCC 6205) using six biocide levels. Each biocide was run alone and in combination with DDAC at 3:1 levels (three parts DDAC to one part of the second biocide). Zinc omadine was found to be insoluble in any solvent, and thus could not be tested. All other biocides were dissolved in toluene.

No combination was shown to be synergistic against at least three of the four fungi examined, and thus further tests were not run.

Prior to this study we had already tested over 60 possible biocide combinations (Schultz and Nicholas, 1995), and no other possible biocide combinations remained untested. Thus, no further work in this area was performed.

4.2 OIL-BORNE DIDECYLDIMETHYLAMMONIUM CHLORIDE/CHLOROTHALONIL (DDAC:CTN)

4.2.1 Soft-rot Test in the Fungus Cellar

A soft-rot test was carried out in the fungus cellar with both the Dorman and Saucier soils, using bending strength as a measure of decay. It is apparent from the data in Table 4.2.1.1 that with regard to soft-rot the Saucier soil is more active than the Dorman soil. Of the treatments evaluated, chlorothalonil and CCA are performing better than the other treatments after 96-weeks exposure but two DDAC:CTN systems are also doing well (Table 4.2.1.1 and Figures 4.2.1.1 and 4.2.1.2). At the 5:1 ratio, the DDAC/CTN formulation is performing better than the 3:1 ratio DDAC/CTN formulation or the straight DDAC formulation. This DDAC/CTN formulation is also performing better than penta, suggesting that it may be a viable commercial formulation. The average result, ranked with the best first, is shown in a Duncan range test for the Dorman (Table 4.2.1.2) and Saucier (Table 4.2.1.3) soils.

4.2.2 Biocide Depletion in the Fungus Cellar

The rate of biocide depletion from treated wood exposed to soil is an important factor affecting the long-term performance. The average depletion of DDAC, CTN, and CCA from the treated wood after 12-weeks exposure to the Dorman and Saucier soils is shown in Table 4.2.2.1 and 36-weeks depletion is given in Table 4.2.2.2. From this data it is apparent that the loss of chlorothalonil is quite high for all three formulations tested. The depletion of DDAC is considerably less and this is probably attributable to its ability to undergo ion exchange reactions with the wood substrate. The depletion of CCA is also fairly low. There do not appear to be any consistent differences in the amount of leaching that occurs in the two types of soil (Figure 4.2.2.1).

4.2.3 Biocide Depletion in the Field Stake Ground Contact Test

After 1-year exposure, the biocide depletion from the field stakes is similar to that found for the fungus cellar leaching test (Table 4.2.3.1). That is, the chlorothalonil shows excessive leaching in comparison with that of DDAC and CCA. The 3-years exposure did not show as great a chlorothalonil loss, perhaps due to the oil carrier migrating down, as per Figures 4.2.3.1 and 4.2.3.2.

4.2.4 Field Ground Contact Decay and Termite Test

The field stake test data for the oil-borne DDAC:CTN treated wood and corresponding controls is shown in Table 4.2.4.1 and Figures 4.2.4.1 and 4.2.4.2. After 3-years exposure all of the treatments are performing satisfactorily at medium and higher retention levels. In view of the relatively high levels of chlorothalonil leaching found in the soil contact leaching tests, the performance of the DDAC:CTN treated wood may suffer in the future. However, additional exposure time will be required before the efficacy of these formulations can be accurately determined. Tables 4.2.4.2 to 4.2.4.5 show the Duncan's range results for field stakes at Dorman and Saucier plots for both decay and termite ratings. The exposure time is insufficient for any statistical differences in the treatments.

4.3 WATER-BORNE DIDECYLDIMETHYLAMMONIUM CHLORIDE:TRIBROMOPHENOL (DDAC:TBP)

4.3.1 Soft-rot Test in the Fungus Cellar

A soft-rot test was carried out with both the Dorman and Saucier soils, using bending strength as a measure of decay. From the 80-week exposure data in Table 4.3.1.1 and Figures 4.3.1.1 and 4.3.1.2, it is apparent that TBP is not effective against the soft-rot fungi. Consequently, the addition of this compound to DDAC does not have any advantages in controlling this particular group of wood decay microorganisms, as can also be observed from the Duncan's Tables (4.3.1.2 and 4.3.1.3). The CCA-treated samples are preforming much better than most of the other samples.

4.3.2 Biocide Depletion in the Fungus Cellar

The data presented in Tables 4.3.2.1 and 4.3.2.2 and Figures 4.3.2.1 and 4.3.2.2 show that excessive leaching of both DDAC and TBP occurred in this soil contact depletion test. Since previous studies indicate lower levels of DDAC depletion when the treated wood is exposed to wet soil, it is probable that the surfactants and possibly other ingredients in these emulsion formulations are responsible for this excess loss. Consequently, additional formulation work will be required before these formulations can be used as treatments for ground contact exposure.

4.3.3 Biocide Depletion in the Field Ground Contact Test

The 1- and 2-years exposure depletion of both DDAC and TBP from the field stakes (Tables 4.3.3.1 and 4.3.3.2 and Figures 4.3.3.1 and 4.3.3.2) is considerably less than that observed for these biocides in the lab leaching test. This difference is at least partially due to the small stakes used in the lab test which accelerates biocide leaching. Despite the reduced depletion in the field test, the amount of TBP lost is still quite high which will ultimately have an impact on the service life of the treated wood.

4.3.4 Field Ground Contact Decay and Termite Tests

Data for the stake tests after two-years exposure are presented in Table 4.3.4.1 and Figures 4.3.4.1 and 4.3.4.2. It is apparent that TBP is not effective against either termites or decay fungi. The stakes treated with the combination of both biocides are performing satisfactorily against decay fungi, but this formulation appears to be less effective against termites. The Duncan's test results are given in Tables 4.3.4.2 to 4.3.4.5, and it is very apparent that even with only 2 years exposure that DDAC:TBP is not very effective.

4.3.5 Biocide Depletion in the Above-ground Decay Test

As expected, lower biocide depletion rates were observed for the above-ground test units in comparison to those found for the soil contact stake tests. In this regard, the data in Table 4.3.5.1 shows very little loss of either biocide after 1-year exposure of the L-joints. However, as mentioned earlier in Section 3.3.8, depletion data for the above-ground samples should all be viewed with caution due to the differences in sample size for the unexposed versus exposed samples.

4.3.6 Above-ground Decay Test

The results of the above-ground decay test are shown in Table 4.3.6.1 and Figures 4.3.6.1 and 4.3.6.2. All of the decay ratings are still very high so additional exposure time will be required to obtain meaningful data, as can be seen from the Duncan's test (Tables 4.3.6.1 and 4.3.6.2).

4.4 WATER-BORNE DIDECYLDIMETHYLAMMONIUM CHLORIDE:CHLOROTHALONIL (DDAC:CTN)

4.4.1 Soft-rot Test in the Fungus Cellar

A soft-rot test was carried out in the fungus cellar using both Dorman and Saucier soils. In general, the DDAC:CTN formulation was slightly less effective against the soft-rot fungi than the CCA and penta controls after 62-weeks exposure (Table 4.4.1.1 and Figures 4.4.1.1 and 4.4.1.2), with the Duncan's results in Tables 4.4.1.2 and 4.4.1.3. Nevertheless, this experimental formulation shows promise in this particular test.

4.4.2 Biocide Depletion in the Fungus Cellar

It is apparent from the data in Tables 4.4.2.1 and 4.4.2.2 and Figures 4.4.2.1 and 4.4.2.2 that the amount of CTN leached from the treated wood is considerably greater than that for CCA. However, the biocide leaching rate decreased sharply after the initial 12-weeks exposure so the long term effect may not be as bad as the initial data indicates. The comparative leachability of DDAC and CTN from several other water-borne formulations were also tested with the data presented in Table 4.4.2.3. This comparative data suggest that it may be possible to develop formulations that are less susceptible to leaching.

4.4.3 Biocide Depletion in the Field Ground Contact Test

The depletion of CTN from the field stakes after 1-year exposure is very high (Table 4.4.3.1) but did not further increase after 2-years exposure (Table 4.4.3.2). The depletion of DDAC from these stakes was somewhat less, but still greater than that found in some of the other formulations. There does not appear to be any major differences in the amount of biocide leaching in the two different soils used in this experiment (Figures 4.4.3.1 and 4.4.3.2). These depletion results are comparable to the depletion observed in the fungus cellar test discussed above (Section 4.4.2.).

4.4.4 Field Ground Contact Decay and Termite Test

Decay and termite ratings for field stakes treated with this formulation along with the CCA controls are presented in Table 4.4.4.1 with the Duncan's results in Tables 4.4.4.2 to 4.4.4.5. With the exception of a few of the lower retentions, all of the treatments are performing satisfactorily. All of the formulations, including CCA, are somewhat less effective against termites (Figures 4.4.4.1 and 4.4.4.2). Several years of additional exposure time will be required before the efficacy of these formulations can be determined.

4.4.5 Biocide Depletion in the Above-ground Test

It is apparent from the data in Table 4.4.5.1 that an excessive amount of both DDAC and CTN has leached from the L-joints after only 1-year exposure which was also observed in the other two tests. This abnormally high preservative loss will undoubtedly have a significant effect on the service life of these treated specimens. The effect of the sample size, however, which was discussed earlier in Section 3.3.8, makes all depletion data from above-ground samples questionable.

4.4.6 Above-ground Decay Tests

At this time all of the L-joints are performing satisfactorily (Table 4.4.6.1), with the Duncan's results in Tables 4.4.6.2 and 4.4.6.3. However, several more years exposure will be required before any definitive conclusions can be made concerning the efficacy of these formulations, since everything but the Hilo-control samples are all 10's.

4.5 WATER-BORNE DIDECYLDIMETHYLAMMONIUM CHLORIDE:SODIUM OMADINE (DDAC:NaO)

4.5.1 Biocide Depletion in the Above-ground Decay Test

It is apparent from the data in Table 4.5.1.1 that there is no loss of DDAC from the L-joints after 1-year exposure. Hence, biocide leaching should be a minor factor in the long term performance of this preservative formulation. The size effect, discussed in Section 3.3.8, makes it difficult to interpret depletion data from the L-joint samples, however.

4.5.2 Above-ground Decay Test

The results are given in Table 4.5.2.1 and Figures 4.5.2.1 and 4.5.2.2. The CCA-treated samples are all showing excellent results. The Hilo site shows more variation, as expected from the warmer and wetter conditions at Hilo as compared to Saucier. It appears that this formulation may not be an acceptable preservative, based on the relatively poor results after only 2.5 years at Hilo, as can be seen from the Duncan's tests (Tables 4.5.2.2 and 4.5.2.3).

4.6 WATER-BORNE DIDECYLDIMETHYL AMMONIUM CHLORIDE:SODIUM OMADINE:WATER REPELLANT (DDAC:NaO:PABA)

4.6.1 Biocide Depletion in the Above-ground Decay Test

Overall, it does not appear that any appreciable amount of DDAC leaches from the L-joints when they are subjected to exterior exposure (Table 4.6.1.1). As noted, one of the retention values shown in the Table is very low but in view of the other data this is not realistic and needs to be re-evaluated. This may be partly due to the size effect discussed in Section 3.3.8.

4.6.2 Above-ground decay test

It is apparent from the data in Table 4.6.2.1 that all of the treated L-joints are totally sound after 2-years exposure. Several years additional exposure time will be required before the long term efficacy of this formulation can be determined. At this time, however, it appears that this formulation is performing as well as the CCA-treated samples <u>not</u> treated with the PABA water repellant (4.5.2). The Duncan's data is given in Tables 4.6.2.2 and 4.6.2.3.

5

FUTURE WORK

The fungal cellar samples have all been pulled and no further strength loss data will be determined. However, we will continue to conduct yearly inspections on the field ground-contact and above-ground samples even though this project has officially ended. These inspections will continue until a particular formulation has been shown to be much worse then the positive controls (CCA and/or penta), or until 7-years exposure data has been collected which shows that the particular formulation is performing adequately.

While the outdoor exposure time is limited to two or three years so far, it appears that two of the four water-borne formulations examined are preforming poorly: DDAC:TBP and the DDAC:NaO system used only for above-ground samples. The DDAC:TBP-treated stakes are giving very poor results after only 2-years exposure, probably due to high TBP depletions. The halogenated phenol, which would likely face poor user acceptance, further makes this system doubtful as a commercial wood preservative. We also have concerns about the DDAC:NaO above-ground system, due to the relatively poor decay ratings obtained at the Hilo site.

In contrast to the poor results discussed above, two systems appear - so far - to give results which are approximately comparable to the commercial preservatives CCA and/or penta. These are the oil-borne DDAC:CTN and the DDAC:NaO:PABA (water repellant) systems. Further exposure time is needed to verify the initial positive results. Additional time will also determine the effectiveness of the water-borne DDAC:CTN system. Further formulation work on this particular system, directed towards minimizing the relatively high depletion of CTN, may be necessary, however.

6

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APPENDIX A

TREATMENT FORMULATIONS

Appendix 4.2. Treatment Information the Oil-Borne DDAC:Chlorothalonil Formulations.

Component	Manufacturer	Lot No.	% a.i.
DDAC	Lonza	F4226189	80
Chlorothalonil	ISK	UN2881	100
KB3	Eastman	R674-01UN	100
Toluene	Exxon	56023004	100
Diesel	-------	-------	100

Charge	Treatment Components
1C	25% Diesel/KB3 + 75% Toluene
2C	0.5% DDAC + 25% Diesel/KB3 + 75% Toluene
3C	0.75% DDAC + 25% Diesel/KB3 + 75% Toluene
4C	1.0% DDAC + 25% Diesel/KB3 + 75% Toluene
5C	1.5% DDAC + 25% Diesel/KB3 + 75% Toluene
6C	0.25% CTN + 25% Diesel/KB3 + 75% Toluene
7C	0.5% CTN + 25% Diesel/KB3 + 75% Toluene
8C	1.0% CTN + 25% Diesel/KB3 + 75% Toluene
9C	0.189% DDAC + 0.063% CTN + 25% Diesel/KB3 + 75% Toluene
10C	0.375% DDAC + 0.125% CTN + 25% Diesel/KB3 + 75% Toluene
11C	0.50% DDAC + 0.167% CTN + 25% Diesel/KB3 + 75% Toluene
12C	0.75% DDAC + 0.250% CTN + 25% Diesel/KB3 + 75% Toluene
13C	1.0% DDAC + 0.333% CTN + 25% Diesel/KB3 + 75% Toluene
14C	0.20% DDAC + 0.04% CTN + 25% Diesel/KB3 + 75% Toluene
15C	0.40% DDAC + 0.08% CTN + 25% Diesel/KB3 + 75% Toluene
16C	0.625% DDAC + 0.125% CTN + 25% Diesel/KB3 + 75% Toluene
17C	0.750% DDAC + 0.150% CTN + 25% Diesel/KB3 + 75% Toluene
18C	1.0% DDAC + 0.20% CTN + 25% Diesel/KB3 + 75% Toluene

Appendix 4.3. Treatment Information for the Water-Borne DDAC:Tribromophenol Formulations.

Component	Manufacturer	Lot No.	% a.i.
DDAC	Lonza	F4226189	80
TBP	Aldrich	02712MT	100
Tween 40	Aldrich	07927AG	100
1-Butanol	Aldrich	0290HF	100

Charge	Treatment Components
1	6% Butanol + Water
2	0.5% DDAC + Water
3	0.75% DDAC + Water
4	1.0% DDAC + Water
5	1.5% DDAC + Water
6	0.5% DDAC + 1.95% Tween 40 + 1.88% 1 N-Butanol + Water
7	0.75% DDAC + 1.95% Tween 40 + 1.88% 1 N-Butanol + Water
8	1.0% DDAC + 1.95% Tween 40 + 1.88% 1 N-Butanol + Water
9	1.50% DDAC + 1.95% Tween 40 + 1.88% 1 N-Butanol + Water
10	0.25% TBP + 1.30% Tween 40 + 0.5% 1 N-Butanol + Water
11	0.5% TBP + 2.7% Tween 40 + 1.5% 1 N-Butanol + Water
13	0.25% DDAC + 0.25% TBP + 0.85% Tween 40 + 1.88% 1 N-Butanol + Water
14	0.35% DDAC + 0.35% TBP + 1.0% Tween 40 + 3.4% 1 N-Butanol + Water
15	0.5% DDAC + 0.5% TBP + 1.5% Tween 40 + 0.5% 1 N-Butanol + Water
16	0.75% DDAC + 0.75% TBP + 1.95% Tween 40 + 1.88% 1 N-Butanol + Water
17	1.0% DDAC + 1.0% TBP + 1.5% Tween 40 + 0.5% 1 N-Butanol + Water
18	0.375% DDAC + 0.125% TBP + 1.0% Tween 40 + 0.3% 1 N-Butanol + Water
19	0.5% DDAC + 0.167% TBP + 1.0% Tween 40 + 0.3% 1 N-Butanol + Water
20	0.75% DDAC + 0.25% TBP + 1.0% Tween 40 + 0.3% 1 N-Butanol + Water
21	1.0% DDAC + 0.33% TBP + 1.10% Tween 40 + 0.5% 1 N-Butanol + Water
22	1.5% DDAC + 0.5% TBP + 2.0% Tween 40 + 0.7% 1 N-Butanol + Water
23	0.25% DDAC + 1.95% Tween 40 + 1.88% 1 N-Butanol + Water
24	0.125% DDAC + 0.125% TBP + 1.0% Tween 40 + 0.0% 1 N-Butanol + Water
25	0.189% DDAC + 0.063% TBP + 0.2% Tween 40 + 0.2% 1 N-Butanol + Water
26	0.25% DDAC + Water

Appendix 4.3.(con't) **Treatment Information for the Water-Borne DDAC:Tribromophenol Formulations.**

Component	Manufacturer	Lot No.	% a.i.
DDAC	Lonza	F4226189	80
TBP	Aldrich	02712MT	100
Tween 40	Aldrich	07927AG	100
1-Butanol	Aldrich	0290HF	100

Charge	Treatment Components
28	1.0% CCA
29	0.630% C-CCA + Water
30	0.370% C-CCA + Water
31	0.19% C-CCA + Water

Appendix 4.4. Treatment Information for the Water-Borne DDAC:Chlorothalonil Formulations.

Component	Manufacturer	Lot No.	% a.i.
DDAC	Lonza	B5227262	80
Chlorothalonil	ISK	UN2811	100
Xylene	Aldrich	00408KG	100

Charge	Treatment Components
1	Water
2	0.5% DDAC + 1.67% Zylene + Water
3	0.75% DDAC + 2.50% Zylene + Water
4	1.0% DDAC + 3.33% Zylene + Water
5	1.5% DDAC + 4.93% Zylene + Water
6	0.189% DDAC + 0.063% CTN + 1.67% Zylene + Water
7	0.375% DDAC + 0.125% CTN + Zylene + Water
8	0.50% DDAC + 0.167% CTN + Zylene + Water
9	0.75% DDAC + 0.25% CTN + Zylene + Water
10	0.189% DDAC + 0.063% CTN + Zylene + Water
11	0.20% DDAC + 0.04% CTN + Zylene + Water
12	0.40% DDAC + 0.08% CTN + Zylene + Water
13	0.625% DDAC + 0.125% CTN + Zylene + Water
14	0.75% DDAC + 0.15% CTN + Zylene + Water
15	0.10% DDAC + 0.20% CTN + 1.67% Zylene + Water
16	0.25% DDAC + 1.67% Zylene + Water
17	0.093% DDAC + 0.031% CTN + Zylene + Water
18	0.105% DDAC + 0.021 CTN + Zylene + Water

Appendix 4.5. Treatment Information for L-Joints and Positive Controls for the DDAC and Sodium Omadine Formulations.

Component	**Manufacturer**	**Lot No.**	**% a.i.**
DDAC	Lonza	F4226189	80
Na Omadine	Olin	4RC-124-P-007	40

Charge	**Treatment Components**
Na1	Water
Na2	0.25% DDAC + Water
Na3	0.50% DDAC + Water
Na4	0.750% DDAC + Water
Na5	1.0% DDAC + Water
Na6	0.05% Na Omadine + Water
Na7	0.10% Na Omadine + Water
Na8	0.20% Na Omadine + Water
Na9	0.40% Na Omadine + Water
Na10	0.10% DDAC + 0.02% Na Omadine + Water
Na11	0.20% DDAC + 0.05% Na Omadine + Water
Na12	0.40% DDAC + 0.10% Na Omadine + Water
Na13	0.60% DDAC + 0.15% Na Omadine + Water
Na14	0.80% DDAC + 0.20% Na Omadine + Water
Na15	0.15% DDAC + 0.02% Na Omadine + Water
Na16	0.20% DDAC + 0.03% Na Omadine + Water
Na17	0.40% DDAC + 0.06 Na Omadine + Water
Na18	0.6% DDAC + 0.09% Na Omadine + Water
Na19	0.8% DDAC + 0.110% Na Omadine + Water
Na20	0.19% CCA + Water
Na21	0.370% CCA + Water
Na22	0.63% CCA + Water
P1	0.5% Penta + 25% KB3/Diesel + 75% Toluene
P2	1.0% Penta + 25% KB3/Diesel + 75% Toluene
P3	1.5% Penta + 25% KB3/Diesel + 75% Toluene

Appendix 4.6. Treatment Information for L-Joints for the DDAC:Na Omadine + PABA Formulations.

Component	Manufacturer	Lot No.	% a.i.
DDAC	Lonza	F4226189	80
Na Omadine	Olin	4RC-124-P-007	40
Palmitic Acid	Aldrich Chemical	10808CY	90
Butylamine	Aldrich Chemical	08629CN	100
Butylamine	Aldrich Chemical	05026DN	100

Charge	Treatment Components
1	5% Palmitic Acid + 3% Butyl Amine + 3% Butyl Carbitol + Water
2	0.25% DDAC + 5% Palmitic Acid + 3% Butyl Amine + 3% Butyl Carbitol + Water
3	0.50% DDAC + 0.50% DDAC + 5% Palmitic Acid + 3% Butyl Amine + 3% Butyl Carbitol + Water
4	0.75% DDAC + 0.25% DDAC + 5% Palmitic Acid + 3% Butyl Amine + 3% Butyl Carbitol + Water
5	1.0% DDAC + 1.0 % DDAC + 5% Palmitic Acid + 3% Butyl Amine + 3% Butyl Carbitol + Water
6	0.05% Na Omadine + 5% Palmitic Acid + 3% Butyl Amine + 3% Butyl Carbitol + Water
7	0.10% Na Omadine + 5% Palmitic Acid + 3% Butyl Amine + 3% Butyl Carbitol + Water
8	0.20% Na Omadine + 5% Palmitic Acid + 3% Butyl Amine + 3% Butyl Carbitol + Water
9	0.40% Na Omadine + 5% Palmitic Acid + 3% Butyl Amine + 3% Butyl Carbitol + Water
10	0.10% DDAC + 0.02% Na Omadine + 5% Palmitic Acid + 3% Butyl Amine + 3% Butyl Carbitol + Water
11	0.20% DDAC + 0.05% Na Omadine + 5% Palmitic Acid + 3% Butyl Amine + 3% Butyl Carbitol + Water
12	0.40% DDAC + 0.10% Na Omadine + 5% Palmitic Acid + 3% Butyl Amine + 3% Butyl Carbitol + Water
13	0.60% DDAC + 0.15% Na Omadine + 5% Palmitic Acid + 3% Butyl Amine + 3% Butyl Carbitol + Water
14	0.80% DDAC + 0.20% Na Omadine + 5% Palmitic Acid + 3% Butyl Amine + 3% Butyl Carbitol + Water
15	0.15% DDAC + 0.02% Na Omadine + 5% Palmitic Acid + 3% Butyl Amine + 3% Butyl Carbitol + Water
16	0.20% DDAC + 0.03% Na Omadine + 5% Palmitic Acid + 3% Butyl Amine + 3% Butyl Carbitol + Water
17	0.40% DDAC + 0.06% Na Omadine + 5% Palmitic Acid + 3% Butyl Amine + 3% Butyl Carbitol + Water
18	0.60% DDAC + 0.09% Na Omadine + 5% Palmitic Acid + 3% Butyl Amine + 3% Butyl Carbitol + Water
19	0.80% DDAC + 0.10% Na Omadine + 5% Palmitic Acid + 3% Butyl Amine + 3% Butyl Carbitol + Water

APPENDIX B

TABLES

Table 4.2.1.1 Average Strength Loss of 3mm Stakes treated with the Oil-borne DDAC:CTN Formulation after 96-weeks Exposure in the Fungus Cellar. CCA and Penta are the water and oil-borne positive controls, respectively.

	RETENTION	AVERAGE % STRENGTH LOSS			
BIOCIDE (SOLVENT)	FUNGUS CELLAR AVERAGE TOTAL RETENTION (pcf)[1]	FUNGUS CELLAR 96 WEEKS DORMAN SOIL[2]		FUNGUS CELLAR 96 WEEKS SAUCIER SOIL	
UNTREATED CONTROLS	0.000	96.89	± 1.88	100	± 0.00
CONTROLS (TOLUENE/DSL/KB3)[3]	0.000	44.16	±10.22	64.46	±20.86
DDAC	0.141	37.78	± 7.97	56.84	± 8.86
(TOLUENE\DSL\KB3)	0.211	27.64	± 6.38	39.54	± 8.95
	0.293	34.46	± 7.62	49.31	±11.42
	0.413	33.44	± 6.68	45.65	± 9.38
CTN	0.079	23.72	± 6.43	35.66	± 7.35
(TOLUENE\DSL\KB3)	0.133	23.42	± 5.76	23.06	± 8.57
	0.318	19.43	± 1.85	19.52	± 3.60
DDAC:CTN (3:1)	0.074	33.52	± 6.69	49.61	±15.65
(TOLUENE\DSL\KB3)	0.157	30.71	± 7.60	37.27	± 6.55
	0.180	35.06	± 6.68	48.72	5.83
	0.312	32.40	± 5.74	52.73	±15.36
	0.373	28.21	± 5.53	49.90	± 8.61
DDAC:CTN (5:1)	0.068	38.96	±12.66	59.16	± 8.52
(TOLUENE\DSL\KB3)	0.144	38.74	± 6.61	55.22	±10.85
	0.215	30.59	± 4.28	40.54	± 6.10
	0.255	26.00	± 5.79	39.54	±13.72
	0.327	30.40	± 5.21	38.99	±11.48
CCA	0.146	28.42	± 2.30	22.92	±3.52
(WATER)	0.290	28.99	± 5.66	25.28	± 5.75
	0.475	25.94	± 3.88	28.79	±7.07
PENTA	0.170	39.25	± 9.32	51.38	± 7.78
(TOLUENE\DSL\KB3)	0.302	33.40	±11.73	44.38	± 8.75
	0.470	32.47	± 5.61	41.25	± 8.97

[1] Total pcf retentions of DDAC and DDAC+Chlorothalonil were calculated on the basis of weight gain and solution concentration.
[2] Average of 6 replicates; ± = Standard Deviation
[3] DSL = Diesel

Table 4.2.1.2 Analysis of variance for Oil-borne DDAC:CTN treated Fungus Cellar stakes Exposed to Dorman Soil for 96-weeks.

Treatment	Retention (pcf)	% Strength Loss	T Grouping[1]								
CTN in Toluene	0.318	19.43									I
CTN in Toluene	0.133	23.42								H	I
CTN in Toluene	0.079	23.72							G	H	I
CCA in Water	0.475	25.94						F	G	H	I
DDAC:CTN (5:1)	0.255	26.00						F	G	H	I
DDAC in Toluene	0.211	27.64						F	G	H	I
DDAC:CTN (3:1)	0.373	28.21					E	F	G	H	I
CCA in Water	0.146	28.42					E	F	G	H	I
CCA in Water	0.290	28.99				D	E	F	G	H	I
DDAC:CTN (5:1)	0.321	30.40			C	D	E	F	G	G	
DDAC:CTN (5:1)	0.215	30.59			C	D	E	F	G	H	
DDAC:CTN (3:1)	0.157	30.71			C	D	E	F	G	H	
DDAC:CTN (3:1)	0.312	32.40			C	D	E	F	G	H	
Penta in Toluene	0.470	32.47			C	D	E	F	G	H	
Penta in Toluene	0.302	33.40			C	D	E	F	G	H	
DDAC in Toluene	0.413	33.44			C	D	E	F	G	H	
DDAC:CTN (3:1)	0.074	33.52			C	D	E	F	G		
DDAC in Toluene	0.293	34.46		B	C	D	E	F			
DDAC:CTN (3:1)	0.180	35.06		B	C	D	E	F			
DDAC in Toluene	0.141	37.78		B	C	D	E				
DDAC:CTN (5:1)	0.144	38.74		B	C	D					
DDAC:CTN (5:1)	0.068	38.95		B	C	D					
Penta in Toluene	0.170	39.25		B	C						
Controls Toluene/DSL/KB3	0.000	44.16		B							
Untreated Controls	0.000	96.89	A								

[1]Means with the same letter are not significantly different.

Table 4.2.1.3 Analysis of variance for Oil-borne DDAC:CTN treated Fungus Cellar stakes Exposed to Saucier Soil for 96-weeks.

Treatment	Retention (pcf)	% Strength Loss	T Grouping[1]												
CTN in Toluene	0.318	19.52													M
CCA in Water	0.146	22.92													M
CTN in Toluene	0.133	23.06												L	M
CCA in Water	0.290	25.28												L	M
CCA in Water	0.475	28.79											K	L	M
CTN in Toluene	0.079	35.66										J	K	L	
DDAC:CTN (3:1)	0.157	37.27									I	J	K	L	
DDAC:CTN (5:1)	0.327	38.99								H	I	J	K		
DDAC in Toluene	0.211	39.54							G	H	I	J	K		
DDAC:CTN (5:1)	0.255	39.54						F	G	G	I	J	K		
DDAC:CTN (5:1)	0.215	40.54						F	G	H	I	J	K		
Penta in Toluene	0.470	41.53						F	G	H	I	J			
Penta in Toluene	0.302	44.38					E	F	G	H	I	J			
DDAC in Toluene	0.413	45.65				D	E	F	G	H	I	J			
DDAC:CTN (3:1)	0.180	48.73			C	D	E	F	G	H	I				
DDAC in Toluene	0.293	49.31			C	D	E	F	G	H	I				
DDAC:CTN (3:1)	0.074	49.61			C	D	E	F	G	H					
DDAC:CTN (3:1)	0.373	49.90			C	D	E	F	G	H					
Penta in Toluene	0.170	51.38			C	D	E	F	G						
DDAC:CTN (3:1)	0.312	52.73		B	C	D	E	F							
DDAC:CTN (5:1)	0.144	55.22		B	C	D	E								
DDAC in Toluene	0.141	56.84		B	C	D									
DDAC:CTN (5:1)	0.068	59.16		B	C										
Controls Toluene/DSL/KB3	0.00	64.46		B											
Untreated Controls	0.00	100.00	A												

[1]Means with the same letter are not significantly different.

Table 4.2.2.1 Average Depletion From Oil-borne DDAC:Chlorothalonil Treated Fungus Cellar Stakes After 12-Weeks Exposure.

BIOCIDE (SOLVENT)	INITIAL AVERAGE RETENTION OF STAKES (PCF)[1]			12-WEEK AVERAGE PERCENT DEPLETION[2]					
				DORMAN SOIL			SAUCIER SOIL		
	DDAC	CTN	CCA	DDAC	CTN	CCA	DDAC	CTN	CCA
CTN (TOLUENE/DSL/KB3)		0.043			58.1	---		27.3	---
DDAC:CTN (3:1) (TOLUENE/DSL/KB3)	0.190	0.078		5.3	51.7	---	5.4	53.3	---
DDAC:CTN (5:1) (TOLUENE/DSL/KB3)	0.192	0.058		13.2	71.0	---	2.6	70.7	---
CCA			0.053	---	---	15.8	---	---	20.9
(WATER)			0.235	---	---	18.4	---	---	15.1
			0.396	---	---	7.9	---	---	9.5

[1]Based on retention of treated, unexposed samples.
[2]Average of 3 separate analyses of a composite sample of 3 stakes.

Table 4.2.2.2 Average Depletion From Oil-borne DDAC:Chlorothalonil Treated Fungus Cellar Stakes After 36-Weeks Exposure.

BIOCIDE (SOLVENT)	INITIAL AVERAGE RETENTION OF STAKES (PCF)[1]			36-WEEK AVERAGE PERCENT DEPLETION[2]					
				DORMAN SOIL			SAUCIER SOIL		
	DDAC	CTN	CCA	DDAC	CTN	CCA	DDAC	CTN	CCA
CTN (TOLUENE/DSL/KB3)		0.043			34.7	--		35.6	--
DDAC:CTN (3:1) (TOLUENE/DSL/KB3)	0.190	0.078		-16.4*	62.9	--	-31.9*	38.4	--
DDAC:CTN (5:1) (TOLUENE/DSL/KB3)	0.192	0.058		-29.9*	70.2	--	-33.4*	71.4	--
CCA			0.053	--	--	30.7	--	--	53.1
(WATER)			0.235	--	--	18.0	--	--	15.9
			0.396	--	--	13.3	--	--	12.8

[1]Based on retention of treated, unexposed samples.
[2]Average of 3 separate analyses of a composite sample of 3 stakes.

*The negative DDAC numbers are probably due to the oil migration down the stake.

Table 4.2.3.1 Average Depletion of Oil-borne DDAC and Chlorothalonil Treated Field Stakes After 1-Year Exposure.

BIOCIDE (SOLVENT)	INITIAL AVERAGE RETENTION OF STAKES (PCF)[1]			AVERAGE PERCENT DEPLETION[2]					
				DORMAN			SAUCIER		
	DDAC	CTN	CCA	DDAC	CTN	CCA	DDAC	CTN	CCA
CTN (TOLUENE/DSL/KB3)		0.072		---	12.8	---	---	28.7	---
DDAC:CTN (3:1) (TOLUENE/DSL/KB3)	0.218	0.073		2.0	44.8	---	-15.2	67.3	---
DDAC:CTN (5:1) (TOLUENE/DSL/KB3)	0.022	0.043		-9.3	71.2	---	-17.5	62.9	---
CCA (WATER)			0.069	---	---	35.9	---	---	18.5
			0.234	---	---	7.6	---	---	8.4
			0.377	---	---	3.2	---	---	1.3

[1]Based on retention of treated, unexposed samples.
[2]Average of 3 separate analysis of a composite sample of 5 stakes.

Table 4.2.3.2 Average Depletion of Oil-borne DDAC and Chlorothalonil Treated Field Stakes After 3-Years Exposure.

BIOCIDE (SOLVENT)	INITIAL AVERAGE RETENTION OF STAKES (PCF)[1]			AVERAGE PERCENT DEPLETION[2]					
				DORMAN			SAUCIER		
	DDAC	CTN	CCA	DDAC	CTN	CCA	DDAC	CTN	CCA
CTN (TOLUENE/DSL/KB3)		0.072		---	23.6	---	---	38.1	---
DDAC:CTN (3:1) (TOLUENE/DSL/KB3)	0.218	0.073		6.7	32.2	---	8.1	35.3	---
DDAC:CTN (5:1) (TOLUENE/DSL/KB3)	0.022	0.043		3.6	37.1	---	5.9	43.2	---
CCA (WATER)			0.069	---	---	15.3	---	---	26.1
			0.234	---	---	33.5	---	---	28.7
			0.377	---	---	32.3	---	---	22.9

[1]Based on retention of treated, unexposed samples.
[2]Average of 3 separate analysis of a composite sample of 5 stakes.

Table 4.2.4.1 Average Decay and Termite Ratings For Oil-borne DDAC:Chlorothalonil Treated Field Stakes.

BIOCIDE (SOLVENT)	FIELD STAKES AVERAGE TOTAL RETENTION (pcf)	3-YEAR DECAY AND TERMITE RATING[1]			
		DORMAN[3]		SAUCIER	
		DECAY	TERMITE	DECAY	TERMITE
UNTREATED CONTROLS	0	2.2 ± 0.4	1.7 ± 0.2	0.4 ± 1.2	0.4 ± 1.2
SOLVENT CONTROLS (TOLUENE/DSL/KB3)[2]	0	9.5 ± 0.7	9.3 ± 0.7	8.4 ± 2.3	8.3 ± 2.4
DDAC	0.138	9.5 ± 0.8	9.5 ± 0.7	9.2 ± 0.8	9.0 ± 0.9
(TOLUENE\DSL\KB3)	0.205	9.5 ± 1.0	9.7 ± 0.6	9.6 ± 0.6	9.4 ± 0.6
	0.281	9.9 ± 0.3	9.9 ± 0.3	9.9 ± 0.3	9.3 ± 0.9
	0.436	10.0 ± 0.0	9.9 ± 0.2	9.8 ± 0.5	9.8 ± 0.4
CTN	0.072	9.9 ± 0.3	9.6 ± 0.7	9.7 ± 0.6	9.4 ± 0.8
(TOLUENE\DSL\KB3)	0.142	10.0 ± 0.0	10.0 ± 0.0	9.8 ± 0.5	9.6 ± 0.8
	0.292	10.0 ± 0.0	10.0 ± 0.0	10.0 ± 0.0	9.8 ± 0.4
DDAC:CTN (3:1)	0.074	9.8 ± 0.4	9.7 ± 0.4	9.3 ± 0.7	9.1 ± 1.0
(TOLUENE\DSL\KB3)	0.142	9.7 ± 0.6	9.7 ± 0.6	9.9 ± 0.3	9.1 ± 1.0
	0.189	9.9 ± 0.3	9.7 ± 0.5	9.9 ± 0.3	9.7 ± 0.5
	0.286	10.0 ± 0.0	9.8 ± 0.4	9.9 ± 0.2	9.6 ± 0.5
	0.386	9.9 ± 0.3	9.6 ± 0.6	9.7 ± 0.4	9.3 ± 0.9
DDAC:CTN (5:1)	0.069	9.9 ± 0.3	9.6 ± 0.6	9.5 ± 0.8	8.8 ± 0.7
(TOLUENE\DSL\KB3)	0.138	9.8 ± 0.4	9.5 ± 0.6	9.8 ± 0.4	9.3 ± 0.8
	0.22	9.9 ± 0.3	9.7 ± 0.6	9.9 ± 0.3	9.5 ± 0.7
	0.259	10.0 ± 0.0	9.8 ± 0.4	9.8 ± 0.5	9.5 ± 0.5
	0.346	9.9 ± 0.3	9.9 ± 0.3	9.8 ± 0.4	9.7 ± 0.4

[1]Average of 15 stakes

[2]75% toluene and 25% diesel/KB3 (9:1)

[3]10=No Decay, 0=Failure.

Table 4.2.4.1(con't). Average Decay and Termite Ratings For Oil-borne DDAC:Chlorothalonil Treated Field Stakes.

BIOCIDE (SOLVENT)	FIELD STAKES AVERAGE TOTAL RETENTION (pcf)	3-YEAR DECAY AND TERMITE RATING[1]			
		DORMAN		SAUCIER	
		DECAY	TERMITE	DECAY	TERMITE
CCA (WATER)	0.100	10.0 ± 0.0	10.0 ± 0.0	10.0 ± 0.0	10.0 ± 0.0
	0.117	9.3 ± 2.4	9.1 ± 2.5	9.3 ± 2.4	9.2 ± 1.1
	0.386	10.0 ± 0.0	9.8 ± 0.5	10.0 ± 0.0	9.8 ± 0.5
PENTA	0.148	10.0 ± 0.0	9.9 ± 0.3	9.5 ± 0.6	9.4 ± 0.6
(TOLUENE\DSL\KB3)	0.294	9.9 ± 0.3	9.9 ± 0.3	9.9 ± 0.2	9.5 ± 0.5
	0.465	10.0 ± 0.0	10.0 ± 0.0	9.9 ± 0.2	9.9 ± 0.3

[1]Average of 15 stakes
[2]75% toluene and 25% diesel/KB3 (9:1)
[3]10=No decay, 0=Failure.

Table 4.2.4.2 Analysis of variance of termite ratings for Oil-borne DDAC: Chlorothalonil treated Field stakes exposed at Saucier for 3-Years.

Treatment	Retention (pcf)	Avg. Rating[1]	T Grouping[2]			
CCA in Water	0.100	10.00	A			
Penta in Toluene/DSL/KB3	0.465	9.90	A			
CTN in Toluene/DSL/KB3	0.292	9.80	A			
DDAC in Toluene/DSL/KB3	0.436	9.80	A			
CCA in Water	0.386	9.80	A			
DDAC:CTN (5:1) in Toluene/DSL/KB3	0.346	9.70	A			
DDAC:CTN (3:1) in Toluene/DSL/KB3	0.189	9.70	A			
DDAC:CTN (3:1) in Toluene/DSL/KB3	0.286	9.60	A			
CTN in Toluene/DSL/KB3	0.142	9.60	A			
Penta in Toluene/DSL/KB3	0.294	9.50	A			
DDAC:CTN (5:1) in Toluene/DSL/KB3	0.259	9.50	A			
DDAC:CTN (5:1) in Toluene/DSL/KB3	0.220	9.50	A			
Penta in Toluene/DSL/KB3	0.148	9.40	A			
CTN in Toluene/DSL/KB3	0.072	9.40	A			
DDAC:CTN (3:1) in Toluene/DSL/KB3	0.386	9.30	A			
DDAC in Toluene/DSL/KB3	0.281	9.30	A			
DDAC:CTN (5:1) in Toluene/DSL/KB3	0.138	9.30	A			
CCA in Water	0.117	9.20	A			
DDAC:CTN (3:1) in Toluene/DSL/KB3	0.142	9.10	A			
DDAC:CTN (3:1) in Toluene/DSL/KB3	0.074	9.10	A			
DDAC in Toluene/DSL/KB3	0.138	9.00	A			
DDAC:CTN (5:1) in Toluene/DSL/KB3	0.069	8.80	A			
Solvent Controls:Toluene\DSL\KB3	0.000	8.30	A			
Untreated Controls	0.000	0.40		B		

[1]10=No decay, 0=Failure.

[2]Means with the same letter are not significantly different.

Table 4.2.4.3 Analysis of variance of decay ratings for Oil-borne DDAC:Chlorothalonil treated Field stakes exposed at Saucier for 3-Years.

Treatment	Retention (pcf)	Avg. Rating[1]	T Grouping[2]			
CCA in Water	0.386	10.00	A			
CTN in Toluene/DSL/KB3	0.292	10.00	A			
DDAC:CTN (5:1) in Toluene/DSL/KB3	0.036	10.00	A			
CCA in Water	0.100	10.00	A			
DDAC:CTN (3:1) in Toluene/DSL/KB3	0.436	10.00	A			
DDAC:CTN (3:1) in Toluene/DSL/KB3	0.286	9.90	A			
DDAC:CTN (5:1) in Toluene/DSL/KB3	0.220	9.90	A			
DDAC in Toluene/DSL/KB3	0.281	9.90	A			
DDAC:CTN (3:1) in Toluene/DSL/KB3	0.142	9.90	A			
Penta in Toluene/DSL/KB3	0.465	9.90	A			
DDAC:CTN (3:1) in Toluene/DSL/KB3	0.189	9.90	A			
Penta in Toluene/DSL/KB3	0.294	9.90	A			
CTN in Toluene/DSL/KB3	0.142	9.80	A			
DDAC:CTN (5:1) in Toluene/DSL/KB3	0.259	9.80	A			
DDAC:CTN (5:1) in Toluene/DSL/KB3	0.138	9.80	A			
DDAC:CTN (3:1) in Toluene/DSL/KB3	0.386	9.70	A			
CTN in Toluene/DSL/KB3	0.072	9.70	A			
DDAC in Toluene/DSL/KB3	0.205	9.60	A			
Penta in Toluene/DSL/KB3	0.148	9.50	A			
DDAC:CTN (5:1) in Toluene/DSL/KB3	0.069	9.50	A			
CCA in Water	0.117	9.30	A			
DDAC in Toluene/DSL/KB3	0.138	9.20	A			
Solvent Controls:Toluene\DSL\KB3	0.000	8.40	A			
Untreated Controls	0.000	0.40		B		

[1]10=No decay, 0=Failure.

[2]Means with the same letter are not significantly different.

Table 4.2.4.4 Analysis of variance of termite ratings for Oil-borne DDAC:Chlorothalonil treated Field stakes exposed at Dorman for 3-Years.

Treatment	Retention (pcf)	Avg. Rating[1]	T Grouping[2]			
CTN in Toluene\DSL\KB3	0.142	10.0	A			
CTN in Toluene\DSL\KB3	0.292	10.0	A			
CCA in Water	0.100	10.0	A			
Penta in Toluene\DSL\KB3	0.465	10.0	A			
DDAC:CTN (5:1) in Toluene\DSL\KB3	0.346	9.93	A			
Penta in Toluene\DSL\KB3	0.294	9.93	A			
DDAC in Toluene\DSL\KB3	0.436	9.93	A			
Penta in Toluene\DSL\KB3	0.148	9.93	A			
DDAC in Toluene\DSL\KB3	0.281	9.86	A			
DDAC:CTN (3:1) in Toluene\DSL\KB3	0.286	9.80	A	B		
CCA in Water	0.386	9.80	A	B		
DDAC:CTN (5:1) in Toluene\DSL\KB3	0.259	9.80	A	B		
DDAC:CTN (5:1) in Toluene\DSL\KB3	0.220	9.73	A	B		
DDAC in Toluene\DSL\KB3	0.205	9.73	A	B		
DDAC:CTN (3:1) in Toluene\DSL\KB3	0.074	9.70	A	B		
DDAC:CTN (3:1) in Toluene\DSL\KB3	0.142	9.70	A	B		
DDAC:CTN (3:1) in Toluene\DSL\KB3	0.189	9.67	A	B		
DDAC:CTN (3:1) in Toluene\DSL\KB3	0.386	9.60	A	B		
CTN in Toluene\DSL\KB3	0.072	9.60	A	B		
DDAC:CTN (5:1) in Toluene\DSL\KB3	0.069	9.60	A	B		
DDAC in Toluene\DSL\KB3	0.138	9.53	A	B		
DDAC:CTN (5:1) in Toluene\DSL\KB3	0.138	9.50	A	B		
Solvent Controls:Toluene\DSL\KB3	0.000	9.33		B		
CCA in Water	0.117	9.13		B		
Untreated Controls	0.000	1.67			C	

[1]10=No decay, 0=Failure.
[2]Means with the same letter are not significantly different.

Table 4.2.4.5 Analysis of variance of decay ratings for Oil-borne DDAC:Chlorothalonil treated Field stakes exposed at Dorman for 3-Years.

Treatment	Retention (pcf)	Avg. Rating[1]	T Grouping[2]			
CTN in Toluene\DSL\KB3	0.142	10.0	A			
CCA in Water	0.386	10.0	A			
CCA in Water	0.100	10.0	A			
DDAC in Toluene\DSL\KB3	0.436	10.0	A			
Penta in Toluene\DSL\KB3	0.465	10.0	A			
CTN in Toluene\DSL\KB3	0.292	10.0	A			
DDAC:CTN (3:1) in Toluene\DSL\KB3	0.286	10.0	A			
Penta in Toluene\DSL\KB3	0.148	10.0	A			
DDAC:CTN (5:1) in Toluene\DSL\KB3	0.259	10.0	A			
DDAC:CTN (5:1) in Toluene\DSL\KB3	0.346	9.93	A			
DDAC:CTN (3:1) in Toluene\DSL\KB3	0.189	9.93	A			
DDAC in Toluene\DSL\KB3	0.281	9.93	A			
Penta in Toluene\DSL\KB3	0.294	9.93	A			
DDAC:CTN (3:1) in Toluene\DSL\KB3	0.386	9.86	A			
DDAC:CTN (5:1) in Toluene\DSL\KB3	0.069	9.86	A			
CTN in Toluene\DSL\KB3	0.072	9.86	A			
DDAC:CTN (5:1) in Toluene\DSL\KB3	0.220	9.86	A			
DDAC:CTN (5:1) in Toluene\DSL\KB3	0.138	9.80	A			
DDAC:CTN (3:1) in Toluene\DSL\KB3	0.074	9.80	A			
DDAC:CTN (3:1) in Toluene\DSL\KB3	0.142	9.73	A			
DDAC in Toluene\DSL\KB3	0.138	9.53	A			
DDAC in Toluene\DSL\KB3	0.205	9.53	A			
Solvent Controls:Toluene\DSL\KB3	0.000	9.53	A			
CCA in Water	0.117	9.33	A			
Untreated Controls	0.000	2.20		B		

[1]10=No decay, 0=Failure.
[2]Means with the same letter are not significantly different.

Table 4.3.1.1 Average Strength Loss of Stakes Treated With the Water-borne DDAC:Tribromophenol Formulation after 80-Weeks Exposure in the Fungus Cellar.

	RETENTION	AVERAGE % STRENGTH LOSS [2]			
BIOCIDE (SOLVENT)	FUNGUS CELLAR AVERAGE TOTAL RETENTION [1] (pcf)	FUNGUS CELLAR 80 WEEKS DORMAN SOIL		FUNGUS CELLAR 80 WEEKS SAUCIER SOIL	
CONTROL	0.00	77.42	± 19.06	56.78	± 13.59
DDAC	0.21	64.48	± 17.65	38.06	± 7.26
(WATER)	0.34	48.23	± 7.87	42.30	± 12.17
	0.45	34.44	± 8.31	35.00	± 5.96
	0.63	34.95	± 10.08	28.22	± 6.26
DDAC	0.21	81.41	± 26.29	36.79	± 9.99
(Tween 40+N-butanol+water)	0.31	75.78	± 18.68	34.62	± 6.41
	0.41	39.68	± 8.27	27.94	± 6.65
	0.62	32.07	± 12.30	20.19	± 9.26
TBP	0.11	76.53	± 22.20	45.92	± 12.49
(Tween 40+N-butanol+water)	0.19	76.91	± 21.35	47.38	± 5.21
DDAC:TBP (1:1)	0.25	83.51	± 13.83	39.04	± 8.80
(Tween 40+N-butanol+water)	0.30	52.29	± 20.20	30.26	± 13.81
	0.43	49.86	± 21.12	30.82	± 11.80
	0.69	40.84	± 17.88	24.48	± 7.42
	0.83	37.82	± 13.85	25.50	± 5.53
DDAC:TBP (3:1)	0.21	65.08	± 21.46	43.49	± 14.71
(Tween 40+N-butanol+water)	0.23	76.11	± 23.39	36.08	± 8.01
	0.39	44.63	± 15.22	25.00	± 5.57
	0.54	38.58	± 12.58	25.59	± 5.31
	0.89	32.90	± 11.64	25.64	± 5.01
CCA (WATER)	0.16	16.39	± 8.28	18.92	± 3.10
	0.27	18.54	± 4.03	15.91	± 7.09
	0.46	30.88	± 2.97	20.27	± 5.50

[1]Total retentions were calculated on the basis of weight gain and solution concentration.
[2]Average of 6 replicates; ± = Standard Deviation

Table 4.3.1.2 Analysis of variance for Water-borne DDAC:Tribromophenol treated Fungus Cellar stakes exposed to Dorman soil for 80-weeks.

Treatment	Retention (pcf)	% Strength Loss	T Grouping[1]								
CCA in Water	0.16	16.39									I
CCA in Water	0.27	18.54								H	I
CCA in Water	0.46	30.88							G	H	I
DDAC	0.62	32.07						F	G	H	I
DDAC:TBP (3:1)	0.89	32.91					E	F	G	H	I
DDAC in Water	0.45	34.44					E	F	G	H	
DDAC in Water	0.63	34.96					E	F	G	H	
DDAC:TBP (1:1)	0.83	37.83				D	E	F	G		
DDAC:TBP (3:1)	0.54	38.58				D	E	F	G		
DDAC	0.41	39.68				D	E	F	G		
DDAC:TBP (1:1)	0.69	40.84				D	E	F	G		
DDAC:TBP (3:1)	0.39	44.63				D	E	F	G		
DDAC in Water	0.34	48.23			C	D	E	F			
DDAC:TBP (1:1)	0.43	49.87			C	D	E				
DDAC:TBP (1:1)	0.30	52.29			C	D					
DDAC in Water	0.21	64.48		B	C						
DDAC:TBP (3:1)	0.21	65.08		B	C						
DDAC	0.31	75.78		B	C						
DDAC:TBP (3:1)	0.23	76.11	A	B							
TBP	0.11	76.53	A	B							
TBP	0.19	76.91	A	B							
Untreated Control	0.00	77.42	A	B							
DDAC	0.21	81.41	A	B							
DDAC:TBP (1:1)	0.25	83.51	A								

[1]Means with the same letter are not significantly different.

Table 4.3.1.3 Analysis of variance for Water-borne DDAC:Tribromophenol treated Fungus Cellar stakes exposed to Saucier soil for 80-weeks.

Treatment	Retention (pcf)	% Strength Loss	T Grouping[1]								
CCA in Water	0.27	15.91									I
CCA in Water	0.16	18.92								H	I
DDAC	0.62	20.20								H	I
CCA in Water	0.46	20.27								H	I
DDAC:TBP (1:1)	0.69	24.48							G	H	I
DDAC:TBP (3:1)	0.39	25.00						F	G	H	I
DDAC:TBP (1:1)	0.83	25.50						F	G	H	I
DDAC:TBP (3:1)	0.54	25.59						F	G	H	I
DDAC:TBP (3:1)	0.89	25.64						F	G	H	I
DDAC	0.41	27.94					E	F	G	H	I
DDAC in Water	0.63	28.22					E	F	G	H	I
DDAC:TBP (1:1)	0.30	30.26					E	F	G	H	
DDAC:TBP (1:1)	0.43	30.82					E	F	G	H	
DDAC	0.31	34.62				D	E	F	G		
DDAC in Water	0.45	35.00			C	D	E	F	G		
DDAC:TBP (3:1)	0.23	36.08			C	D	E	F			
DDAC	0.21	36.80		B	C	D	E				
DDAC in Water	0.21	38.06		B	C	D	E				
DDAC:TBP (1:1)	0.25	39.04		B	C	D	E				
DDAC in Water	0.34	42.30		B	C	D					
DDAC:TBP (3:1)	0.21	43.49		B	C	D					
TBP	0.11	45.92	A	B	C						
TBP	0.19	47.38	A	B							
Untreated Control	0.00	56.78	A								

[1]Means with the same letter are not significantly different.

Table 4.3.2.1 Average Depletion From Water-borne DDAC:Tribromophenol Treated Fungus Cellar Stakes After 12-Weeks Exposure.

BIOCIDE (SOLVENT)	INITIAL AVERAGE RETENTION OF STAKES (PCF)[1]			12 WEEK AVERAGE PERCENT DEPLETION[2]					
				DORMAN SOIL			SAUCIER SOIL		
	DDAC	TBP	CCA	DDAC	TBP	CCA	DDAC	TBP	CCA
DDAC (Tween 40+N-butanol+water)	0.280			20.2	---	---	20.5	---	---
DDAC:TBP (1:1) (Tween 40+N-butanol+water)	0.220	0.220		25.5	66.5	---	32.1	80.0	---
DDAC:TBP (3:1) (Tween 40+N-butanol+water)	0.290	0.100		27.1	61.0	---	31.9	69.8	---
CCA (WATER)			0.400	---	---	14.0	---	---	23.6
			0.300	---	---	9.4	---	---	24.1
			0.090	---	---	15.7	---	---	32.3

[1]Based on retention of treated, unexposed samples.
[2]Average of 3 separate analyses of a composite sample of 3 stakes.

Table 4.3.2.2 Average Depletion From Water-borne DDAC:Tribromophenol Treated Fungus Cellar Stakes After 36-Weeks Exposure

BIOCIDE (SOLVENT)	INITIAL AVERAGE RETENTION OF STAKES (PCF)[1]			36 WEEK AVERAGE PERCENT DEPLETION[2]					
				DORMAN SOIL			SAUCIER SOIL		
	DDAC	TBP	CCA	DDAC	TBP	CCA	DDAC	TBP	CCA
DDAC (Tween 40+N-butanol+water)	0.300			40.1	---	---	49.9	---	---
DDAC:TBP (1:1) (Tween 40+N-butanol+water)	0.210	0.210		44.4	87.1	---	54.4	96.5	---
DDAC:TBP (3:1) (Tween 40+N-butanol+water)	0.240	0.080		38.3	84.1	---	51.2	91.3	---
CCA (WATER)			0.140	---	---	23.4	---	---	31.5
			0.260	---	---	8.1	---	---	20.6
			0.440	---	---	11.0	---	---	16.5

[1]Based on retention of treated, unexposed samples.
[2]Average of 3 separate analyses of a composite sample of 3 stakes.

Table 4.3.3.1 Average Depletion of Water-borne DDAC:Tribromophenol Treated Field Stakes After 1-Year Exposure.

BIOCIDE (SOLVENT)	INITIAL AVERAGE RETENTION OF STAKES (PCF)[1]			AVERAGE PERCENT DEPLETION[2]					
				DORMAN			SAUCIER		
	DDAC	TBP	CCA	DDAC	TBP	CCA	DDAC	TBP	CCA
DDAC (Tween 40+N-butanol+water)	0.290	0.000		4.8	---	---	6.6	---	---
DDAC:TBP (1:1) (Tween 40+N-butanol+water)	0.190	0.190		8.8	24.7	---	5.0	65.2	---
DDAC:TBP (3:1) (Tween 40+N-butanol+water)	0.240	0.080		4.6	21.9	---	4.9	27.9	---
CCA (WATER)			0.070	---	---	7.1	---	---	23.4
			0.270	---	---	0.7	---	---	13.0
			0.410	---	---	0.2	---	---	17.2

[1]Based on retention of treated, unexposed samples.
[2]Average of 3 separate analyses of a composite sample of 5 stakes.

Table 4.3.3.2 Average Depletion of Water-borne DDAC:Tribromophenol Treated Field Stakes After 2-Years Exposure.

BIOCIDE (SOLVENT)	INITIAL AVERAGE RETENTION OF STAKES (PCF)[1]			AVERAGE PERCENT DEPLETION[2]					
				DORMAN			SAUCIER		
	DDAC	TBP	CCA	DDAC	TBP	CCA	DDAC	TBP	CCA
DDAC (Tween 40+N-butanol+water)	0.290	0.000		45.3	---	---	42.5	---	---
DDAC:TBP (1:1) (Tween 40+N-butanol+water)	0.190	0.190		44.7	79.6	---	43.1	83.2	---
DDAC:TBP (3:1) (Tween 40+N-butanol+water)	0.240	0.080		32.5	70.7	---	28.8	93.7	---
CCA (WATER)			0.070	---		24.2	---		26.4
			0.270	---		23.1	---		24.2
			0.410	---		17.8	---		21.2

[1]Based on retention of treated, unexposed samples.
[2]Average of 3 separate analyses of a composite sample of 5 stakes.

Table 4.3.4.1 Average Decay and Termite Ratings for Water-borne DDAC:Tribromophenol Field Stakes After 2-Years Exposure.

BIOCIDE (SOLVENT)	FIELD STAKES AVERAGE TOTAL RETENTION (pcf)	1-YEAR DECAY AND TERMITE RATING[1]				2-YEAR DECAY AND TERMITE RATING			
		DORMAN[2]		SAUCIER		DORMAN		SAUCIER	
		DECAY	TERMITE	DECAY	TERMITE	DECAY	TERMITE	DECAY	TERMITE
CONTROL	0.00	7 ± 1.7	9 ± 1.7	4.5 ± 4.5	. 5.6 ± 4.0	3.3 ± 4.4	3.2 ± 3.7	3.0 ± 3.9	1.3 ±3.5
DDAC	0.21	10 ± 0	10 ± 0	10 ± 0	10± 0	9.3 ± 0.8	9.4 ± 0.9	9.8 ± 0.4	7.3 ± 2.5
(WATER)	0.31	10 ± 0	10 ± 0	10 ± 0	9.8 ± .6	9.3 ± 0.9	9.1 ± 1.0	9.4 ±1.6	8.3 ± 1.8
	0.39	10 ± 0	10 ± 0	10 ± 0	9.9 ± .25	9.7 ± 0.5	9.6 ± 0.5	9.7 ± 0.5	8.7 ± 0.9
	0.60	10 ± 0	10 ± 0	10 ± 0	10 ± 0	9.9 ± 0.3	9.7 ± 0.5	9.8 ± 0.4	9.0 ± 0.7
DDAC	0.20	10 ± 0	10 ± 0	9.9 ± 0.4	9.4 ± 1.2	9.4 ± 1.0	9.3 ± 1.0	9.7 ± 0.5	7.2 ± 2.6
(Tween 40+N-butanol+water)	0.28	10 ± 0	10 ± 0	9.9 ± 0.4	9.7 ± .6	9.3 ± 1.6	9.4 ± 0.7	9.9 ± 0.4	8.4 ± 1.0
	0.29	10 ± 0	10 ± 0	10 ± 0	9.7 ± .6	9.6 ± 0.7	9.3 ± 0.9	9.9 ± 0.4	8.4 ± 0.6
	0.58	10 ± 0	10 ± 0	10 ± 0	10 ± 0	9.7 ± 1.1	9.8 ± 0.6	10 ± 0	9.2 ± 0.8
TBP	0.10	10 ± 0	10 ± 0	9.2 ± 0.6	8.1 ± 2.9	7.9 ± 2.7	6.4 ± 4.2	5.3 ± 4.5	2.4 ± 3.7
(Tween 40+N-butanol+water)	0.16	9.9 ± .36	9.9 ± .36	9.7 ± 0.6	8.9 ± 1.4	8.3 ± 3.4	8.7 ± 1.6	6.6 ± 4.2	2.9 ± 3.5
DDAC:TBP (1:1)	0.19	10 ± 0	10 ± 0	9.8 ± .0.4	9.5 ± .7	8.8 ± 2.3	9.4 ± 1.1	9.7 ± 0.5	6.2 ± 3.7
(Tween 40+N-butanol+water)	0.26	9.9 ± 0	10 ± 0	9.9 ± 0.2	9.5 ± 1.2	9.7 ± 0.7	9.4 ± 1.1	9.7 ± 0.6	6.6 ± 2.5
	0.38	10 ± 0	10 ± 0	10 ± 0	10 ± 0	9.9 ± 0.5	9.6 ± 0.7	9.9 ± 0.3	8.6 ± 1.8
	0.57	10 ± 0	10 ± 0	10 ± 0	9.9 ± .5	9.9 ± 0.3	9.9 ± 0.6	10 ± 0	9.4 ± 0.9
	0.68	10 ± 0	10 ± 0	10 ± 0	9.9 ± .3	9.9 ± 0.3	9.8 ± 0.4	9.9 ± 0.3	9.2 ± 0.9
DDAC:TBP (3:1)	0.19	10 ± 0	10 ± 0	10 ± 0	9.5 ± .7	9.7 ± 0.6	8.9 ± 1.2	9.1 ± 2.7	6.6 ± 3.0
(Tween 40+N-butanol+water)	0.21	10 ± 0	10 ± 0	10 ± 0	9.5 ± .9	9.8 ± 0.6	9.5 ± 1.8	9.9 ± 0.4	7.8 ± 1.4
	0.33	9.9 ± .26	9.9 ± .26	10 ± 0	9.9 ± .3	9.9 ± 0.3	9.5 ± 0.5	10 ± 0	8.9 ± 1.0
	0.49	10 ± 0	10 ± 0	10 ± 0	10 ± 0	9.3 ± 2.3	9.5 ± 0.7	9.7 ± 0.4	9.1 ± 0.9
	0.74	10 ± 0	10 ± 0	10 ± 0	10 ± 0	10 ± 0	9.9 ± 0.3	9.9 ± 0.3	9.7 ± 0.5
CCA	0.15	10 ± 0	10 ± 0	10 ± 0	9.9 ± 0.3	10 ± 0	10 ± 0	9.9 ± 0.3	9.9 ± 0.3
(WATER)	0.26	10 ± .27	9.9 ± .27	10 ± 0	10 ± 0	9.9 ± 0.3	9.4 ± 0.4	10 ± 0	9.8 ± 0.5
	0.41	9.9 ± 0	10 ± 0	10 ± 0	10 ± 0	10 ± 0	9.9 ± 0.3	10 ± 0	9.4 ± 0.8

[1]Average of 15 stakes [2]10=No decay, 0=Failure

Table 4.3.4.2 Analysis of variance of termite ratings for Water-borne DDAC:Tribromophenol treated field stakes exposed at Dorman for 2-Years.

Treatment	Retention (pcf)	Avg. Rating[1]	T Grouping[2]				
CCA in Water	0.15	10.00	A				
DDAC:TBP (3:1)	0.74	9.94	A				
CCA in Water	0.41	9.93	A				
DDAC:TBP (1:1)	0.57	9.93	A	B			
DDAC	0.58	9.80	A	B			
DDAC:TBP (1:1)	0.68	9.80	A	B			
DDAC in Water	0.60	9.67	A	B	C		
DDAC in Water	0.39	9.60	A	B	C		
DDAC:TBP (1:1)	0.38	9.60	A	B	C		
DDAC:TBP (3:1)	0.21	9.53	A	B	C		
DDAC:TBP (3:1)	0.33	9.53	A	B	C		
DDAC:TBP (3:1)	0.49	9.51	A	B	C		
CCA in Water	0.26	9.41	A	B	C		
DDAC:TBP (1:1)	0.19	9.40	A	B	C		
DDAC:TBP (1:1)	0.26	9.40	A	B	C		
DDAC	0.28	9.40	A	B	C		
DDAC in Water	0.21	9.40	A	B	C		
DDAC	0.20	9.33	A	B	C		
DDAC	0.29	9.26	A	B	C		
DDAC in Water	0.31	9.06	A	B	C		
DDAC:TBP (3:1)	0.19	8.86		B	C		
TBP	0.16	8.70		B	C		
TBP	0.10	6.40				D	
Untreated Control	0.00	3.20					E

[1]10=No decay, 0=Failure.

[2]Means with the same letter are not significantly different.

Table 4.3.4.3 Analysis of variance of decay ratings for Water-borne DDAC:Tribromophenol treated field stakes exposed at Dorman for 2-Years.

Treatment	Retention (pcf)	Avg. Rating[1]	T Grouping[2]				
CCA in Water	0.41	10.00	A				
CCA in Water	0.15	10.00	A				
DDAC:TBP (3:1)	0.74	10.00	A				
DDAC in Water	0.60	9.93	A				
CCA in Water	0.26	9.93	A				
DDAC:TBP (1:1)	0.68	9.86	A	B			
DDAC:TBP (3:1)	0.33	9.86	A	B			
DDAC:TBP (1:1)	0.57	9.86	A	B			
DDAC:TBP (1:1)	0.38	9.86	A	B			
DDAC:TBP (3:1)	0.21	9.80	A	B			
DDAC in Water	0.39	9.73	A	B			
DDAC	0.58	9.67	A	B			
DDAC:TBP (1:1)	0.26	9.67	A	B			
DDAC:TBP (3:1)	0.19	9.67	A	B			
DDAC	0.29	9.58	A	B			
DDAC	0.20	9.40	A	B	C		
DDAC in Water	0.21	9.33	A	B	C		
DDAC in Water	0.31	9.33	A	B	C		
DDAC	0.28	9.33	A	B	C		
DDAC:TBP (3:1)	0.49	9.30	A	B	C		
DDAC:TBP (1:1)	0.19	8.80		B	C	D	
TBP	0.16	8.30			C	D	
TBP	0.10	7.93				D	
Untreated Control	0.00	3.30					E

[1]10=No decay, 0=Failure.
[2]Means with the same letter are not significantly different.

Table 4.3.4.4 Analysis of variance of <u>termite</u> ratings for Water-borne DDAC:Tribromophenol treated field stakes exposed at <u>Saucier</u> for 2-Years.

Treatment	Retention (pcf)	Avg. Rating[1]	T Grouping[2]								
CCA in Water	0.15	9.93	A								
CCA in Water	0.26	9.80	A								
DDAC:TBP (3:1)	0.74	9.66	A	B							
CCA in Water	0.41	9.40	A	B							
DDAC:TBP (1:1)	0.57	9.40	A	B							
DDAC:TBP (1:1)	0.68	9.21	A	B	C						
DDAC	0.58	9.20	A	B	C						
DDAC:TBP (3:1)	0.49	9.13	A	B	C						
DDAC in Water	0.60	9.00	A	B	C						
DDAC:TBP (3:1)	0.33	8.93	A	B	C						
DDAC in Water	0.39	8.73	A	B	C	D	E				
DDAC:TBP (1:1)	0.38	8.60	A	B	C	D	E				
DDAC	0.28	8.40	A	B	C	D	E				
DDAC	0.29	8.40		B	C	D	E				
DDAC in Water	0.31	8.30		B	C	D	E				
DDAC:TBP (3:1)	0.21	7.80			C	D	E	F			
DDAC in Water	0.21	7.31				D	E	F	G		
DDAC	0.20	7.20					E	F	G		
DDAC:TBP (3:1)	0.19	6.60						F	G		
DDAC:TBP (1:1)	0.26	6.60						F	G		
DDAC:TBP (1:1)	0.19	6.20							G		
TBP	0.16	2.90							G	H	
TBP	0.10	2.40								H	I
Untreated Control	0.00	1.33									I

[1]10=No decay, 0=Failure.

[2]Means with the same letter are not significantly different.

Table 4.3.4.5 Analysis of variance of decay ratings for Water-borne DDAC:Tribromophenol treated field stakes exposed at Saucier for 2-Years.

Treatment	Retention (pcf)	Avg. Rating[1]	T Grouping[2]				
CCA in Water	0.41	10.00	A				
DDAC:TBP (3:1)	0.33	10.00	A				
DDAC:TBP (1:1)	0.57	10.00	A				
DDAC	0.58	10.00	A				
CCA in Water	0.26	10.00	A				
CCA in Water	0.15	9.93	A				
DDAC:TBP (3:1)	0.74	9.93	A				
DDAC:TBP (1:1)	0.68	9.93	A				
DDAC:TBP (1:1)	0.38	9.93	A				
DDAC	0.29	9.91	A				
DDAC	0.28	9.86	A				
DDAC:TBP (3:1)	0.21	9.86	A				
DDAC in Water	0.21	9.80	A				
DDAC in Water	0.60	9.78	A				
DDAC:TBP (1:1)	0.26	9.73	A				
DDAC:TBP (1:1)	0.19	9.73	A				
DDAC:TBP (3:1)	0.49	9.71	A				
DDAC	0.20	9.67	A				
DDAC in Water	0.39	9.66	A				
DDAC in Water	0.31	9.40	A				
DDAC:TBP (3:1)	0.19	9.06	A				
TBP	0.16	6.60		B			
TBP	0.10	5.26			C		
Untreated Control	0.00	3.00				D	

[1]10=No decay, 0=Failure.
[2]Means with the same letter are not significantly different.

Table 4.3.5.1 Average Retentions of DDAC and Tribromophenol in L-Joints After 1-Year Exposure at Two Test Sites.

BIOCIDE (SOLVENT)	SAUCIER				HILO			
	INITIAL RETENTION (pcf)[1]		1 YEAR EXPOSED RETENTIONS (pcf)[2]		INITIAL RETENTION (pcf)		1 YEAR EXPOSED RETENTIONS (pcf)	
	DDAC	TBP	DDAC	TBP	DDAC	TBP	DDAC	TBP
DDAC (WATER)	0.31	---	0.30	---	0.32	---	0.23	---
DDAC:TBP(1:1) (Tween 40+N-butanol+water)	0.22	0.12	0.30	0.22	0.22	0.11	0.23	0.15
DDAC:TBP(3:1) (Tween 40+N-butanol+water)	0.31	0.05	0.32	0.09	0.31	0.06	0.33	0.09

[1]Initial retentions from outer 3/8" inch of L-joint center section. Each value is the average of 3 analyses of 5 composite samples.
[2]Exposed retentions from inner 1/4" of L-joint tenon.

Table 4.3.6.1 Average Decay Ratings for DDAC:Tribromophenol Treated L-Joints After 1 and 2-Years Exposure.

TREATMENT	L-JOINT TOTAL RETENTION (pcf)	1-YEAR DECAY RATING[1]		2-YEAR DECAY RATING	
		HILO[2]	SAUCIER	HILO	SAUCIER
		DECAY	DECAY	DECAY	DECAY
CONTROL/WATER	0.000	10.0 ± 0.0	10.0 ± 0.0	8.8 ± 1.98	9.2 ± 0.8
DDAC	0.27	10.0 ± 0.0	10.0 ± 0.0	10.0 ± 0.0	10.0 ± 0.0
IN WATER	0.65	10.0 ± 0.0	10.0 ± 0.0	10.0 ± 0.0	10.0 ± 0.0
	1.04	10.0 ± 0.0	10.0 ± 0.0	10.0 ± 0.0	10.0 ± 0.0
	1.48	10.0 ± 0.0	10.0 ± 0.0	10.0 ± 0.0	10.0 ± 0.0
DDAC	0.33	10.0 ± 0.0	10.0 ± 0.0	10.0 ± 0.0	10.0 ± 0.0
IN TWEEN 40 +	0.63	10.0 ± 0.0	10.0 ± 0.0	10.0 ± 0.0	10.0 ± 0.0
N-Butanol +WATER	0.97	10.0 ± 0.0	10.0 ± 0.0	10.0 ± 0.0	10.0 ± 0.0
	1.16	10.0 ±0.0	10.0 ± 0.0	10.0 ± 0.0	10.0 ± 0.0
DDAC:TBP (1:1)	0.30	10.0 ± 0.0	10.0 ± 0.0	10.0 ± 0.0	10.0 ± 0.0
IN TWEEN 40 +	0.69	10.0 ± 0.0	10.0 ± 0.0	10.0 ± 0.0	10.0 ± 0.0
N-Butanol +WATER	0.91	10.0 ± 0.0	10.0 ± 0.0	10.0 ± 0.0	10.0 ± 0.0
	1.12	10.0 ± 0.0	10.0 ± 0.0	10.0 ± 0.0	10.0 ± 0.0
DDAC:TBP (3:1)	0.26	10.0 ± 0.0	10.0 ± 0.0	10.0 ± 0.0	10.0 ± 0.0
IN TWEEN 40 +	0.70	10.0 ± 0.0	10.0 ± 0.0	10.0 ± 0.0	10.0 ± 0.0
N-Butanol +WATER	0.70	10.0 ± 0.0	10.0 ± 0.0	10.0 ± 0.0	10.0 ± 0.0
	1.29	10.0 ± 0.0	10.0 ± 0.0	10.0 ± 0.0	10.0 ± 0.0
CCA IN WATER	0.27	10.0 ± 0.0	10.0 ± 0.0	10.0 ± 0.0	10.0 ± 0.0
	0.56	10.0 ± 0.0	10.0 ± 0.0	10.0 ± 0.0	10.0 ± 0.0
	0.88	10.0 ± 0.0	10.0 ± 0.0	10.0 ± 0.0	10.0 ± 0.0

[1]Average of 10 L-Joints

[2]10= No decay, 0= Failure

Table 4.3.6.2 Analysis of variance of decay ratings for DDAC:Tribromophenol treated L-Joints exposed at Hilo for 2-Years.

Treatment	Retention (pcf)	Avg. Rating[1]	T Grouping[2]				
DDAC in Water	0.27	10.0	A				
DDAC in Water	0.65	10.0	A				
DDAC in Water	1.04	10.0	A				
DDAC in Water	1.48	10.0	A				
DDAC in Tween 40+N-Butanol + Water	0.33	10.0	A				
DDAC in Tween 40+N-Butanol + Water	0.63	10.0	A				
DDAC in Tween 40+N-Butanol + Water	0.97	10.0	A				
DDAC in Tween 40+N-Butanol + Water	1.16	10.0	A				
DDAC:TBP (1:1)	0.30	10.0	A				
DDAC:TBP (1:1)	0.69	10.0	A				
DDAC:TBP (1:1)	0.91	10.0	A				
DDAC:TBP (1:1)	1.12	10.0	A				
DDAC:TBP (3:1)	0.26	10.0	A				
DDAC:TBP (3:1)	0.70	10.0	A				
DDAC:TBP (3:1)	0.70	10.0	A				
DDAC:TBP (3:1)	1.29	10.0	A				
CCA in Water	0.27	10.0	A				
CCA in Water	0.56	10.0	A				
CCA in Water	0.88	10.0	A				
Untreated Control	0.00	8.80		B			

[1]10=No decay, 0=Failure.

[2]Means with the same letter are not significantly different.

Table 4.3.6.3 Analysis of variance of decay ratings for DDAC:Tribromophenol treated L-Joints exposed at Saucier for 2-Years.

Treatment	Retention (pcf)	Avg. Rating[1]	T Grouping[2]				
DDAC in Water	0.27	10.0	A				
DDAC in Water	0.65	10.0	A				
DDAC in Water	1.04	10.0	A				
DDAC in Water	1.48	10.0	A				
DDAC in Tween 40+N-Butanol + Water	0.33	10.0	A				
DDAC in Tween 40+N-Butanol + Water	0.63	10.0	A				
DDAC in Tween 40+N-Butanol + Water	0.97	10.0	A				
DDAC in Tween 40+N-Butanol + Water	1.16	10.0	A				
DDAC:TBP (1:1)	0.30	10.0	A				
DDAC:TBP (1:1)	0.69	10.0	A				
DDAC:TBP (1:1)	0.91	10.0	A				
DDAC:TBP (1:1)	1.12	10.0	A				
DDAC:TBP (3:1)	0.26	10.0	A				
DDAC:TBP (3:1)	0.70	10.0	A				
DDAC:TBP (3:1)	0.70	10.0	A				
DDAC:TBP (3:1)	1.29	10.0	A				
CCA in Water	0.27	10.0	A				
CCA in Water	0.56	10.0	A				
CCA in Water	0.88	10.0	A				
Untreated Control	0.00	9.20		B			

[1]10=No decay, 0=Failure.

[2]Means with the same letter are not significantly different.

Table 4.4.1.1 Average Strength Loss of 3mm Stakes Treated with the Water-borne DDAC:Chlorothalonil Formulation After 62-Weeks Exposure In The Fungus Cellar. The positive controls are CCA (water-borne) and pentachlorophenol (penta, oil-borne).[1]

	RETENTION	AVERAGE % STRENGTH LOSS			
BIOCIDE (SOLVENT)	FUNGUS CELLAR AVERAGE TOTAL RETENTION (pcf)[2]	FUNGUS CELLAR 40 WEEKS DORMAN SOIL[3]		FUNGUS CELLAR 40 WEEKS SAUCIER SOIL	
CONTROL (WATER+XYLENE)	0.000	48.94	±5.87	42.62	±6.00
DDAC	0.201	32.83	±7.51	27.53	±11.86
(WATER+XYLENE)	0.299	22.68	±2.41	26.30	±3.56
	0.393	25.73	±7.83	28.03	±4.97
	0.532	17.63	±2.54	20.44	±4.21
DDAC:CTN (3:1)	0.100	36.45	±14.42	33.76	±11.64
(WATER+XYLENE)	0.201	27.10	±2.94	26.21	±2.61
	0.255	22.96	±5.69	23.99	±4.55
	0.400	25.04	±4.15	28.43	±2.80
	0.537	23.50	±3.05	26.63	±3.43
DDAC:CTN(5:1)	0.096	28.81	±7.08	31.67	±9.60
(WATER+XYLENE)	0.190	25.14	±12.02	32.02	±4.22
	0.281	28.69	±4.68	31.86	±2.60
	0.365	27.32	±7.22	25.53	±4.75
	0.477	25.19	±2.60	26.85	±3.01
CCA	0.150	17.46	±1.44	17.73	±2.14
(WATER)	0.279	16.02	±0.59	18.30	±1.57
	0.449	16.58	±4.85	19.46	±2.19
PENTA	0.162	18.65	±5.24	20.92	±.5.29
(TOLUENE/DSL/KB3)	0.355	17.17	±5.79	19.21	±5.84
	0.476	15.04	±2.44	19.34	±6.00

[1]The emulsion formulation required the presence of DDAC, and thus no treatments were made with CTN alone.
[2]Total pcf retentions of DDAC and DDAC+Chlorothalonil were calculated on the basis of weight gain and solution concentration.
[3]Average of 6 replicates; ± = Standard Deviation

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Table 4.4.1.2 Analysis of variance for Water-borne DDAC:Chlorothalonil treated Fungus Cellar stakes exposed to Saucier Soil for 62-weeks.

Treatment	Retention (pcf)	% Strengh Loss	T Grouping[1]							
CCA	0.150	17.73								H
CCA	0.279	18.30								H
PENTA	0.355	19.21							G	H
PENTA	0.476	19.34							G	H
CCA	0.449	19.46							G	H
DDAC	0.532	20.44					E	F	G	
PENTA	0.162	20.92					E	F	G	
DDAC:CTN(3:1)	0.255	23.99					E	F	G	
DDAC:CTN(5:1)	0.365	25.53					E	F		
DDAC:CTN(3:1)	0.201	26.21					E			
DDAC	0.299	26.30					E			
DDAC:CTN(3:1)	0.537	26.63				D	E			
DDAC:CTN(5:1)	0.477	26.85			C	D	E			
DDAC	0.201	27.53			C	D	E			
DDAC	0.393	28.03			C	D	E			
DDAC:CTN(3:1)	0.400	28.43			C	D	E			
DDAC:CTN(5:1)	0.096	31.67		B	C	D				
DDAC:CTN(5:1)	0.281	31.86		B	C					
DDAC:CTN(5:1)	0.190	32.02		B	C					
DDAC:CTN(3:1)	0.100	33.76		B						
Control (water+zylene)	0.000	42.61	A							

[1]Means with the same letter are not significantly different.

Table 4.4.1.3 Analysis of variance for Water-borne DDAC:Chlorothalonil treated Fungus Cellar stakes exposed to Dorman Soil for 62-weeks.

Treatment	Retention (pcf)	% Strengh Loss	T Grouping[1]								
PENTA	0.476	15.04									I
CCA	0.279	16.02							G	H	
CCA	0.449	16.58						F	G	H	
PENTA	0.355	17.17						F	G	H	
CCA	0.150	17.46						F	G	H	
DDAC	0.532	17.63						F	G	H	
PENTA	0.162	18.65						F	G	H	
DDAC	0.299	22.68				D	E	F			
DDAC:CTN(3:1)	0.255	22.96				D	E	F			
DDAC:CTN(3:1)	0.537	23.50				D	E	F			
DDAC:CTN(3:1)	0.400	25.04				D	E				
DDAC:CTN(5:1)	0.190	25.14				D	E				
DDAC:CTN(5:1)	0.477	25.19				D	E				
DDAC	0.393	25.73			C	D					
DDAC:CTN(3:1)	0.201	27.10			C	D					
DDAC:CTN(5:1)	0.365	27.32			C	D					
DDAC:CTN(5:1)	0.281	28.69			C	D					
DDAC:CTN(5:1)	0.096	28.81			C	D					
DDAC	0.201	32.83		B	C						
DDAC:CTN(3:1)	0.100	36.45		B							
Control (water+zylene)	0.000	48.94	A								

[1]Means with the same letter are not significantly different.

Table 4.4.2.1 Average Depletion of Water-borne DDAC:Chlorothalonil From Fungus Cellar Stakes After 12-Weeks Exposure.

BIOCIDE (SOLVENT)	INITIAL AVERAGE RETENTION OF STAKES (PCF)[1]			12 WEEK AVERAGE PERCENT DEPLETION[2]					
				DORMAN SOIL			SAUCIER SOIL		
	DDAC	CTN	CCA	DDAC	CTN	CCA	DDAC	CTN	CCA
DDAC:CTN (3:1) (WATER+XYLENE)	0.306	0.102		0.3	72.9	---	28.4	72.1	---
DDAC:CTN (5:1) (WATER+XYLENE)	0.303	0.061		24.2	71.6	---	21.4	76.6	---
CCA (WATER)			0.064	---	---	18.2	---	---	22.2
			0.220	---	---	8.9	---	---	16.5
			0.332	---	---	12.2	---	---	18.3

[1]Based on retention of treated, unexposed samples.
[2]Average of 3 separate analyses of a composite sample of 3 stakes.

Table 4.4.2.2 Average Depletion of Water-borne DDAC:Chlorothalonil From Fungus Cellar Stakes After 36-Weeks Exposure

BIOCIDE (SOLVENT)	INITIAL AVERAGE RETENTION OF STAKES (PCF)[1]			36 WEEK AVERAGE PERCENT DEPLETION[2]					
				DORMAN SOIL			SAUCIER SOIL		
	DDAC	CTN	CCA	DDAC	CTN	CCA	DDAC	CTN	CCA
DDAC:CTN (3:1) (WATER+XYLENE)	0.306	0.102		23.9	88.4	---	33.7	77.5	---
DDAC:CTN (5:1) (WATER+XYLENE)	0.303	0.061		36.4	76.2	---	28.5	78.3	---
CCA (WATER)			0.064	---	---	22.7	---	---	23.3
			0.220	---	---	10.0	---	---	16.9
			0.332	---	---	14.6	---	---	22.1

[1]Based on retention of treated, unexposed samples.
[2]Average of 3 separate analyses of a composite sample of 3 stakes.

Table 4.4.2.3 Average Percent Depletion of DDAC and Chlorothalonil From Stakes Treated with Water-borne Formulations After Exposure to Two Different Soils.

Formulation #1 0.18% CTN / 1.0% DDAC / 0.7% Emcol 42 / 3.0% Xylene/Water							
I.D. #	Soil	DDAC			CTN		
		Initial Ret'n (pcf)	Final Ret'n (pcf)	% Loss	Initial Ret'n (pcf)	Final Ret'n (pcf)	% Loss
1.01	Dorman	0.269	0.260	3.35	0.117	0.065	44.64
2.01	Dorman	0.272	0.259	4.78	0.113	0.049	57.08
3.01	Dorman	0.266	0.250	6.02	0.115	0.050	56.33
4.01	Dorman	0.249	0.210	15.66	0.112	0.058	48.21
5.01	Saucier	0.237	0.196	17.30	0.114	0.051	55.07
6.01	Saucier	0.267	0.218	18.35	0.119	0.049	59.07
7.01	Saucier	0.291	0.186	36.08	0.111	0.033	70.27
8.01	Saucier	0.237	0.161	32.07	0.110	0.023	79.09
Ave	Dorman	0.264	0.245	7.29	0.114	0.055	51.54
Ave	Saucier	0.258	0.190	26.26	0.113	0.039	65.67

Formulation #2 0.18% CTN / 1.0% DDAC / 0.7% Emcol 42 / 3.0% Xylene / 0.25% PBD / Water							
I.D. #	Soil	DDAC			CTN		
		Initial Ret'n (pcf)	Final Ret'n (pcf)	% Loss	Initial Ret'n (pcf)	Final Ret'n (pcf)	% Loss
1.02	Dorman	0.265	0.240	9.43	0.122	0.048	61.07
2.02	Dorman	0.286	0.266	6.99	0.119	0.068	42.62
3.02	Dorman	0.282	0.265	6.03	0.126	0.057	54.76
4.02	Dorman	0.281	0.248	11.74	0.131	0.061	53.26
5.02	Saucier	0.248	0.250	-0.81	0.112	0.055	51.12
6.02	Saucier	0.253	0.248	1.98	0.114	0.072	37.00
7.02	Saucier	0.247	0.230	6.88	0.109	0.070	36.24
8.02	Saucier	0.261	0.224	14.18	0.119	0.054	54.43
Ave	Dorman	0.279	0.255	8.53	0.124	0.058	53.02
Ave	Saucier	0.252	0.238	5.65	0.113	0.062	44.86

Table 4.4.2.3 (con't) **Average Percent Depletion of DDAC and Chlorothalonil From Stakes Treated with Water-borne Formulations After Exposure to Two Different Soils.**

Formulation #3 0.18% CTN / 1.0% DDAC / 0.7% Emcol 55 / 3.0% Xylene / 0.25% PIBSA / Water							
I.D. #	Soil	DDAC			CTN		
		Initial Ret'n (pcf)	Final Ret'n (pcf)	% Loss	Initial Ret'n (pcf)	Final Ret'n (pcf)	% Loss
1.03	Dorman	0.260	0.223	14.23	0.114	0.044	61.84
2.03	Dorman	0.253	0.209	17.39	0.117	0.041	65.38
3.03	Dorman	0.264	0.223	15.53	0.101	0.055	45.54
4.03	Dorman	0.264	0.193	26.89	0.120	0.050	58.75
5.03	Saucier	0.271	0.145	46.49	0.117	0.050	57.27
6.03	Saucier	0.246	0.183	25.61	0.111	0.042	61.99
7.03	Saucier	0.259	0.241	6.95	0.122	0.054	55.56
8.03	Saucier	0.261	0.207	20.69	0.111	0.055	50.23
Ave	Dorman	0.260	0.212	18.54	0.113	0.047	58.30
Ave	Saucier	0.259	0.194	25.17	0.115	0.050	56.26

Formulation #4 0.18% CTN / 1.0% DDAC / 0.7% Emcol 55 / 3.0% Xylene / 0.25% PBH-300 / Water							
I.D. #	Soil	DDAC			CTN		
		Initial Ret'n (pcf)	Final Ret'n (pcf)	% Loss	Initial Ret'n (pcf)	Final Ret'n (pcf)	% Loss
1.04	Dorman	0.311	0.207	33.44	0.113	0.041	64.00
2.04	Dorman	0.249	0.222	10.84	0.114	0.041	64.04
3.04	Dorman	0.230	0.218	5.22	0.108	0.048	55.35
4.04	Dorman	0.259	0.186	28.19	0.114	0.034	70.18
5.04	Saucier	0.282	0.208	26.24	0.117	0.042	64.53
6.04	Saucier	0.276	0.226	18.12	0.113	0.049	57.08
7.04	Saucier	0.290	0.256	11.72	0.122	0.053	56.56
8.04	Saucier	0.278	0.247	11.15	0.124	0.043	65.18
Ave	Dorman	0.262	0.208	20.59	0.112	0.041	63.50
Ave	Saucier	0.282	0.234	16.79	0.119	0.047	60.88

Table 4.4.3.1 Average Depletion of DDAC and Chlorothalonil from Field Stakes Treated with a Water-Borne Formulation After 1-Year Exposure.

BIOCIDE (SOLVENT)	INITIAL AVERAGE RETENTION OF STAKES (PCF)[1]			AVERAGE PERCENT DEPLETION[2]					
				DORMAN			SAUCIER		
	DDAC	CTN	CCA	DDAC	CTN	CCA	DDAC	CTN	CCA
DDAC:CTN (3:1) (WATER+XYLENE)	0.228	0.096		19.8	43.4	---	9.6	37.0	---
DDAC:CTN (5:1) (WATER+XYLENE)	0.288	0.058		17.3	57.1	---	22.4	62.3	---
CCA (WATER)			0.059	---	---	21.9	---	---	31.6
			0.235	---	---	23.6	---	---	31.2
			0.375	---	---	11.9	---	---	9.8

[1]Based on retention of treated, unexposed samples.
[2]Average of 3 separate analyses of a composite sample of 5 stakes.

Table 4.4.3.2 Average Depletion of DDAC and Chlorothalonil from Field Stakes Treated with a Water-Borne Formulation After 2-Years Exposure.

BIOCIDE (SOLVENT)	INITIAL AVERAGE RETENTION OF STAKES (PCF)[1]			AVERAGE PERCENT DEPLETION[2]					
				DORMAN			SAUCIER		
	DDAC	CTN	CCA	DDAC	CTN	CCA	DDAC	CTN	CCA
DDAC:CTN (3:1) (WATER+XYLENE)	0.228	0.096		23.4	57.7	---	18.9	54.7	---
DDAC:CTN (5:1) (WATER+XYLENE)	0.288	0.058		26.2	53.0	---	28.9	61.8	---
CCA (WATER)			0.059	---	---	19.8	---	---	21.3
			0.235	---	---	26.8	---	---	11.4
			0.375	---	---	10.2	---	---	6.5

[1]Based on retention of treated, unexposed samples.
[2]Average of 3 separate analyses of a composite sample of 5 stakes.

Table 4.4.4.1 Average Decay and Termite Ratings for Field Stakes Treated with Water-borne DDAC:Chlorothalonil and CCA Formulations.

BIOCIDE (SOLVENT)	FIELD STAKES AVERAGE TOTAL RETENTION (pcf)[1]	1-YEAR DECAY AND TERMITE RATING[1]				2-YEAR DECAY AND TERMITE RATING			
		DORMAN		SAUCIER		DORMAN		SAUCIER	
		DECAY	TERMITE	DECAY	TERMITE	DECAY	TERMITE	DECAY	TERMITE
CONTROL (WATER+XYLENE)	0	6.8 ± 4.1	8.5 ± 1.8	6.3 ± 4.2	4.9 ±4.1	3.6 ± 4.1	3.6 ± 4.4	5.1 ± 4.5	1.5 ± 3.4
DDAC	0.199	10.0 ± 0.0	9.9 ± 0.2	10.0 ±0.0	9.1 ±1.3	9.5 ± 0.5	9.3 ± 0.7	9.8 ± 0.4	6.1 ± 3.7
(WATER+XYLENE)	0.268	9.9 ± 0.5	10.0 ± 0.0	9.9 ± 0.3	9.9 ±0.4	9.5 ± 0.6	9.3 ± 0.7	9.9 ± 0.4	9.3 ± 0.8
	0.386	10.0 ± 0.0	10.0 ± 0.0	9.9 ± 0.4	10.0 ±0.0	9.8 ± 0.4	9.7 ± 0.5	9.8 ± 0.4	9.4 ± 0.8
	0.540	10.0 ± 0.0	10.0 ± 0.0	10.0 ± 0.0	9.9 ±0.3	9.6 ± 0.6	9.9 ± 0.3	10 ± 0	9.6 ± 0.6
DDAC:CTN(3:1)	0.096	9.6 ± 1.55	10.0 ± 0.0	9.9 ± 0.4	9.0 ±2.7	8.7 ± 2.8	8.9 ± 2.7	9.7 ± 0.8	7.1 ± 3.4
(WATER+XYLENE)	0.190	9.9 ± 0.3	10.0 ± 0.0	10.0 ±0.0	9.6 ±0.9	9.6 ± 0.5	9.2 ± 1.0	9.7 ± 0.6	7.7 ± 3.4
	0.238	10.0 ± 0.0	10.0 ± 0.0	10.0 ± 0.0	9.5 ±1.0	9.9 ± 0.3	9.5 ± 0.9	9.5 ± 1.1	9.0 ± 1.6
	0.383	10.0 ± 0.0	10.0 ± 0.0	10.0 ± 0.0	9.8 ±0.6	9.9 ± 0.4	9.8 ± 0.6	10 ± 0	9.3 ± 1.2
	0.517	10.0 ± 0.0	10.0 ± 0.0	10.0 ±0.0	9.7 ±0.8	9.9 ± 0.3	9.9 ± 0.4	10 ± 0	9.5 ± 1.1
DDAC:CTN(5:1)	0.090	10.0 ± 0.0	9.9 ± 0.3	9.3 ±0.3	8.5 ±2.2	9.5 ± 0.7	8.4 ± 1.4	9.5 ± 0.9	6.3 ± 4.3
(WATER+XYLENE)	0.178	9.9 ± 0.3	10.0 ± 0.0	9.7 ±0.6	9.4 ±1.2	9.6 ± 0.5	9.3 ± 0.8	9.4 ± 1.1	7.8 ± 2.0
	0.246	10.0 ± 0.0	10.0 ± 0.0	10.0 ±0.0	9.8 ±0.4	9.9 ± 0.3	9.4 ± 0.6	9.9 ± 0.4	9.1 ± 1.0
	0.347	10.0 ± 0.0	9.8 ± 0.5	10.0 ±0.0	9.9 ±0.4	9.9 ± 0.3	9.8 ± 0.6	9.7 ± 0.6	9.7 ± 0.5
	0.468	10.0 ± 0.0	10.0 ± 0.0	10.0 ±0.0	9.9 ±0.3	9.9 ± 0.4	9.9 ± 0.3	10 ± 0	9.7 ± 0.6
CCA	0.120	10.0 ± 0.0	10.0 ± 0.0	10.0 ±0.0	9.8 ±0.4	10 ± 0	10 ± 0	10 ± 0	9.7 ± 0.5
(WATER)	0.192	10.0 ± 0.0	10.0 ± 0.0	10.0 ±0.0	9.9 ±0.3	10 ± 0	10 ± 0	10 ± 0	9.9 ± 0.3
	0.378	10.0 ± 0.0	10.0 ± 0.0	9.9 ±0.3	9.9 ±0.3	10 ± 0	10 ± 0	9.9 ± 0.3	9.9 ± 0.4

[1]Average of 15 stakes

Table 4.4.4.1(con't) Average Decay and Termite Ratings for Field Stakes Treated with Water-borne DDAC:Chlorothalonil and CCA Formulations.

BIOCIDE (SOLVENT)	FIELD STAKES AVERAGE TOTAL RETENTION (pcf)[1]	1-YEAR DECAY AND TERMITE RATING[1]				2-YEAR DECAY AND TERMITE RATING			
		DORMAN		SAUCIER		DORMAN		SAUCIER	
		DECAY	TERMITE	DECAY	TERMITE	DECAY	TERMITE	DECAY	TERMITE
PENTA	0.147	10.0 ± 0.0	10.0 ± 0.0	10.0 ±0.0	9.7 ±0.5	9.8 ± 0.4	9.9 ± 0.4	9.9 ± 0.3	9.7 ± 0.5
(TOLUENE/DSL/KB3)	0.291	10.0 ± 0.0	10.0 ± 0.0	10.0 ±0.0	10.0 ±0.0	10 ± 0	9.9 ± 0.3	9.9 ± 0.3	9.7 ± 0.5
	0.453	10.0 ± 0.0	10.0 ± 0.0	9.9 ±0.3	9.9 ±0.4	10 ± 0	10 ± 0	10 ± 0	9.8 ± 0.4

[1]Average of 15 stakes

Table 4.4.4.2 Analysis of variance of decay for Water-borne DDAC:Chlorothalonil Treated field stakes exposed at Dorman for 2-Years.

Treatment	Retention (pcf)	Avg. Rating[1]	T Grouping[2]			
Penta in Toluene/DSL/KB3	0.453	10.0	A			
CCA in Water	0.192	10.0	A			
CCA in Water	0.120	10.0	A			
Penta in Toluene/DSL/KB3	0.291	10.0	A			
CCA in Water	0.378	10.0	A			
DDAC:CTN (5:1) Water + Xylene	0.347	9.93	A			
DDAC:CTN (3:1) Water + Xylene	0.517	9.93	A			
DDAC:CTN (5:1) Water + Xylene	0.246	9.93	A			
DDAC:CTN (3:1) Water + Xylene	0.238	9.93	A			
DDAC:CTN (5:1) Water + Xylene	0.468	9.86	A			
DDAC:CTN (3:1) Water + Xylene	0.383	9.86	A			
DDAC in Water + Xylene	0.386	9.80	A			
Penta in Toluene/DSL/KB3	0.147	9.79	A			
DDAC in Water + Xylene	0.540	9.62	A			
DDAC:CTN (5:1) Water + Xylene	0.178	9.61	A			
DDAC:CTN (3:1) Water + Xylene	0.190	9.60	A			
DDAC:CTN (5:1) Water + Xylene	0.090	9.53	A			
DDAC in Water + Xylene	0.199	9.53	A			
DDAC in Water + Xylene	0.268	9.53	A			
DDAC:CTN (3:1) Water + Xylene	0.096	8.67		B		
Untreated Control	0.000	3.60			C	

[1]10=No decay, 0=Failure.

[2]Means with the same letter are not significantly different.

Table 4.4.4.3 Analysis of variance of termite for Water-borne DDAC:Chlorothalonil Treated field stakes exposed at Dorman for 2-Years.

Treatment	Retention (pcf)	Avg. Rating[1]	T Grouping[2]			
Penta in Toluenc/DSL/KB3	0.453	10.0	A			
CCA in Water	0.192	10.0	A			
CCA in Water	0.120	10.0	A			
CCA in Water	0.378	10.0	A			
DDAC in Water + Xylene	0.540	9.93	A			
Penta in Toluene/DSL/KB3	0.291	9.93	A			
DDAC:CTN (5:1) Water + Xylene	0.468	9.93	A			
DDAC:CTN (3:1) Water + Xylene	0.517	9.86	A	B		
Penta in Toluene/DSL/KB3	0.147	9.86	A	B		
DDAC:CTN (5:1) Water + Xylene	0.347	9.80	A	B		
DDAC:CTN (3:1) Water + Xylene	0.383	9.80	A	B		
DDAC in Water + Xylene	0.386	9.73	A	B		
DDAC:CTN (3:1) Water + Xylene	0.238	9.46	A	B		
DDAC:CTN (5:1) Water + Xylene	0.246	9.40	A	B		
DDAC:CTN (5:1) Water + Xylene	0.178	9.33	A	B		
DDAC in Water + Xylene	0.199	9.33	A	B		
DDAC in Water + Xylene	0.268	9.26	A	B	C	
DDAC:CTN (3:1) Water + Xylene	0.190	9.20	A	B	C	
DDAC:CTN (3:1) Water + Xylene	0.096	8.90		B	C	
DDAC:CTN (5:1) Water + Xylene	0.090	8.40			C	
Untreated Control	0.000	3.60				D

[1]10=No decay, 0=Failure.

[2]Means with the same letter are not significantly different.

Table 4.4.4.4 Analysis of variance of decay for Water-borne DDAC: Chlorothalonil Treated field stakes exposed at Saucier for 2-Years.

Treatment	Retention (pcf)	Avg. Rating[1]	T Grouping[2]			
Penta in Toluene/DSL/KB3	0.453	10.0	A			
DDAC:CTN (5:1) Water + Xylene	0.468	10.0	A			
DDAC:CTN (3:1) Water + Xylene	0.517	10.0	A			
DDAC in Water + Xylene	0.540	10.0	A			
CCA in Water	0.120	10.0	A			
CCA in Water	0.192	10.0	A			
DDAC:CTN (3:1) Water + Xylene	0.383	10.0	A			
CCA in Water	0.378	9.93	A			
Penta in Toluene/DSL/KB3	0.147	9.93	A			
DDAC in Water + Xylene	0.268	9.86	A			
DDAC:CTN (5:1) Water + Xylene	0.246	9.86	A			
Penta in Toluene/DSL/KB3	0.291	9.86	A			
DDAC in Water + Xylene	0.386	9.80	A			
DDAC in Water + Xylene	0.199	9.80	A			
DDAC:CTN (5:1) Water + Xylene	0.347	9.73	A			
DDAC:CTN (3:1) Water + Xylene	0.190	9.73	A			
DDAC:CTN (3:1) Water + Xylene	0.096	9.73	A			
DDAC:CTN (3:1) Water + Xylene	0.238	9.53	A			
DDAC:CTN (5:1) Water + Xylene	0.090	9.53	A			
DDAC:CTN (5:1) Water + Xylene	0.178	9.40	A			
Untreated Controls	0.000	5.06		B		

[1]10=No decay, 0=Failure.

[2]Means with the same letter are not significantly different.

Table 4.4.4.5 Analysis of variance of termite for Water-borne DDAC: Chlorothalonil Treated field stakes exposed at Saucier for 2-Years.

Treatment	Retention (pcf)	Avg. Rating[1]	T Grouping[2]						
CCA in Water	0.192	9.90	A						
CCA in Water	0.378	9.86	A						
Penta in Toluene/DSL/KB3	0.453	9.80	A						
Penta in Toluene/DSL/KB3	0.291	9.73	A						
CCA in Water	0.120	9.73	A						
DDAC:CTN (5:1) Water + Xylene	0.347	9.67	A						
Penta in Toluene/DSL/KB3	0.147	9.67	A						
DDAC:CTN (5:1) Water + Xylene	0.468	9.67	A						
DDAC in Water + Xylene	0.540	9.60	A						
DDAC:CTN (3:1) Water + Xylene	0.517	9.46	A						
DDAC in Water + Xylene	0.386	9.40	A						
DDAC in Water + Xylene	0.268	9.33	A						
DDAC:CTN (3:1) Water + Xylene	0.383	9.26	A	B					
DDAC:CTN (5:1) Water + Xylene	0.246	9.13	A	B	C				
DDAC:CTN (3:1) Water + Xylene	0.238	9.00	A	B	C				
DDAC:CTN (5:1) Water + Xylene	0.178	7.86		B	C	D			
DDAC:CTN (3:1) Water + Xylene	0.190	7.73			C	D	E		
DDAC:CTN (3:1) Water + Xylene	0.096	7.08				D	E	F	
DDAC:CTN (5:1) Water + Xylene	0.090	6.33					E	F	
DDAC in Water + Xylene	0.199	6.13						F	
Untreated Controls	0.000	1.53							G

[1]10=No decay, 0=Failure.

[2]Means with the same letter are not significantly different.

Table 4.4.5.1 Average Retentions of DDAC and Chlorothalonil for L-joints treated with Water-Borne Formulations After 1-Year Exposure.

BIOCIDE (SOLVENT)	SAUCIER				HILO			
	INITIAL RETENTION (pcf)[1]		1 YEAR EXPOSED RETENTIONS (pcf)[2]		INITIAL RETENTION (pcf)		1 YEAR EXPOSED RETENTIONS (pcf)	
	DDAC	CTN	DDAC	CTN	DDAC	CTN	DDAC	CTN
DDAC:CTN (3:1) (Water + Xylene)	0.28	0.06	0.05	0.01	0.24	0.05	0.07	0.02
DDAC:CTN (5:1) (Water + Xylene)	0.31	0.04	0.05	0.01	0.33	0.03	0.06	0.02

[1]Initial retentions from outer 3/8" inch of L-joint center section. Each value is the average of 3 analyses of 5 composite samples.
[2]Exposed retentions from inner 1/4" of L-joint tenon.

Table 4.4.6.1 Average Decay Ratings for L-Joints Treated with Water-borne DDAC:Chlorothalonil After 2-Years Exposure.

BIOCIDE (SOLVENT)	L-JOINT TOTAL RETENTION (pcf)[1]	1-YEAR DECAY RATING[1]		2-YEAR DECAY RATING[1]	
		HILO	SAUCIER	HILO	SAUCIER
		DECAY[2]	DECAY[2]	DECAY[2]	DECAY[2]
CONTROL (WATER)	0.000	9.5 ±0.5	10.0 ±0.0	6.5 ± 2.5	10.0 ±0.0
DDAC	0.088	10.0 ±0.0	10.0 ±0.0	10.0 ± 0.0	10.0 ±0.0
(WATER+XYLENE)	0.186	10.0 ±0.0	10.0 ±0.0	10.0 ± 0.0	10.0 ±0.0
	0.254	10.0 ±0.0	10.0 ±0.0	10.0 ± 0.0	10.0 ±0.0
	0.388	10.0 ±0.0	10.0 ±0.0	10.0 ± 0.0	10.0 ±0.0
DDAC:CTN (3:1)	0.032	10.0 ±0.0	10.0 ±0.0	10.0 ± 0.0	10.0 ±0.0
(WATER+XYLENE)	0.067	10.0 ±0.0	10.0 ±0.0	10.0 ± 0.0	10.0 ±0.0
	0.134	10.0 ±0.0	10.0 ±0.0	10.0 ± 0.0	10.0 ±0.0
	0.164	10.0 ±0.0	10.0 ±0.0	10.0 ± 0.0	10.0 ±0.0
	0.260	10.0 ± 0.0	10.0 ±0.0	10.0 ± 0.0	10.0 ±0.0
DDAC:CTN (5:1)	0.041	10.0 ± 0.0	10.0 ±0.0	10.0 ± 0.0	10.0 ±0.0
(WATER+XYLENE)	0.068	10.0 ± 0.0	10.0 ±0.0	10.0 ± 0.0	10.0 ±0.0
	0.140	10.0 ± 0.0	10.0 ±0.0	10.0 ± 0.0	10.0 ±0.0
	0.197	10.0 ±0.0	10.0 ±0.0	10.0 ± 0.0	10.0 ±0.0
	0.267	10.0 ± 0.0	10.0 ±0.0	10.0 ± 0.0	10.0 ±0.0

[1] Average of 10 L-Joints

[2] 10 =no decay; 0 =failure

Table 4.4.6.2 Analysis of variance of decay ratings for Water-borne DDAC:Chlorothalonil Treated L-Joints exposed at Hilo for 2-Years.

Treatment	Retention (pcf)	Avg. Rating[1]	T Grouping[2]				
DDAC in Water	0.088	10.0	A				
DDAC in Water	0.186	10.0	A				
DDAC in Water	0.254	10.0	A				
DDAC in Water	0.388	10.0	A				
DDAC:CTN (3:1)	0.032	10.0	A				
DDAC:CTN (3:1)	0.067	10.0	A				
DDAC:CTN (3:1)	0.134	10.0	A				
DDAC:CTN (3:1)	0.134	10.0	A				
DDAC:CTN (3:1)	0.260	10.0	A				
DDAC:CTN (5:1)	0.041	10.0	A				
DDAC:CTN (5:1)	0.068	10.0	A				
DDAC:CTN (5:1)	0.140	10.0	A				
DDAC:CTN (5:1)	0.197	10.0	A				
DDAC:CTN (5:1)	0.267	10.0	A				
Untreated Control	0.00	6.50		B			

[1]10=No decay, 0=Failure.
[2]Means with the same letter are not significantly different.

Table 4.4.6.3 Analysis of variance of <u>decay</u> ratings for Water-borne DDAC:Chlorothalonil Treated L-Joints exposed at <u>Saucier</u> for 2-Years.

Treatment	Retention (pcf)	Avg. Rating[1]	T Grouping[2]				
DDAC in Water	0.088	10.0	A				
DDAC in Water	0.186	10.0	A				
DDAC in Water	0.254	10.0	A				
DDAC in Water	0.388	10.0	A				
DDAC:CTN (3:1)	0.032	10.0	A				
DDAC:CTN (3:1)	0.067	10.0	A				
DDAC:CTN (3:1)	0.134	10.0	A				
DDAC:CTN (3:1)	0.134	10.0	A				
DDAC:CTN (3:1)	0.260	10.0	A				
DDAC:CTN (5:1)	0.041	10.0	A				
DDAC:CTN (5:1)	0.068	10.0	A				
DDAC:CTN (5:1)	0.140	10.0	A				
DDAC:CTN (5:1)	0.197	10.0	A				
DDAC:CTN (5:1)	0.267	10.0	A				
Untreated Control	0.00	10.0	A				

[1]10=No decay, 0=Failure.

[2]Means with the same letter are not significantly different.

Table 4.5.1.1 Average Retentions of DDAC in Water-borne DDAC:Na Omadine Treated L-Joints After 1-Year Exposure.

BIOCIDE (SOLVENT)	SAUCIER		HILO	
	INITIAL RETENTION (pcf)[1]	1 YEAR EXPOSED RETENTIONS (pcf)[2]	INITIAL RETENTION (pcf)	1 YEAR EXPOSED RETENTIONS (pcf)
	DDAC	DDAC	DDAC	DDAC
DDAC (WATER)	0.225	0.309	0.303	0.307
DDAC:Na OMADINE (4:1) (WATER)	0.196	0.235	0.258	0.215
DDAC:Na OMADINE (7:1) (WATER)	0.219	0.268	0.273	0.311

[1]Initial retentions from outer 3/8" inch of L-joint center section. Each value is the average of 3 analyses of 5 composite samples.
[2]Exposed retentions from inner 1/4" of L-joint tenon.

Table 4.5.2.1 Average Decay Ratings for the Water-borne DDAC:Na Omadine Treated L-Joints After 1, 2 and 2.5-Years Exposure.

BIOCIDE (SOLVENT)	L-JOINT TOTAL RETENTION (pcf)	1-YEAR DECAY RATING[1]		2-YEAR DECAY RATING[1]		2.5 YEAR DECAY RATING[1]	
		HILO	SAUCIER	HILO	SAUCIER	HILO	SAUCIER
		DECAY[2]	DECAY[2]	DECAY[2]	DECAY[2]	DECAY[2]	DECAY[2]
CONTROL	0.000	9.8 ±0.3	9.8 ±0.3	8.5 ± 1.2	9.8 ± 0.4	7.1 ± 2.8	9.3 ± 0.5
DDAC	0.088	10.0 ±0.0	10.0 ±0.0	9.9 ± 0.3	10.0 ±0.0	9.6 ± 0.7	10.0 ± 0.0
(WATER)	0.169	10.0 ±0.0	10.0 ±0.0	10.0 ±0.0	10.0 ±0.0	10.0 ± 0.0	10.0 ± 0.0
	0.259	10.0 ±0.0	10.0 ±0.0	10.0 ±0.0	10.0 ±0.0	9.9 ± 0.3	10.0 ± 0.0
	0.335	10.0 ±0.0	10.0 ±0.0	10.0 ±0.0	10.0 ±0.0	10.0 ± 0.0	10.0 ± 0.0
Na Omadine	0.015	10.0 ±0.0	10.0 ±0.0	7.7 ± 2.8	10.0 ±0.0	6.6 ± 2.4	9.6 ± 0.7
(WATER)	0.037	10.0 ±0.0	10.0 ±0.0	9.6 ± 0.7	10.0 ±0.0	8.9 ± 1.19	9.3 ± 0.8
	0.073	10.0 ±0.0	10.0 ±0.0	6.7 ± 3.7	10.0 ±0.0	8.0 ± 5.1	9.5 ± 0.7
	0.127	10.0 ±0.0	10.0 ±0.0	8.4 ± 1.3	10.0 ±0.0	7.9 ± 0.83	8.9 ± 1.1
DDAC:Na Omadine (4:1)	0.039	10.0 ± 0.0	10.0 ±0.0	9.5 ± 0.5	10.0 ±0.0	3.6 ± 4.11	9.9 ± 0.3
(WATER)	0.085	10.0 ± 0.0	10.0 ±0.0	9.9 ± 0.3	10.0 ±0.0	6.1 ± 4.28	10.0 ± 0.0
	0.154	10.0 ± 0.0	10.0 ±0.0	10.0 ±0.0	10.0 ±0.0	8.1 ± 1.37	10.0 ± 0.0
	0.239	10.0 ± 0.0	10.0 ±0.0	10.0 ±0.0	10.0 ±0.0	9.2 ± 1.03	10.0 ± 0.0
	0.363	10.0 ±0.0	10.0 ±0.0	9.8 ± 0.4	10.0 ±0.0	9.6 ± 0.7	10.0 ± 0.0
DDAC:Na Omadine (7:1)	0.057	10.0 ± 0.0	10.0 ±0.0	9.5 ± 0.8	10.0 ±0.0	9.4 ± 0.6	10.0 ± 0.0
(WATER)	0.077	10.0 ± 0.0	10.0 ±0.0	9.9 ± 0.3	10.0 ±0.0	7.5 ± 4.08	10.0 ± 0.0
	0.143	10.0 ± 0.0	10.0 ±0.0	10.0 ±0.0	10.0 ±0.0	9.4 ± 0.7	10.0 ± 0.0
	0.209	10.0 ± 0.0	10.0 ±0.0	10.0 ±0.0	10.0 ±0.0	9.8 ± 0.4	10.0 ± 0.0
CCA	0.27	10.0 ± 0.0	10.0 ± 0.0	10.0 ±0.0	10.0 ±0.0	10.0 ± 0.0	10.0 ± 0.0
(WATER)	0.56	10.0 ± 0.0	10.0 ± 0.0	10.0 ±0.0	10.0 ±0.0	10.0 ± 0.0	10.0 ± 0.0
	0.88	10.0 ± 0.0	10.0 ± 0.0	10.0 ±0.0	10.0 ±0.0	10.0 ± 0.0	10.0 ± 0.0

[1]Average of 10 L-Joints.
[2]10=No decay, 0=Failure.

Table 4.5.2.2 Analysis of variance of decay ratings for Water-borne DDAC:NaOmadine Treated L-Joints exposed at Saucier for 2.5 Years.

Treatment	Retention (pcf)	Avg. Rating[1]	T Grouping[2]				
CCA in Water	0.27	10.0	A				
CCA in Water	0.56	10.0	A				
CCA in Water	0.88	10.0	A				
DDAC:NaOmadine (4:1)	0.239	10.0	A				
DDAC:NaOmadine (4:1)	0.363	10.0	A				
DDAC:NaOmadine (7:1)	0.057	10.0	A				
DDAC:NaOmadine (7:1)	0.077	10.0	A				
DDAC:NaOmadine (4:1)	0.085	10.0	A				
DDAC:NaOmadine (7:1)	0.143	10.0	A				
DDAC:NaOmadine (4:1)	0.154	10.0	A				
DDAC:NaOmadine (7:1)	0.209	10.0	A				
DDAC	0.259	10.0	A				
DDAC	0.335	10.0	A				
DDAC	0.088	10.0	A				
DDAC	0.169	10.0	A				
DDAC:NaOmadine (4:1)	0.039	9.9	A	B			
NaOmadine	0.015	9.6		B	C		
NaOmadine	0.073	9.5			C		
NaOmadine	0.037	9.3			C		
Control	0.00	9.3			C		
NaOmadine	0.127	8.9				D	

[1] 10=No decay, 0=Failure.
[2] Means with the same letter are not significantly different.

Table 4.5.2.3 Analysis of variance of decay ratings for Water-borne DDAC:NaOmadine Treated L-Joints exposed at Hilo for 2.5 Years.

Treatment	Retention (pcf)	Avg. Rating[1]	T Grouping[2]						
CCA in Water	0.270	10.00	A						
CCA in Water	0.560	10.00	A						
CCA in Water	0.880	10.00	A						
DDAC	0.335	10.00	A						
DDAC	0.169	10.00	A						
DDAC	0.259	9.90	A						
DDAC:NaOmadine (7:1)	0.209	9.80	A						
DDAC	0.088	9.60	A	B					
DDAC:NaOmadine (4:1)	0.363	9.60	A	B					
DDAC:NaOmadine (7:1)	0.057	9.40	A	B					
DDAC:NaOmadine (7:1)	0.143	9.40	A	B					
DDAC:NaOmadine (4:1)	0.239	9.20	A	B	C				
NaOmadine	0.037	8.90	A	B	C	D			
DDAC:NaOmadine (4:1)	0.154	8.10	A	B	C	D	E		
NaOmadine	0.073	8.00	A	B	C	D	E	F	
NaOmadine	0.127	7.90		B	C	D	E	F	
DDAC:NaOmadine (7:1)	0.077	7.50			C	D	E	F	
Control	0.000	7.10				D	E	F	
NaOmadine	0.015	6.60				D	E	F	
DDAC:NaOmadine (4:1)	0.085	6.10						F	
DDAC:NaOmadine (4:1)	0.039	3.60							G

[1] 10=No decay, 0=Failure.
[2] Means with the same letter are not significantly different.

Table 4.6.1.1 Average Retentions of DDAC in L-joints Treated with Water-Borne DDAC:NaOmadine:PABA After 1-Year Exposure.

BIOCIDE (SOLVENT)	SAUCIER		HILO	
	INITIAL RETENTION (pcf)[1]	1 YEAR EXPOSED RETENTIONS (pcf)[2]	INITIAL RETENTION (pcf)	1 YEAR EXPOSED RETENTIONS (pcf)
	DDAC	DDAC	DDAC	DDAC
DDAC (PABA)	0.237	0.160	0.239	0.236
DDAC:NaOMADINE (4:1) (PABA)	0.248	0.010[3]	0.242	0.215
DDAC:NaOMADINE (7:1) (PABA)	0.256	0.234	0.261	0.214

[1]Initial retentions from outer 3/8" inch of L-joint center section. Each value is the average of 3 analyses of 5 composite samples.
[2]Exposed retentions from inner 1/4" of L-joint tenon.
[3]This DDAC value is unrealistically low, and needs to be re-evaluated.

Table 4.6.2.1 Average Decay Ratings for DDAC:Na Omadine + PABA Treated L-Joints After 1- and 2-Years Exposure.

BIOCIDE (SOLVENT)	L-JOINT TOTAL RETENTION (pcf)	1-YEAR DECAY RATING[1]		2-YEAR DECAY RATING[1]	
		HILO	SAUCIER	HILO	SAUCIER
		DECAY[2]	DECAY[2]	DECAY[2]	DECAY[2]
CONTROL + PABA	0.000	10.0 ±0.0	9.8 ± 0.2	10.0 ± 0.0	9.8 ± 0.2
DDAC + PABA	0.088	10.0 ±0.0	10.0 ± 0.0	10.0 ± 0.0	10.0 ± 0.0
(WATER)	0.149	10.0 ±0.0	10.0 ± 0.0	10.0 ± 0.0	10.0 ± 0.0
	0.206	10.0 ±0.0	10.0 ± 0.0	10.0 ± 0.0	10.0 ± 0.0
	0.377	10.0 ±0.0	10.0 ± 0.0	10.0 ± 0.0	10.0 ± 0.0
NaOMADINE + PABA	0.015	10.0 ±0.0	10.0 ± 0.0	10.0 ± 0.0	10.0 ± 0.0
(WATER)	0.031	10.0 ±0.0	10.0 ± 0.0	10.0 ± 0.0	10.0 ± 0.0
	0.060	10.0 ±0.0	10.0 ± 0.0	10.0 ± 0.0	10.0 ± 0.0
	0.124	10.0 ±0.0	10.0 ± 0.0	10.0 ± 0.0	10.0 ± 0.0
DDAC:Na OMADINE	0.039	10.0 ± 0.0	10.0 ± 0.0	10.0 ± 0.0	10.0 ± 0.0
+ PABA (4:1)	0.076	10.0 ± 0.0	10.0 ± 0.0	10.0 ± 0.0	10.0 ± 0.0
(WATER)	0.148	10.0 ± 0.0	10.0 ± 0.0	10.0 ± 0.0	10.0 ± 0.0
	0.269	10.0 ± 0.0	10.0 ± 0.0	10.0 ± 0.0	10.0 ± 0.0
	0.347	10.0 ±0.0	10.0 ± 0.0	10.0 ± 0.0	10.0 ± 0.0
DDAC:Na OMADINE	0.064	10.0 ± 0.0	10.0 ± 0.0	10.0 ± 0.0	10.0 ± 0.0
+ PABA (7:1)	0.078	10.0 ± 0.0	10.0 ± 0.0	10.0 ± 0.0	10.0 ± 0.0
(WATER)	0.164	10.0 ± 0.0	10.0 ± 0.0	10.0 ± 0.0	10.0 ± 0.0
	0.234	10.0 ± 0.0	10.0 ± 0.0	10.0 ± 0.0	10.0 ± 0.0
	0.326	10.0 ± 0.0	10.0 ± 0.0	10.0 ± 0.0	10.0 ± 0.0
CCA	0.27	10.0 ± 0.0	10.0 ± 0.0	10.0 ± 0.0	10.0 ± 0.0
(WATER)	0.56	10.0 ± 0.0	10.0 ± 0.0	10.0 ± 0.0	10.0 ± 0.0
	0.88	10.0 ± 0.0	10.0 ± 0.0	10.0 ± 0.0	10.0 ± 0.0

[1]Average of 10 L-Joints.
[2]10=No decay, 0=Failure

Table 4.6.2.2 Analysis of variance of decay ratings for DDAC:Na Omadine + PABA Treated L-Joints exposed at Hilo for 2 Years.

Treatment	Retention (pcf)	Avg. Rating[1]	T Grouping[2]				
DDAC +PABA in Water	0.088	10.0	A				
DDAC +PABA in Water	0.149	10.0	A				
DDAC +PABA in Water	0.206	10.0	A				
DDAC +PABA in Water	0.377	10.0	A				
NaOmadine + PABA in Water	0.015	10.0	A				
NaOmadine + PABA in Water	0.031	10.0	A				
NaOmadine + PABA in Water	0.060	10.0	A				
NaOmadine + PABA in Water	0.124	10.0	A				
DDAC:NaOmadine + PABA (4:1)	0.039	10.0	A				
DDAC:NaOmadine + PABA (4:1)	0.076	10.0	A				
DDAC:NaOmadine + PABA (4:1)	0.148	10.0	A				
DDAC:NaOmadine + PABA (4:1)	0.269	10.0	A				
DDAC:NaOmadine + PABA (4:1)	0.347	10.0	A				
DDAC:NaOmadine + PABA (7:1)	0.064	10.0	A				
DDAC:NaOmadine + PABA (7:1)	0.078	10.0	A				
DDAC:NaOmadine + PABA (7:1)	0.164	10.0	A				
DDAC:NaOmadine + PABA (7:1)	0.234	10.0	A				
DDAC:NaOmadine + PABA (7:1)	0.326	10.0	A				
CCA in Water	0.27	10.0	A				
CCA in Water	0.56	10.0	A				
CCA in Water	0.88	10.0	A				
Untreated Control + PABA	0.00	10.0	A				

[1]10=No decay, 0= Failure.

[2]Means with the same letter are not significantly different.

Table 4.6.2.3 Analysis of variance of decay ratings for DDAC:Na Omadine + PABA Treated L-Joints exposed at Saucier for 2 Years.

Treatment	Retention (pcf)	Avg. Rating[2]	T Grouping[1]				
DDAC +PABA in Water	0.088	10.0	A				
DDAC +PABA in Water	0.149	10.0	A				
DDAC +PABA in Water	0.206	10.0	A				
DDAC +PABA in Water	0.377	10.0	A				
NaOmadine + PABA in Water	0.015	10.0	A				
NaOmadine + PABA in Water	0.031	10.0	A				
NaOmadine + PABA in Water	0.060	10.0	A				
NaOmadine + PABA in Water	0.124	10.0	A				
DDAC:NaOmadine + PABA (4:1)	0.039	10.0	A				
DDAC:NaOmadine + PABA (4:1)	0.076	10.0	A				
DDAC:NaOmadine + PABA (4:1)	0.148	10.0	A				
DDAC:NaOmadine + PABA (4:1)	0.269	10.0	A				
DDAC:NaOmadine + PABA (4:1)	0.347	10.0	A				
DDAC:NaOmadine + PABA (7:1)	0.064	10.0	A				
DDAC:NaOmadine + PABA (7:1)	0.078	10.0	A				
DDAC:NaOmadine + PABA (7:1)	0.164	10.0	A				
DDAC:NaOmadine + PABA (7:1)	0.234	10.0	A				
DDAC:NaOmadine + PABA (7:1)	0.326	10.0	A				
CCA in Water	0.27	10.0	A				
CCA in Water	0.56	10.0	A				
CCA in Water	0.88	10.0	A				
Untreated Control + PABA	0.00	9.80	A	B			

[1]10=No decay, 0=Failure.
[2]Means with the same letter are not significantly different.

APPENDIX C

FIGURES

Figure 4.2.1.1. Average Strength Loss for Oil-borne DDAC:Chlorothalonil, Penta and CCA Treated Fungus Cellar Stakes After 96-Weeks Exposure to Dorman Soil.

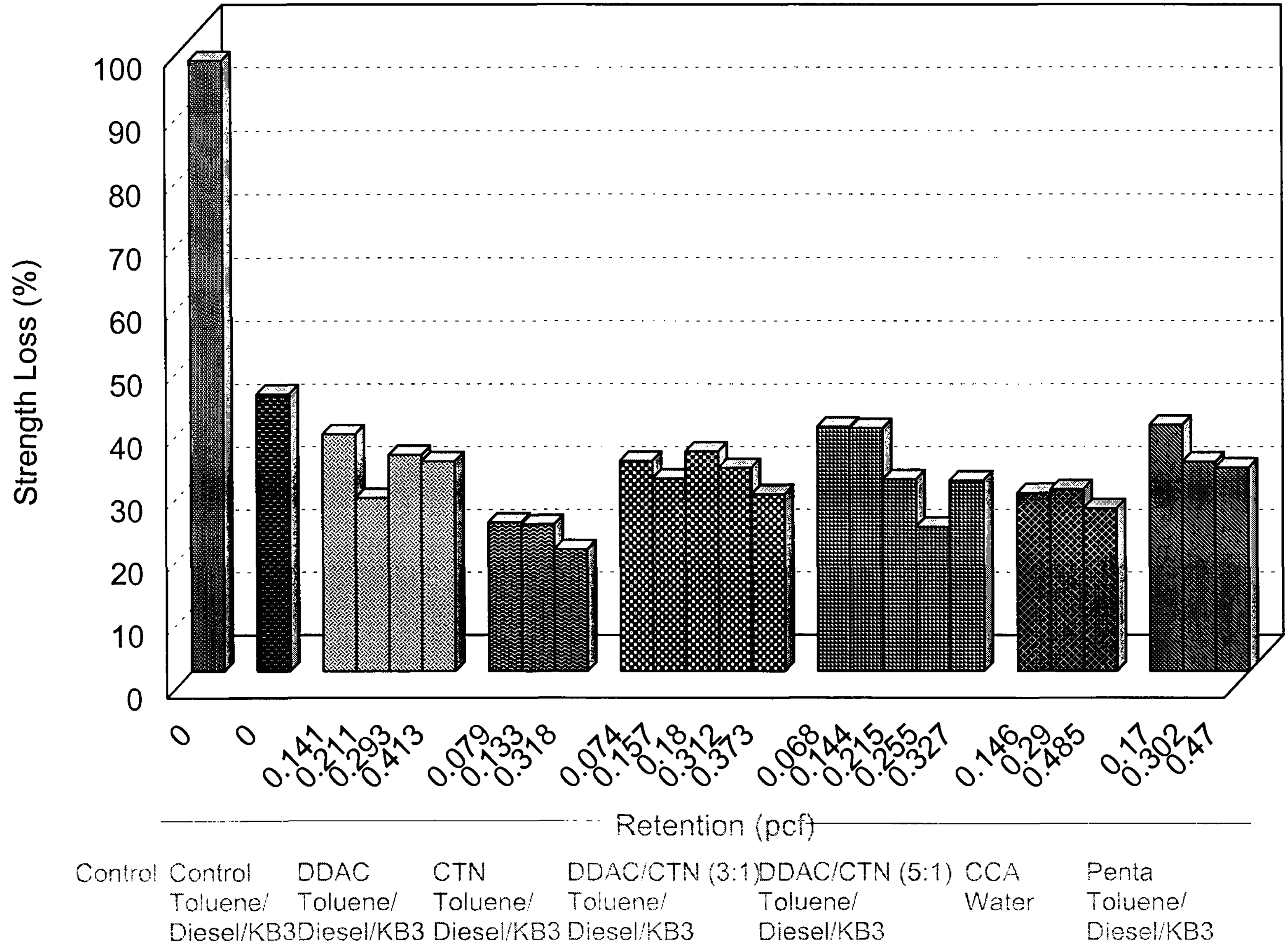


Figure 4.2.1.2. Average Strength Loss for Oil-borne DDAC:Chlorothalonil and CCA Treated Fungus Cellar Stakes After 96-Weeks Exposure to Saucier Soil.

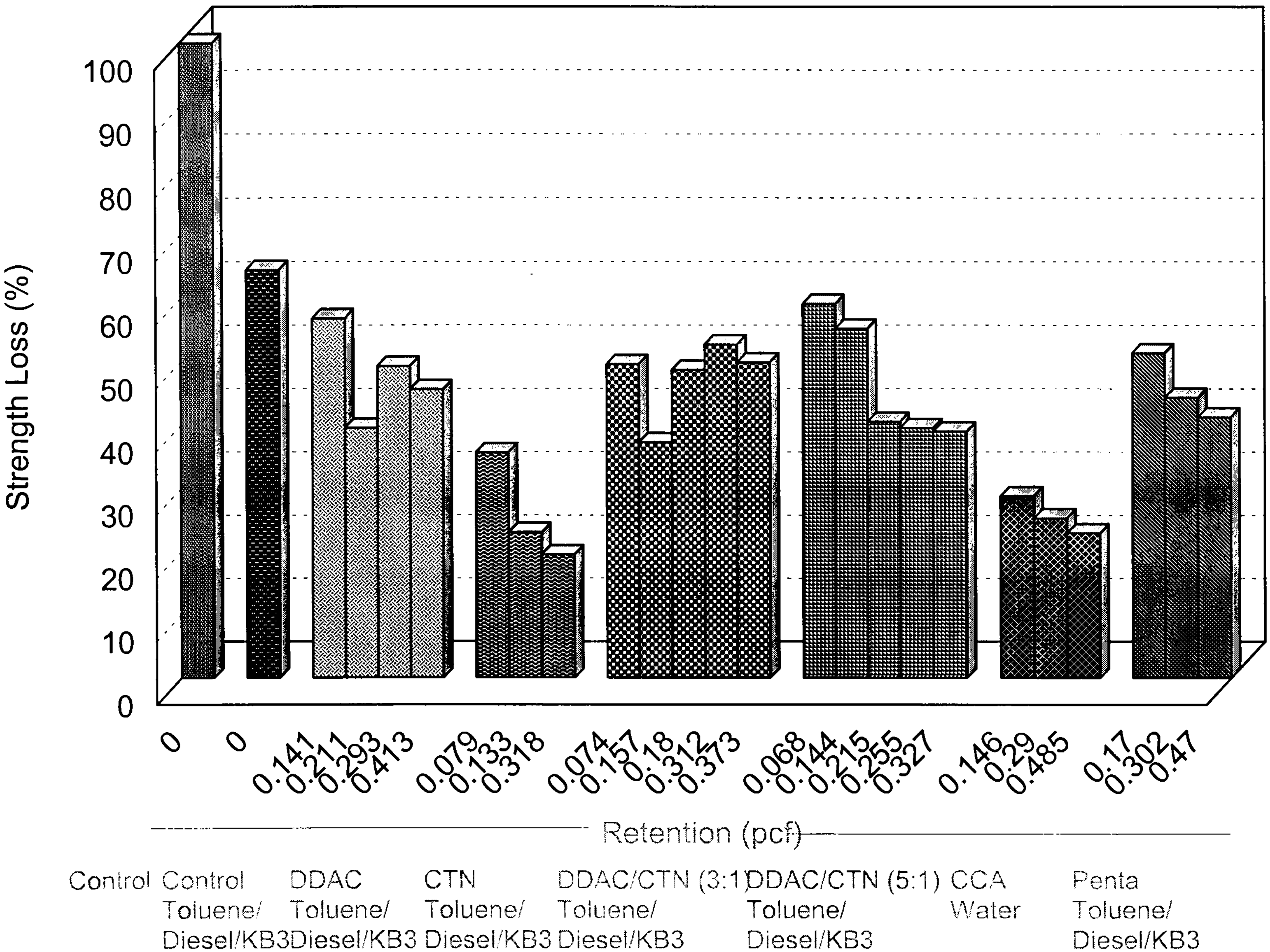


Figure 4.2.2.1. **Average Percent Depeletion for Oil-borne DDAC:Chlorothalonil and CCA Treated Fungus Cellar Stakes After 12- Weeks Exposure To Dorman and Saucier Soil.**

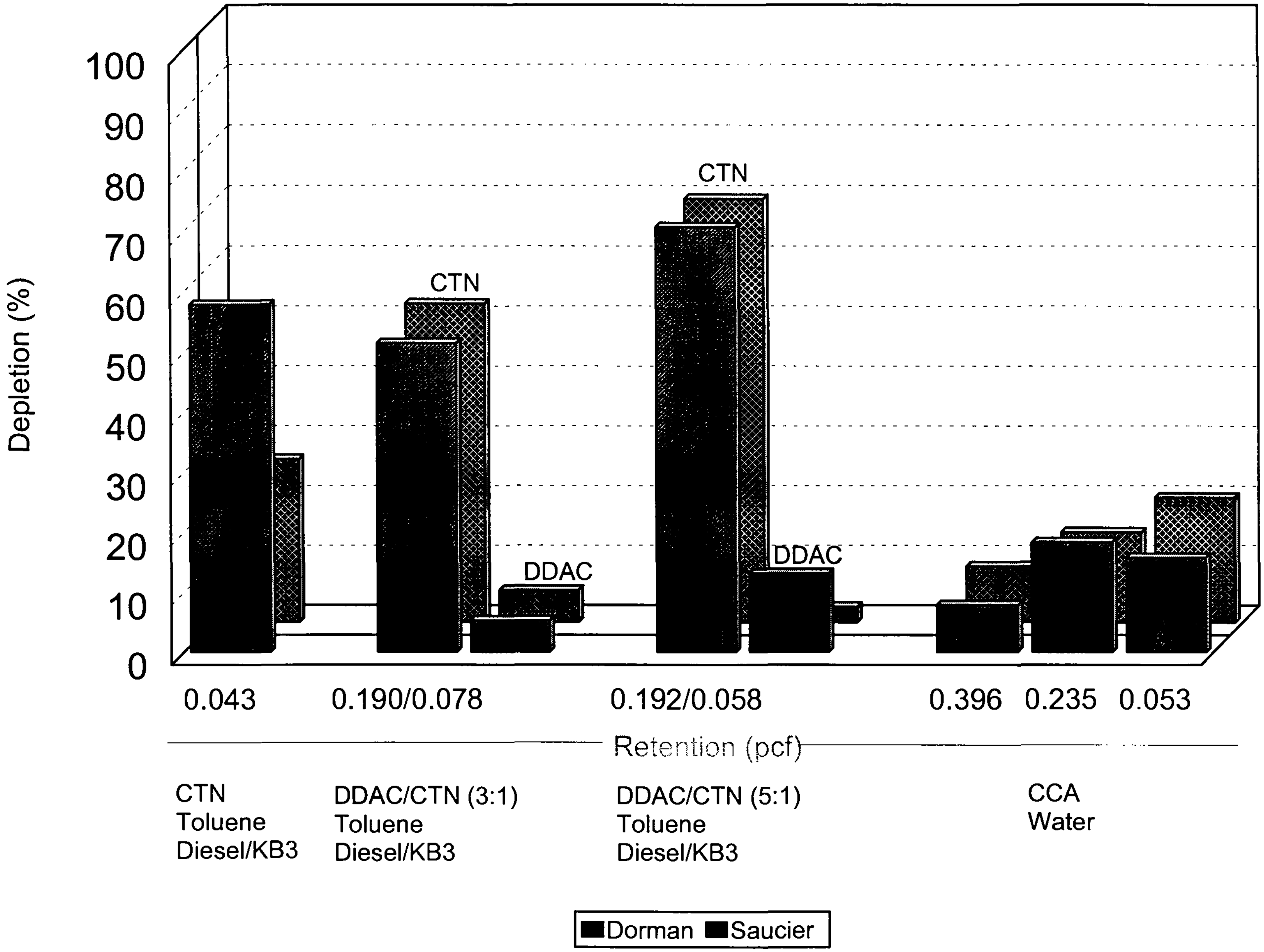


Figure 4.2.3.1. Average Percent Depletion for Oil-borne DDAC:Chlorothalonil and CCA Treated Field Stakes After 1-Year Exposure.

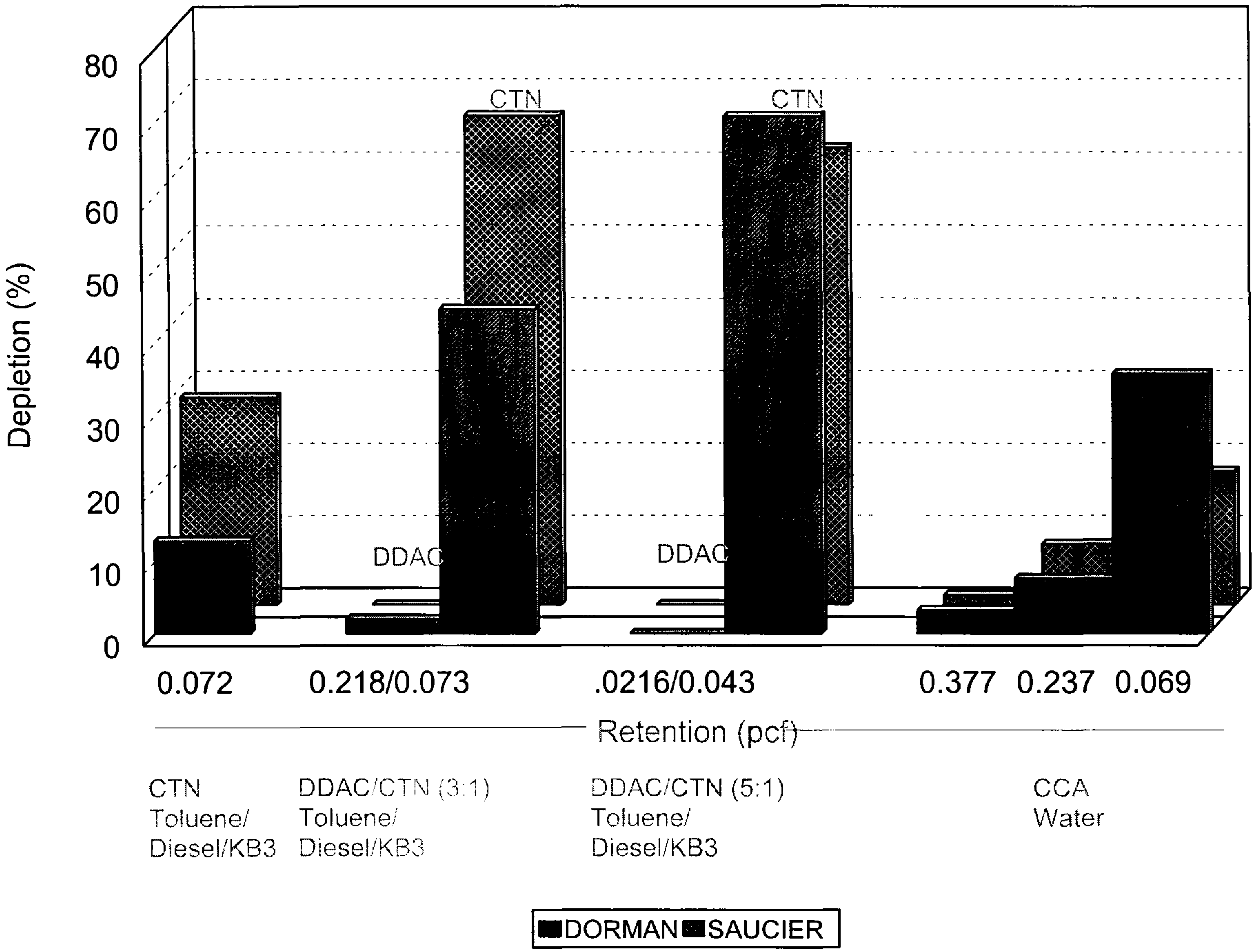


Figure 4.2.3.2. Average Percent Depletion for Oil-borne DDAC:Chlorothalonil and CCA Treated Field Stakes After 3-Year Exposure.

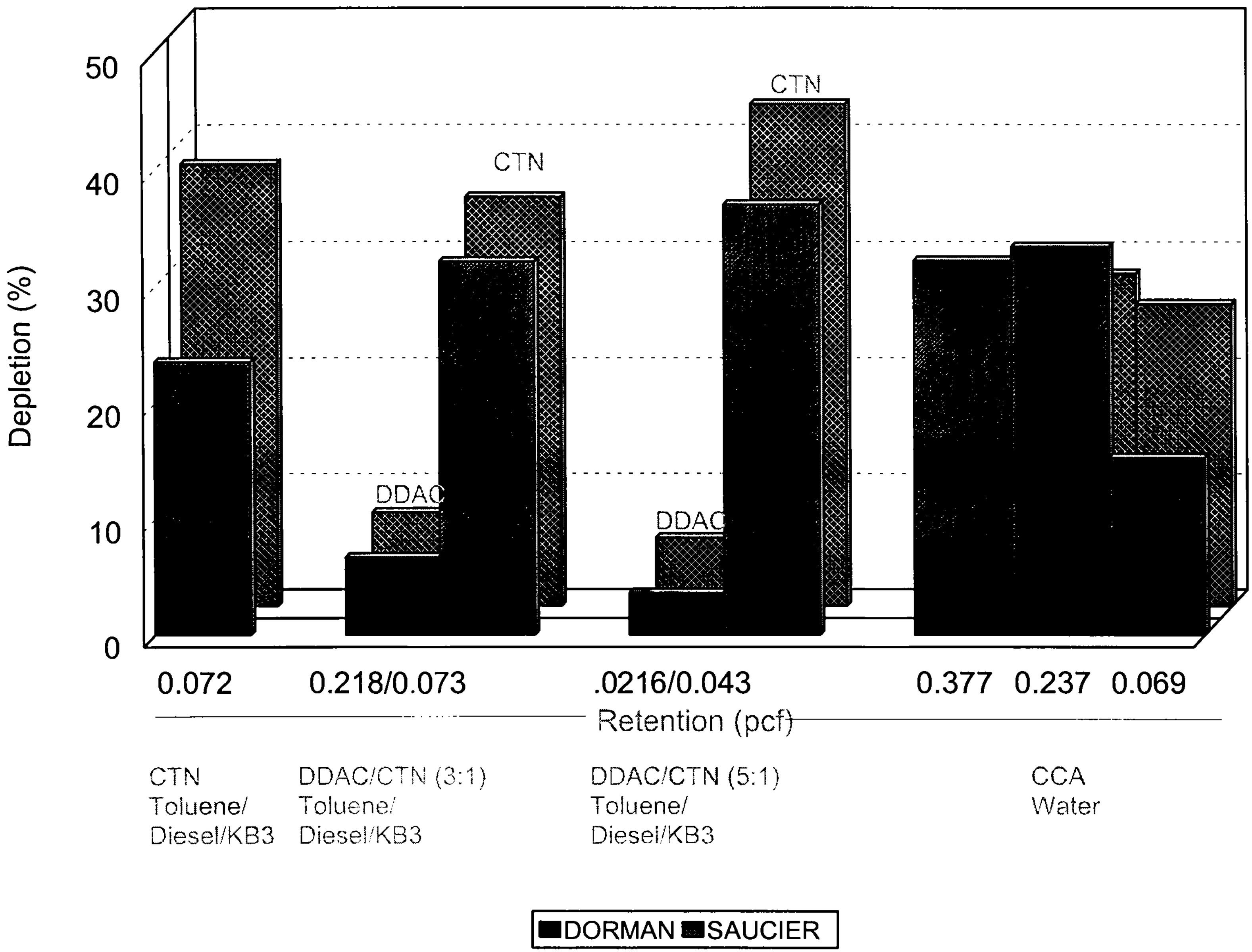


Figure 4.2.4.1. Average Decay and Termite Ratings for Oil-borne DDAC:Chlorothalonil, Penta and CCA Treated Field Stakes After 3-Years Exposure at Dorman.

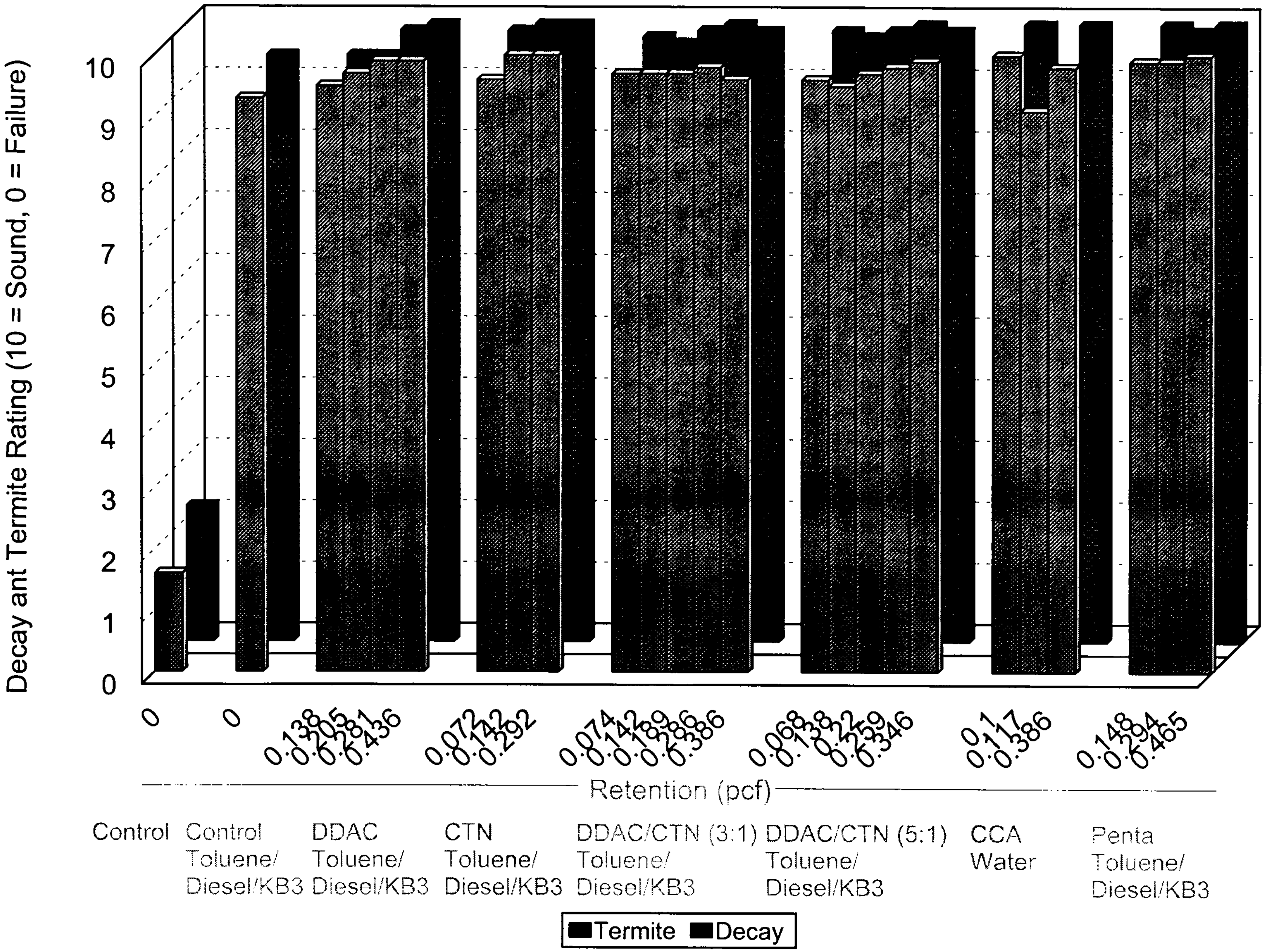


Figure 4.2.4.2. Average Decay and Termite Ratings for Oil-borne DDAC:Chlorothalonil, Penta and CCA Treated Field Stakes After 3-Years Exposure at Saucier.

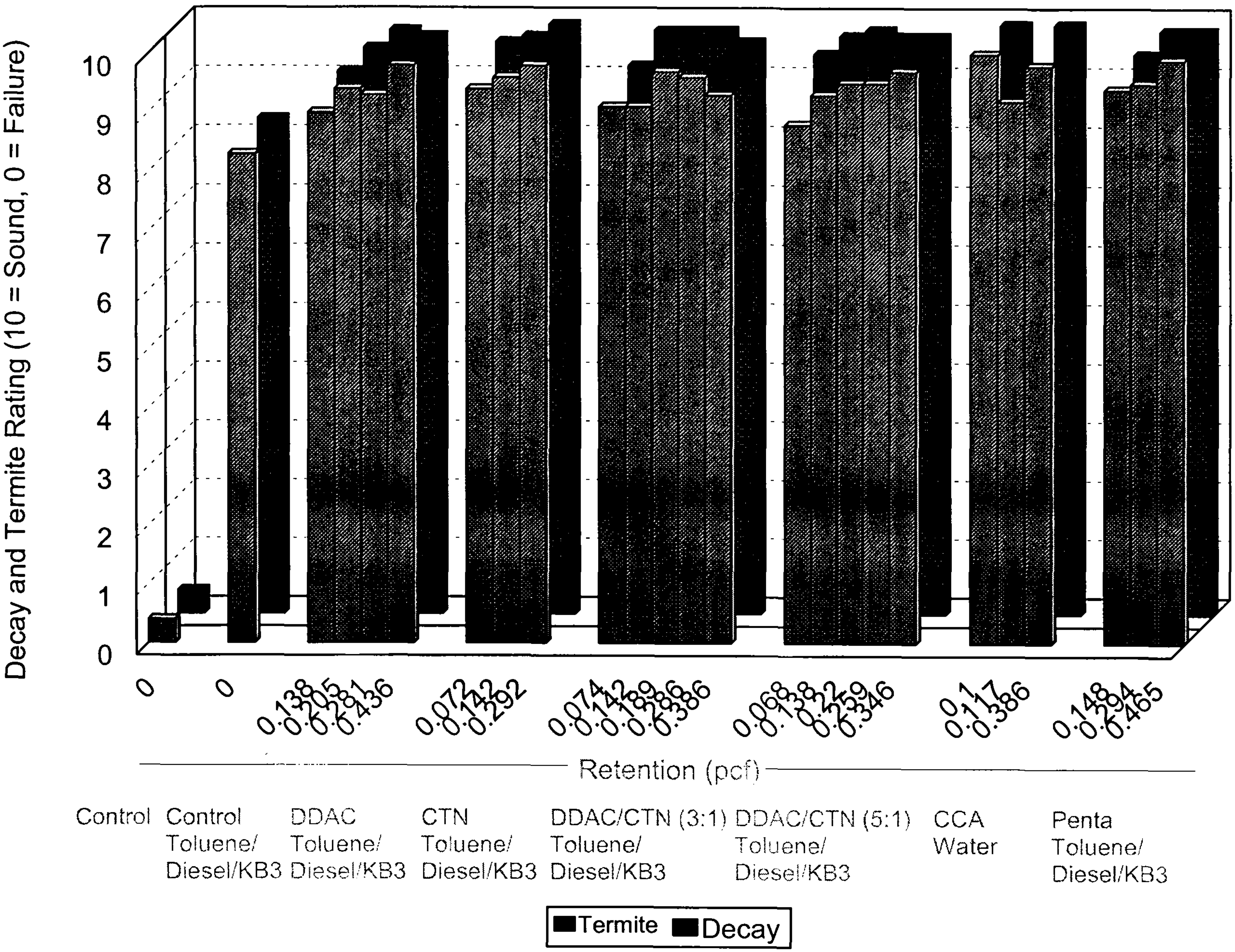


Figure 4.3.1.1. Average Strength Loss for Water-borne DDAC:Tribromophenol and CCA Treated Stakes After 80-Weeks Exposure to Dorman Soil in The Fungus Cellar.

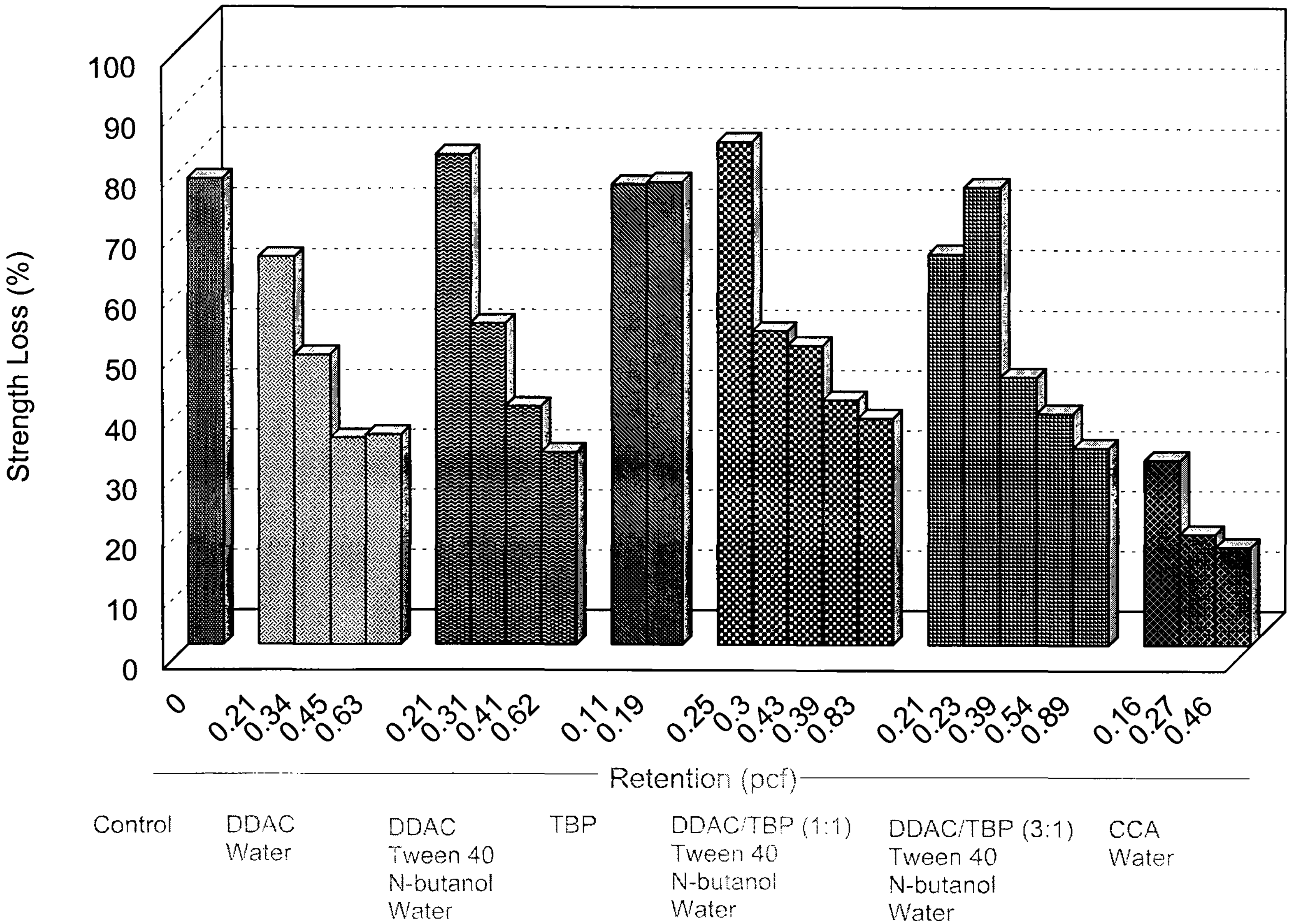


Figure 4.3.1.2. Average Strength Loss for Water-borne DDAC:Tribromophenol and CCA Treated Stakes After 80-Weeks Exposure to Saucier Soil In The Fungus Cellar.

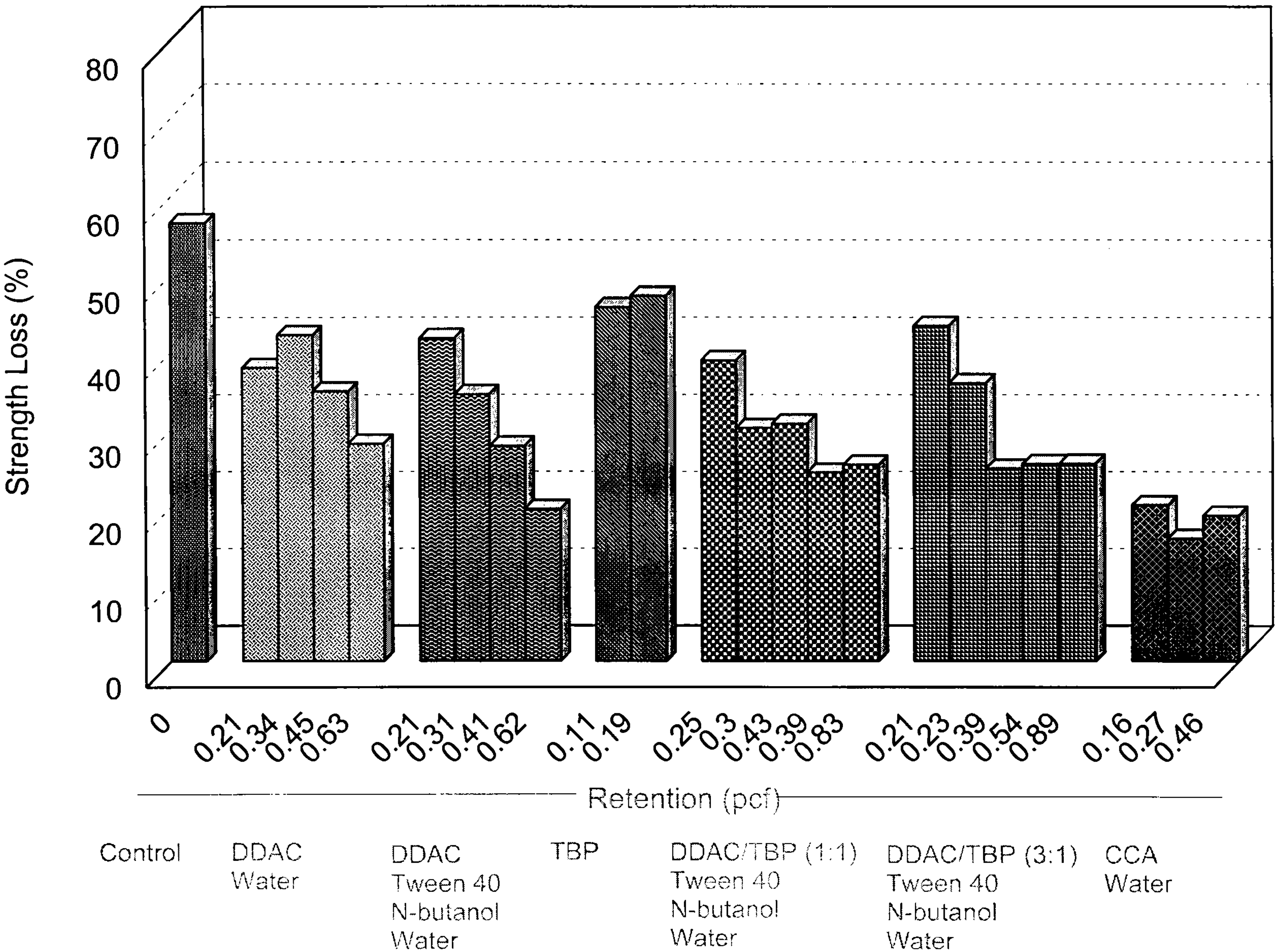


Figure 4.3.2.1. Average Percent Depeletion for Water-borne DDAC:Tribrormophenol and CCA Treated Fungus Cellar Stakes After 12-Weeks Exposure.

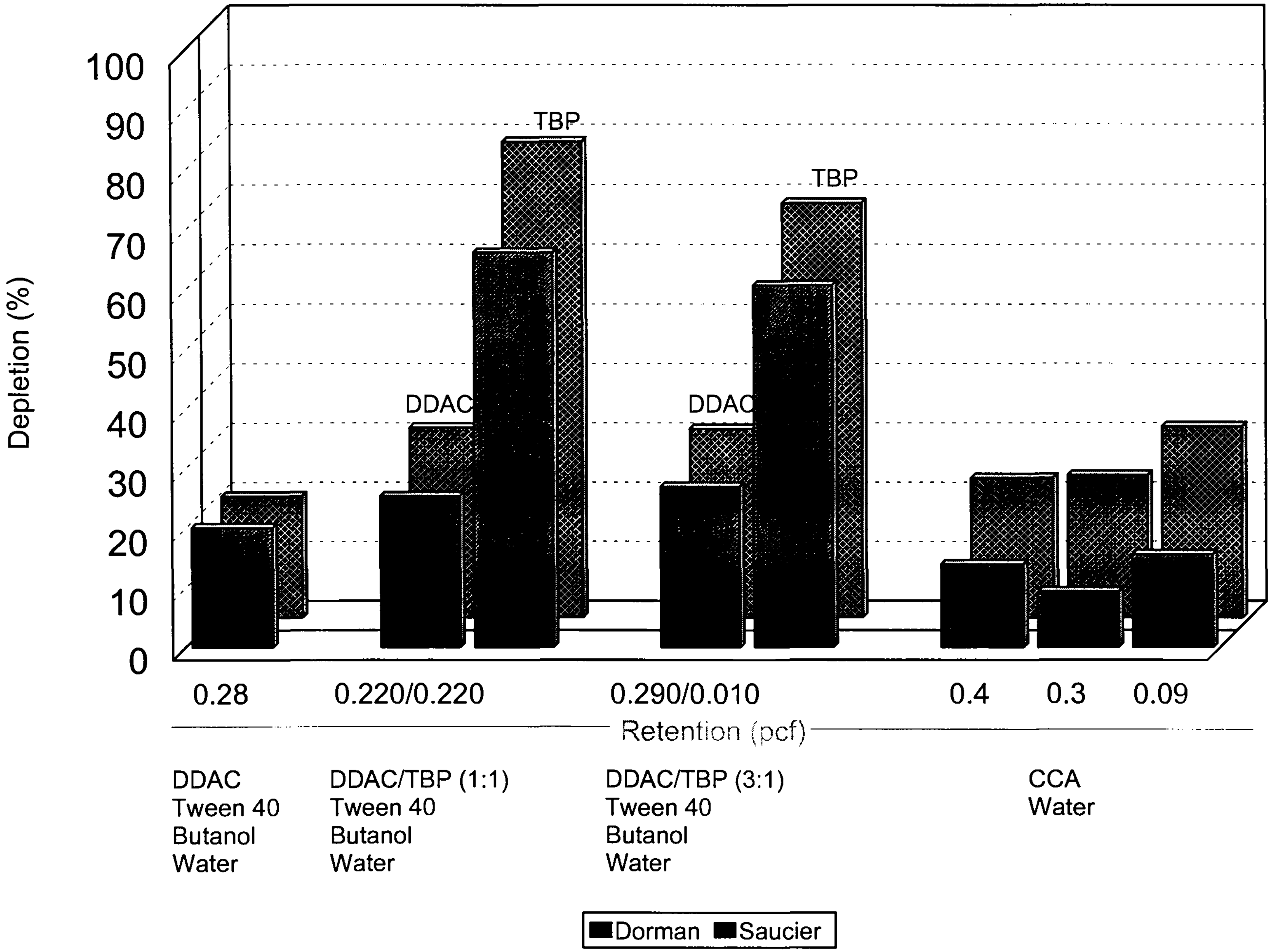


Figure 4.3.2.2. Average Percent Depletion for Water-borne DDAC:Tribromophenol Treated Fungus Cellar Stakes After 36-Weeks Exposure.

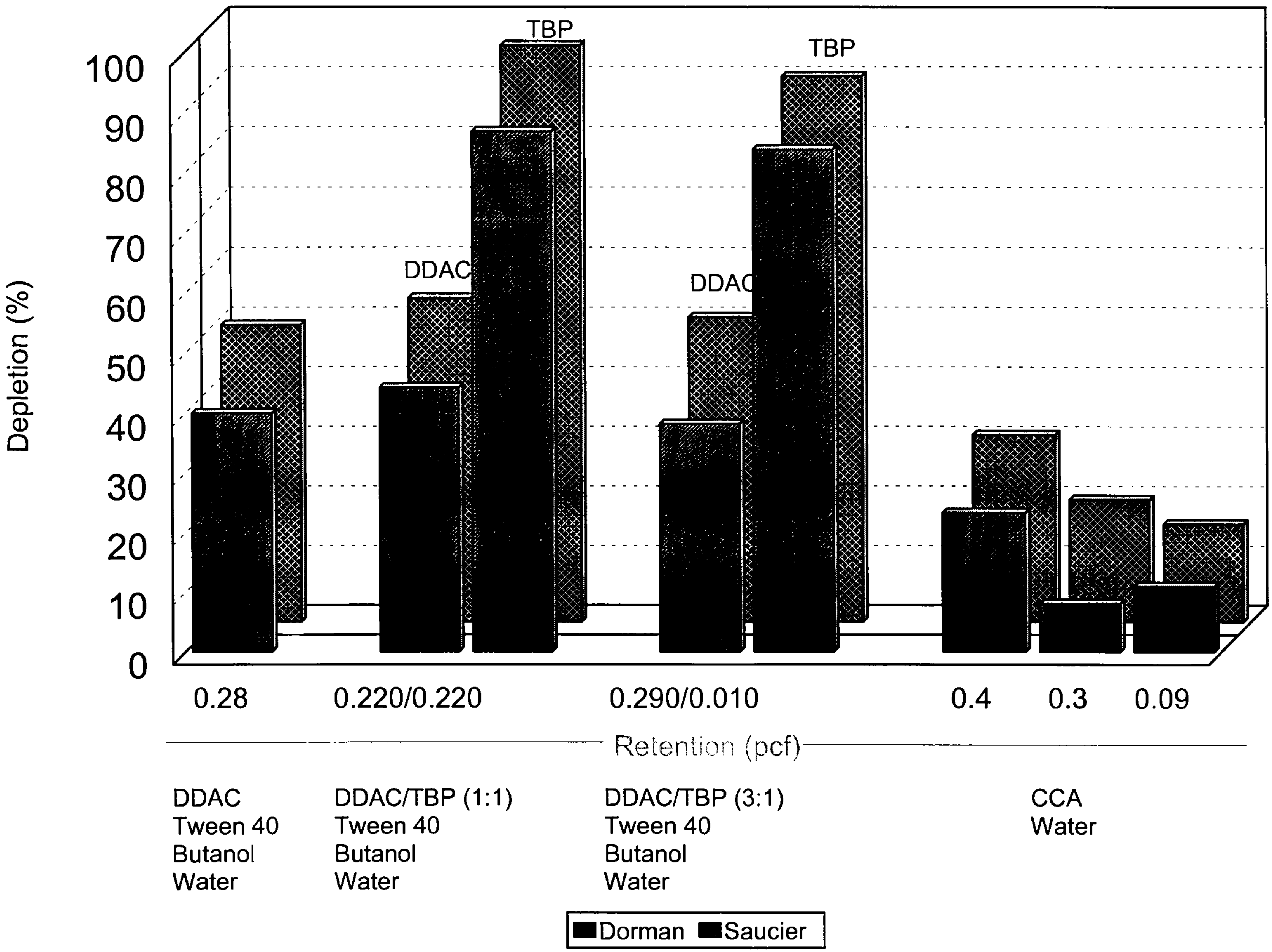


Figure 4.3.3.1. Average Percent Depletion of Water-borne DDAC:Tribromophenol and CCA Treated Field Stakes After 1-Year Exposure.

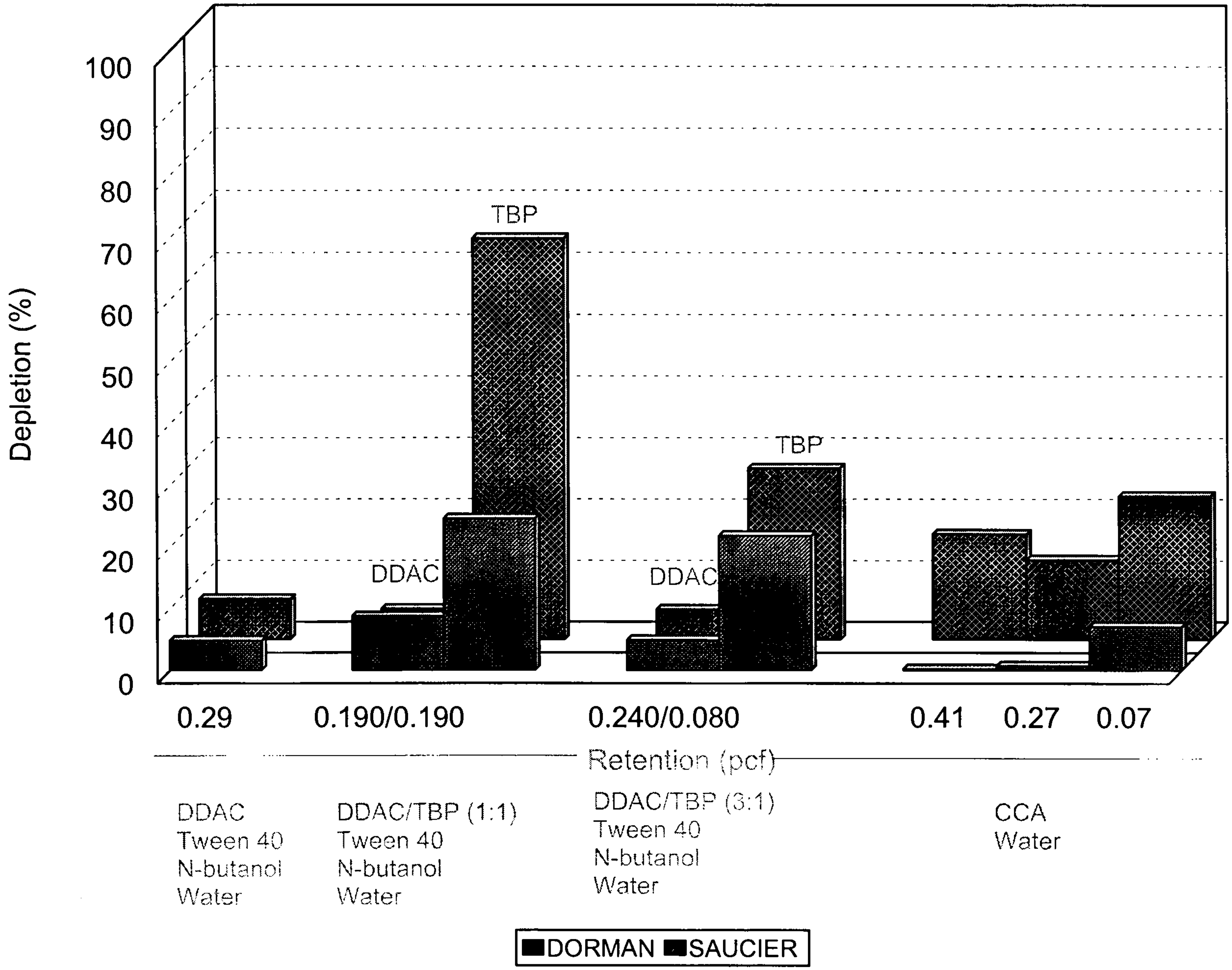


Figure 4.3.3.2 Average Percent Depletion of Water-borne DDAC:Tribromophenol and CCA Treated Field Stakes After 2-Year Exposure.

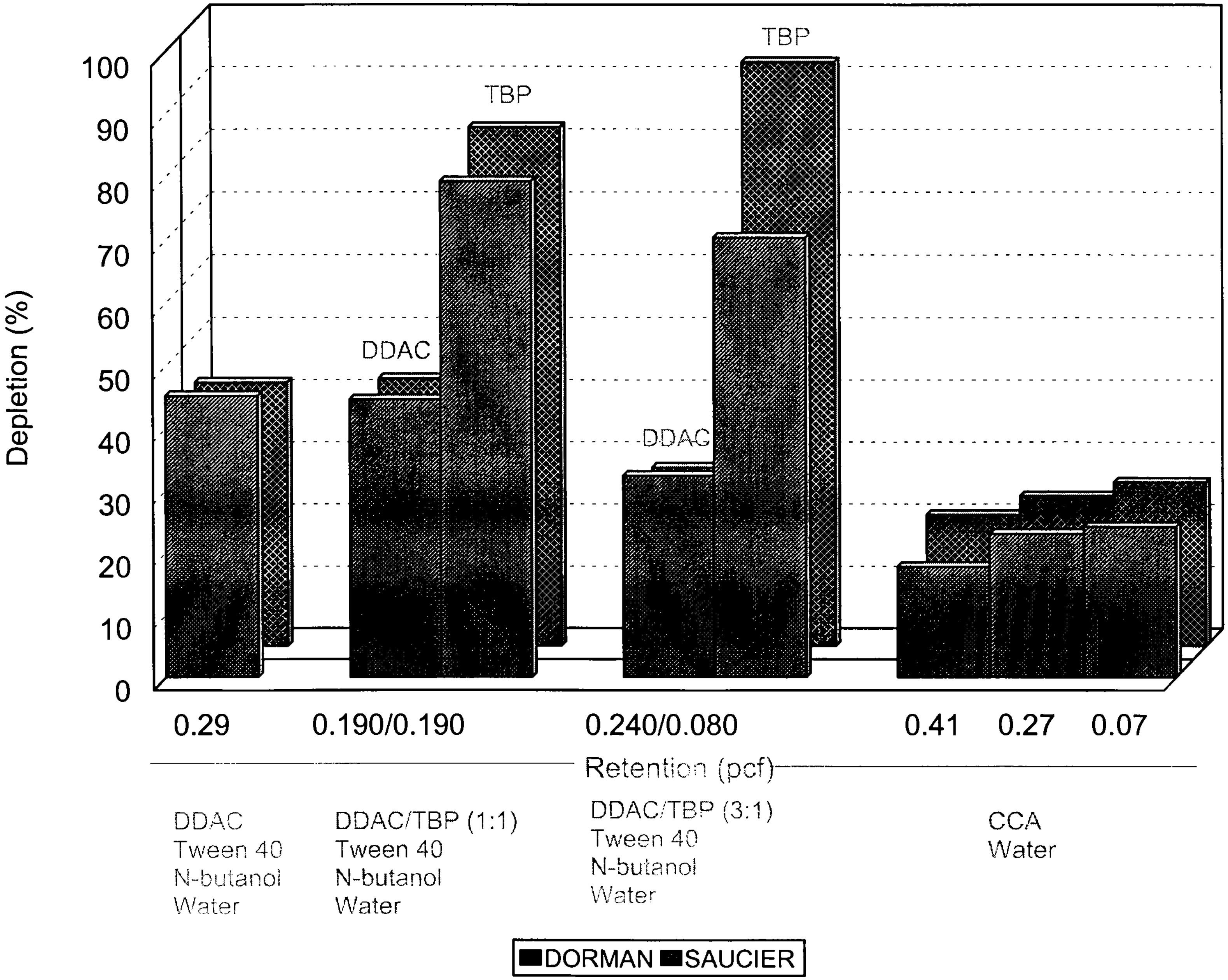


Figure 4.3.4.1. Average Decay and Termite Ratings for Water-borne DDAC:Tribromophenol and CCA Treated Field Stakes After 2-Years Exposure at Dorman.

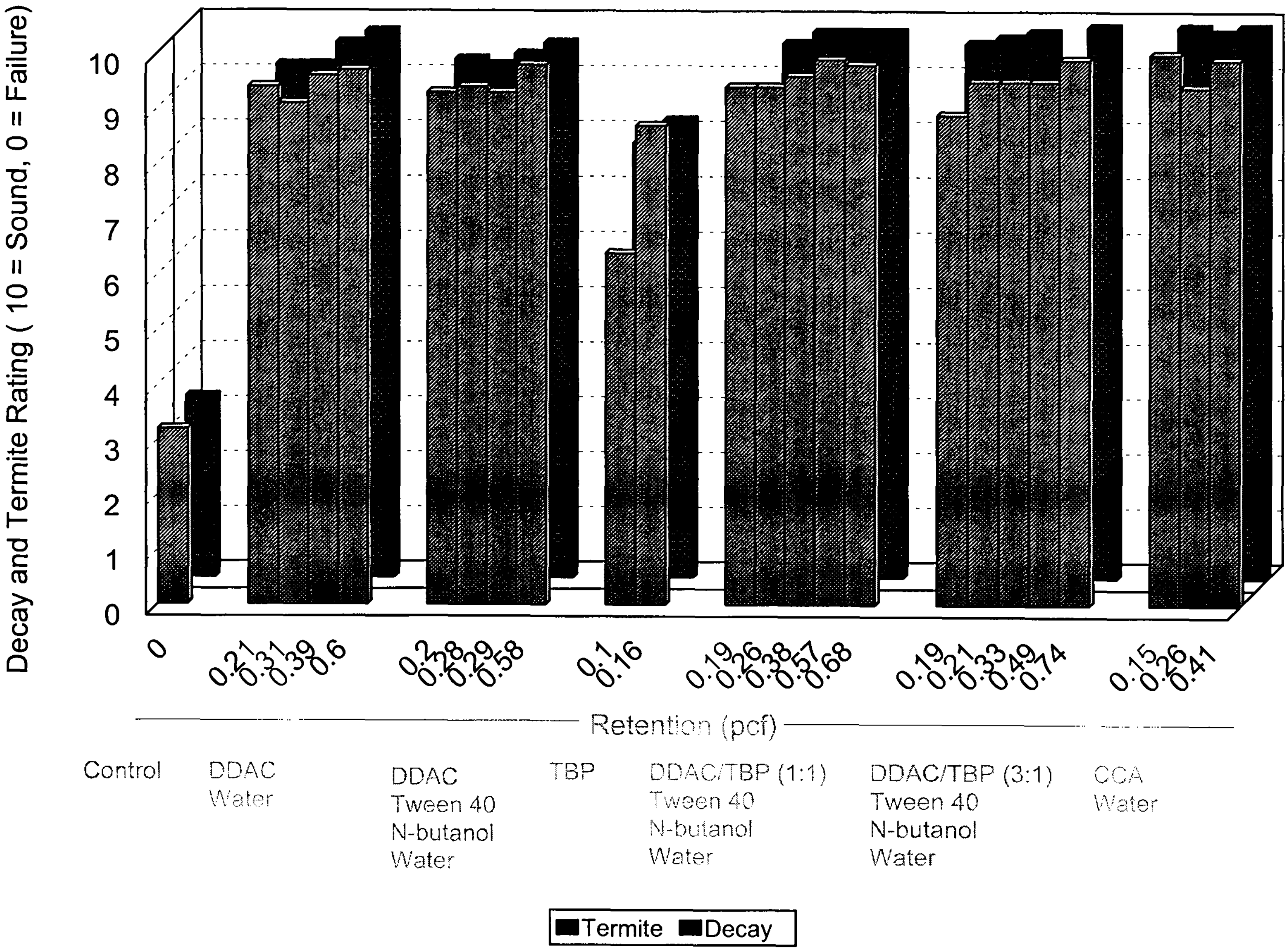


Figure 4.3.4.2. Average Decay and Termite Ratings for Water-borne DDAC:Tribromophenol and CCA Treated Field Stakes After 2-Years Exposure at Saucier.

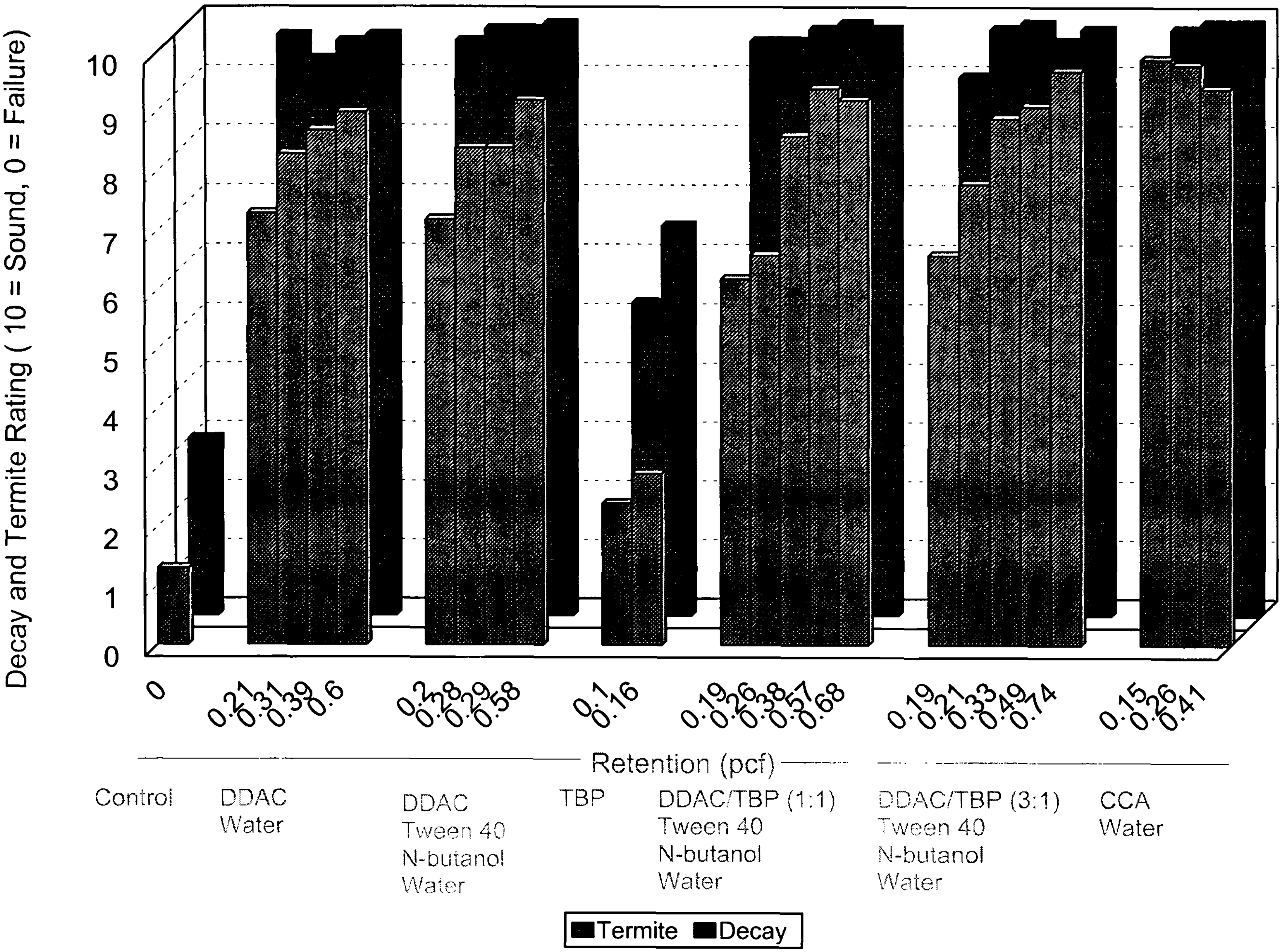


Figure 4.3.6.1. Average Decay Ratings for Water-borne DDAC:Tribromophenol and CCA Treated L-Joints After 2-Years Exposure at Saucier.

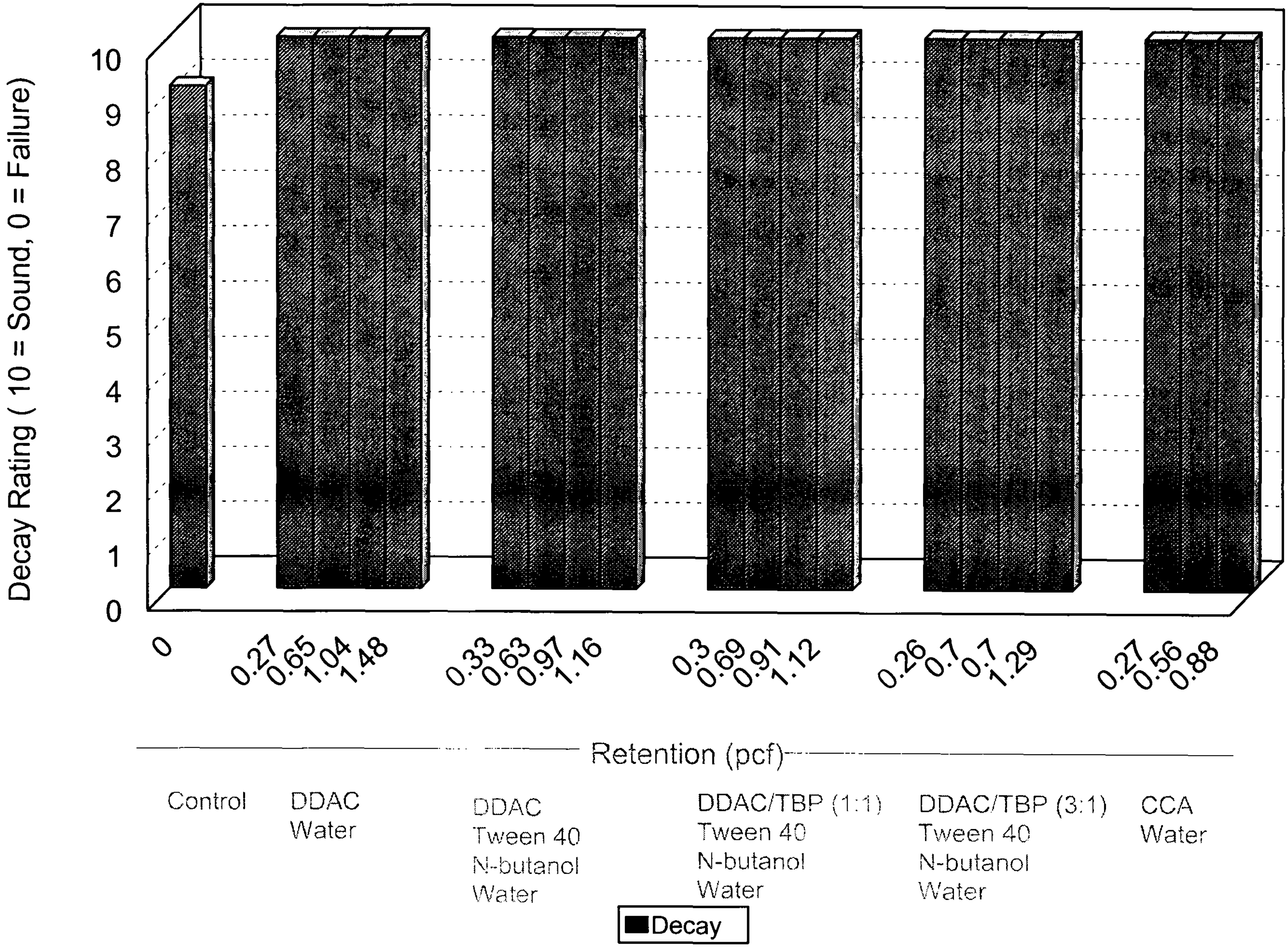


Figure 4.3.6.2. Average Decay Ratings for Water-borne DDAC:Tribromophenol and CCA Treated L-Joints After 2-Years Exposure at Hilo.

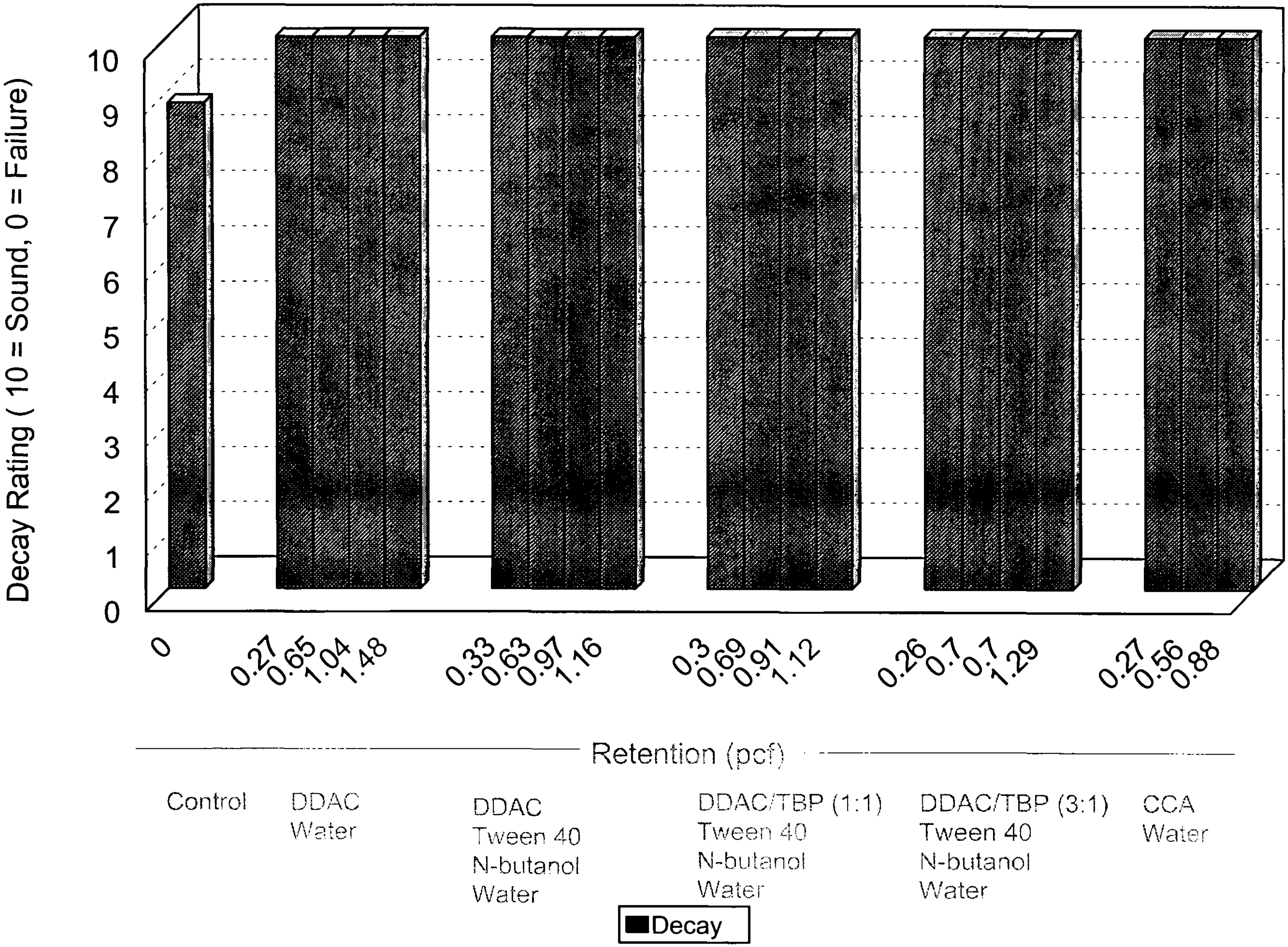


Figure 4.4.1.1. Average Strength Loss for Water-borne DDAC:Chlorothalonil, Penta and CCA Treated Stakes After 62-Weeks Exposure to Dorman Soil In The Fungus Cellar.

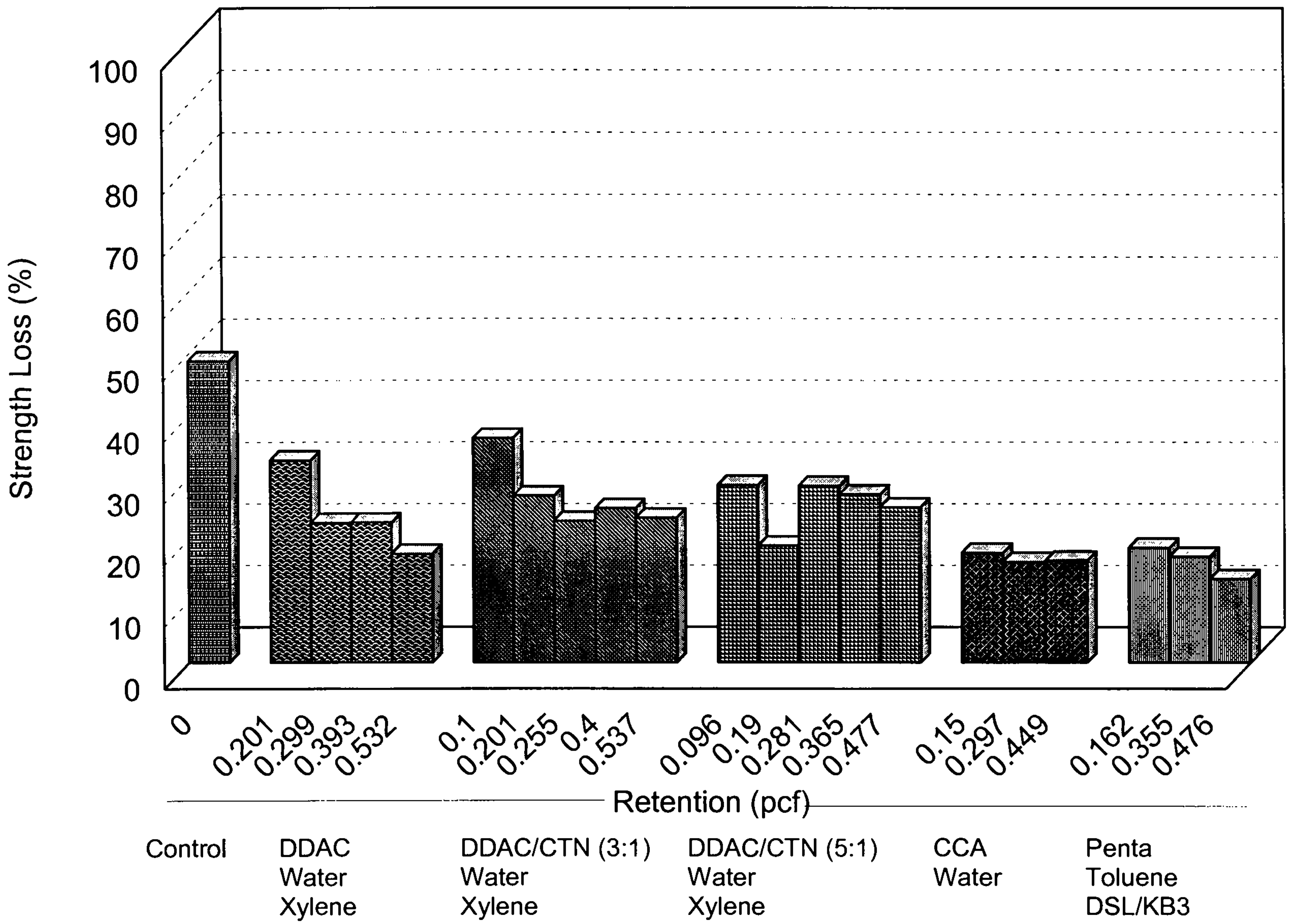


Figure 4.4.1.2. Average Strength Loss for Water-borne DDAC:Chlorothalonil, Penta and CCA Treated Stakes After 62-Weeks Exposure to Saucier Soil in the Fungus Cellar.

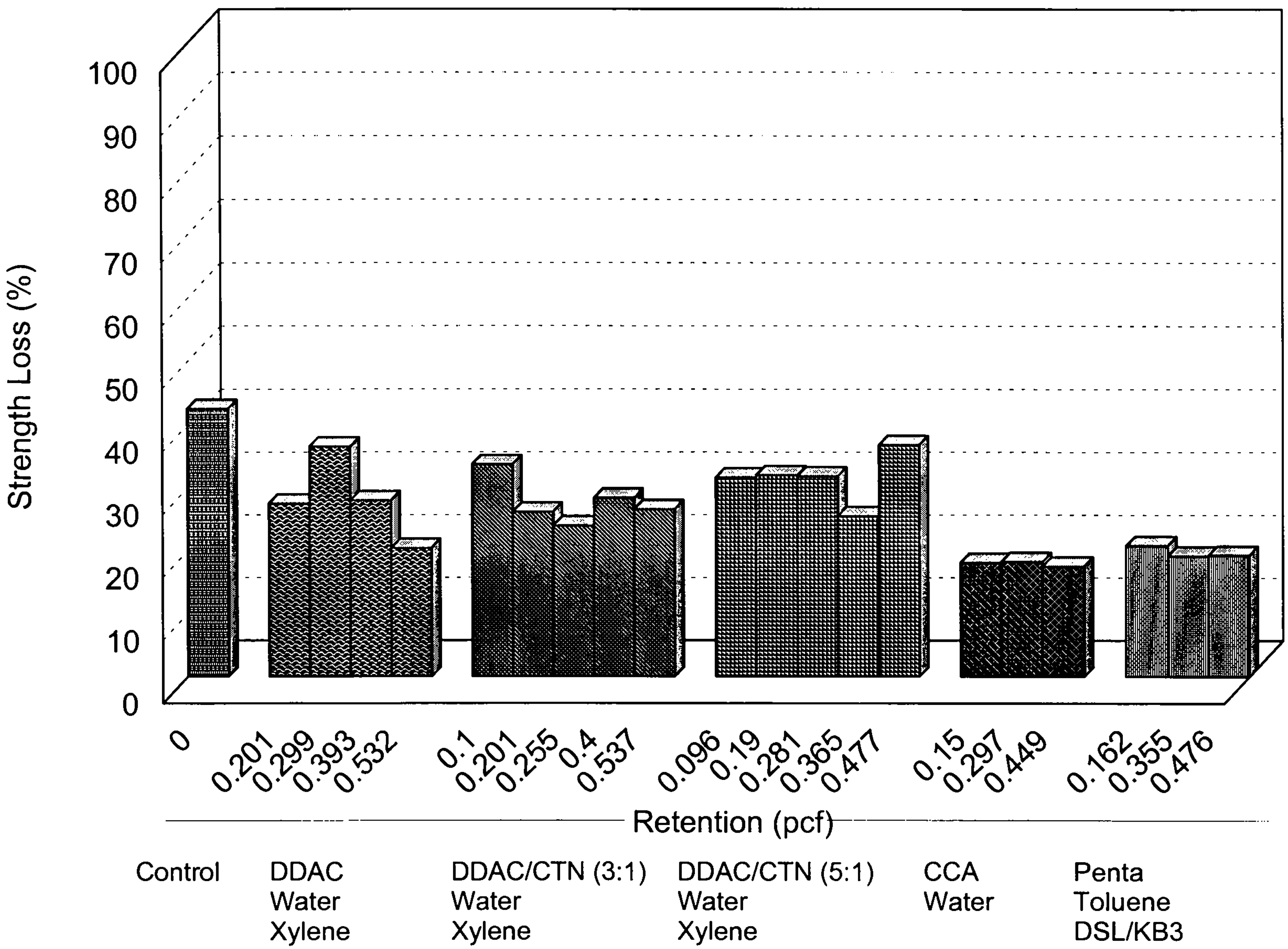


Figure 4.4.2.1. Average Percent Depletion for Water-borne DDAC:Chlorothalonil and CCA From Fungus Cellar Stakes After 12-Weeks Exposure.

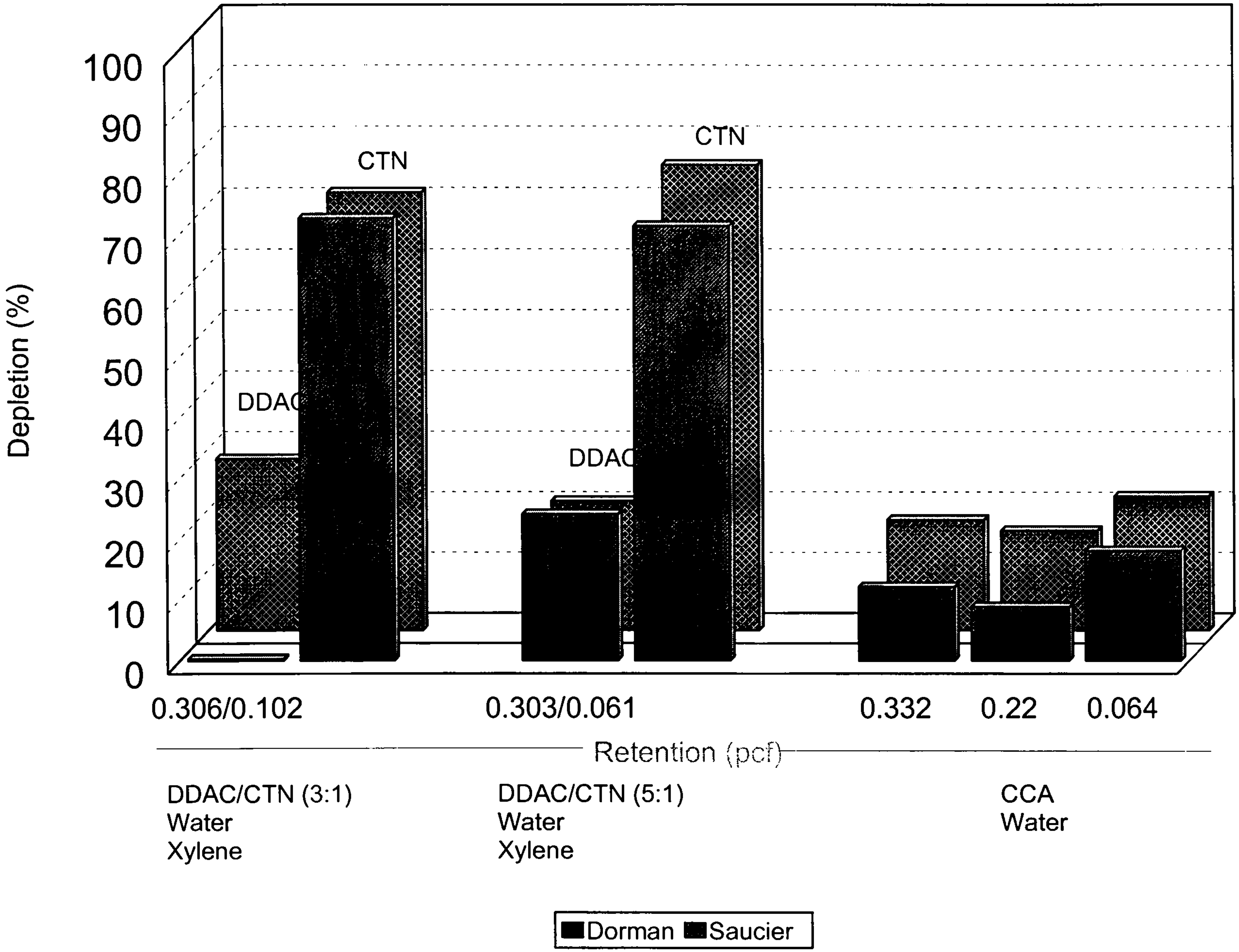


Figure 4.4.2.2. Average Percent Depletion for Water-borne DDAC:Chlorothalonil and CCAFromFungusCellarStakes After 36-Weeks Exposure.

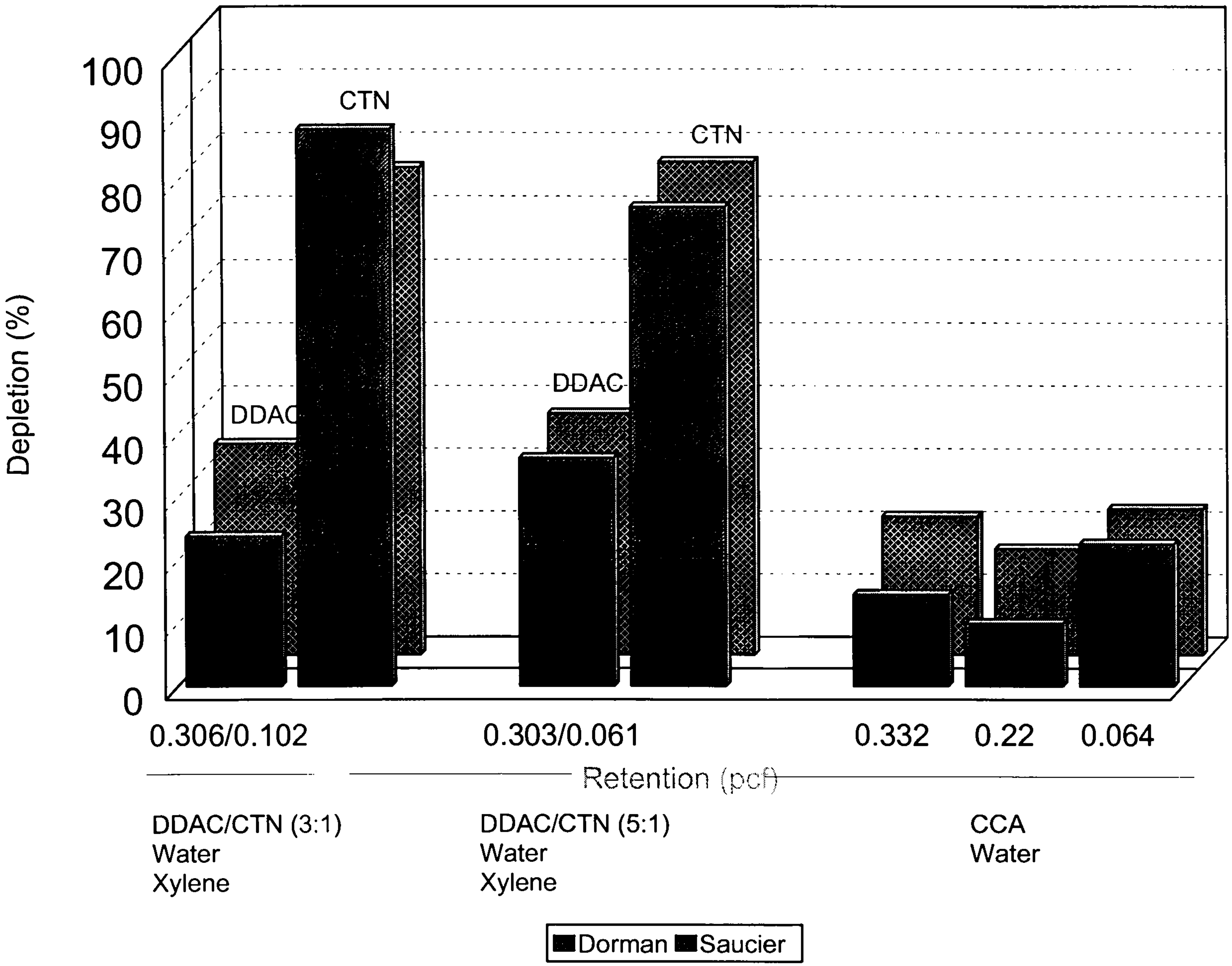


Figure 4.4.3.1. Average Percent Depletion for Water-borne DDAC:Chlorothalonil and CCA From Stakes After 1-Year Exposure .

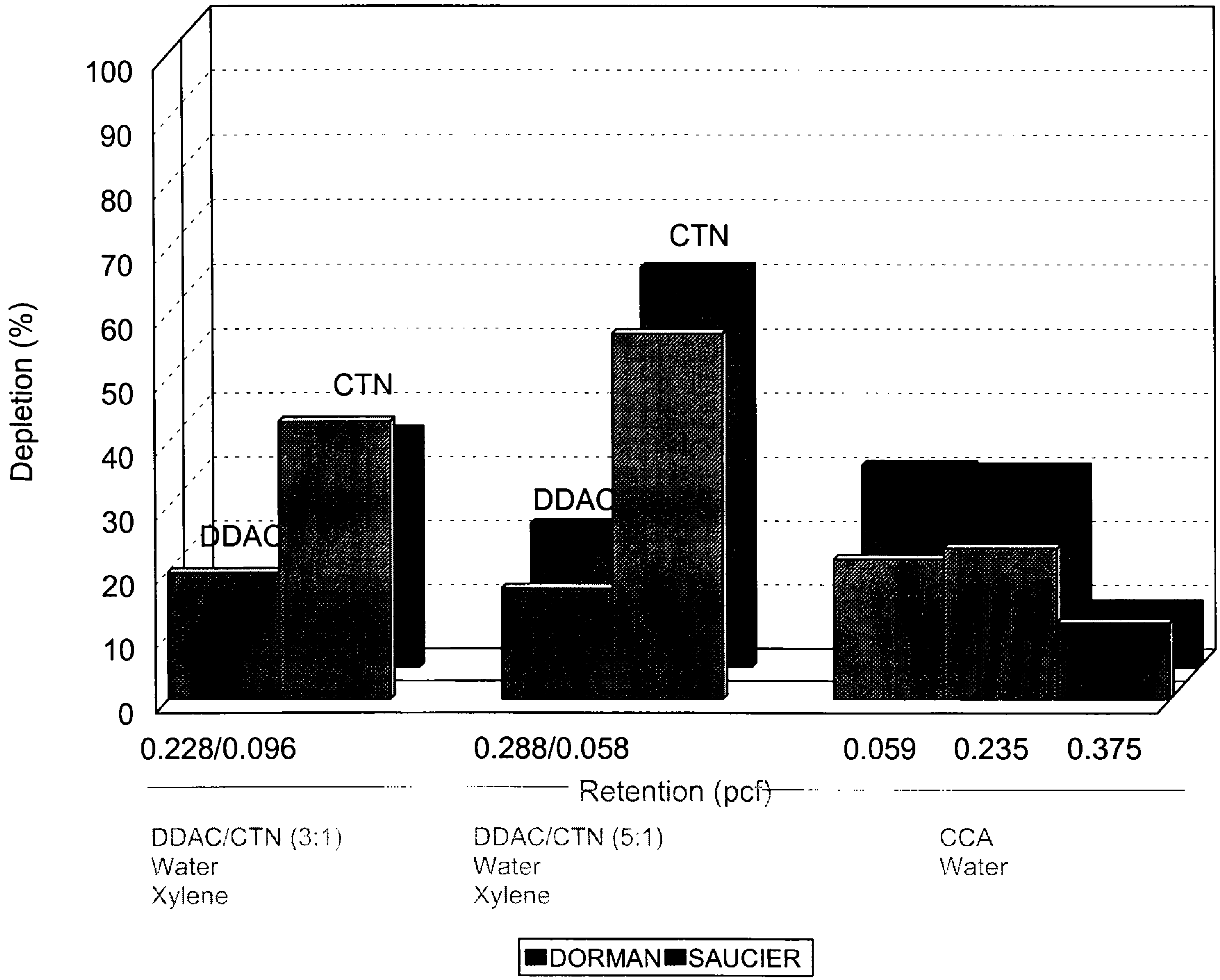


Figure 4.4.3.2. Average Percent Depletion for Water-borne DDAC:Chlorothalonil and CCA From Stakes After 2-Year Exposure .

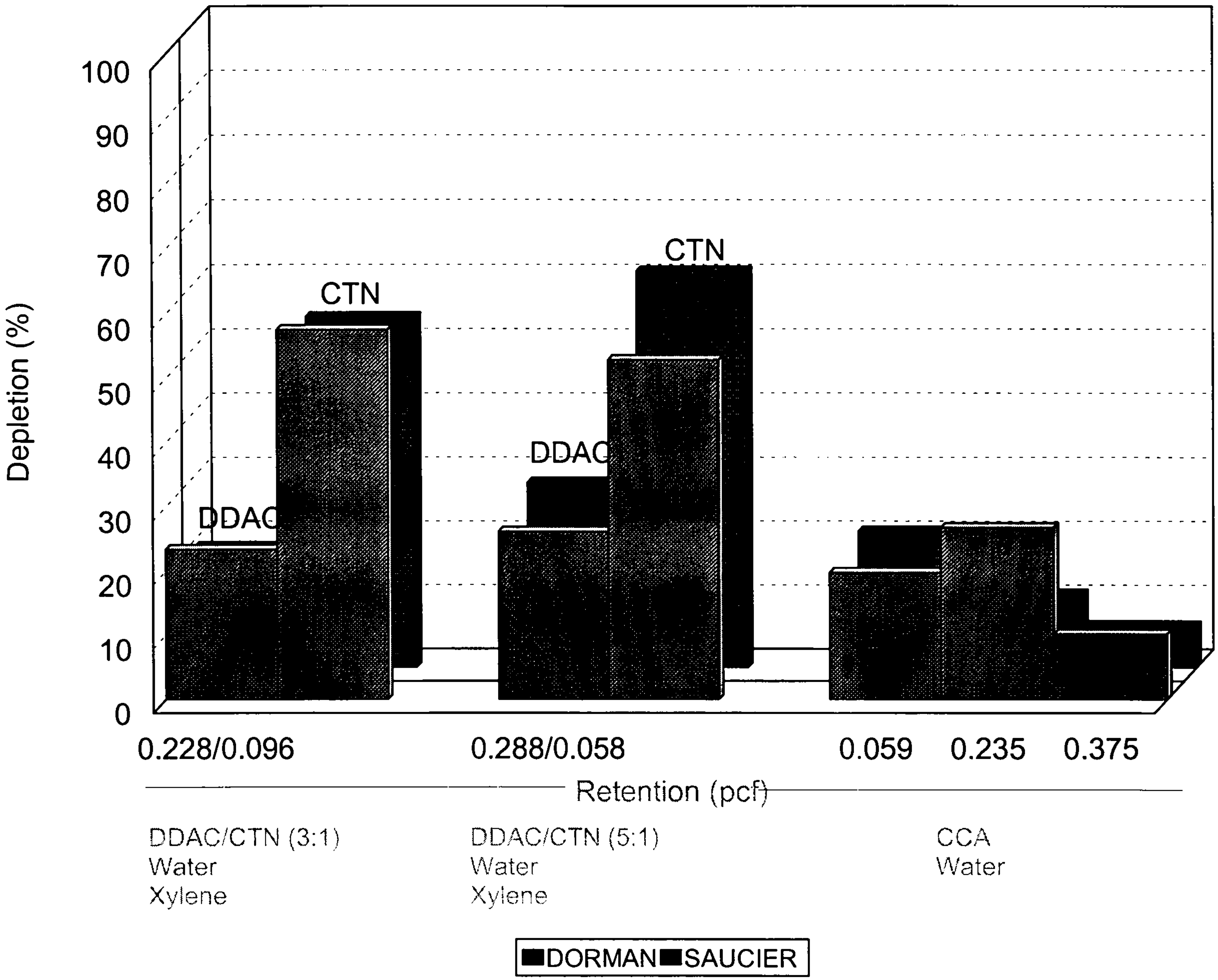


Figure 4.4.4.1. Average Decay and Termite Ratings for Water-borne DDAC:Chlorothalonil and CCA Treated Field Stakes After 2-Years Exposure at Dorman.

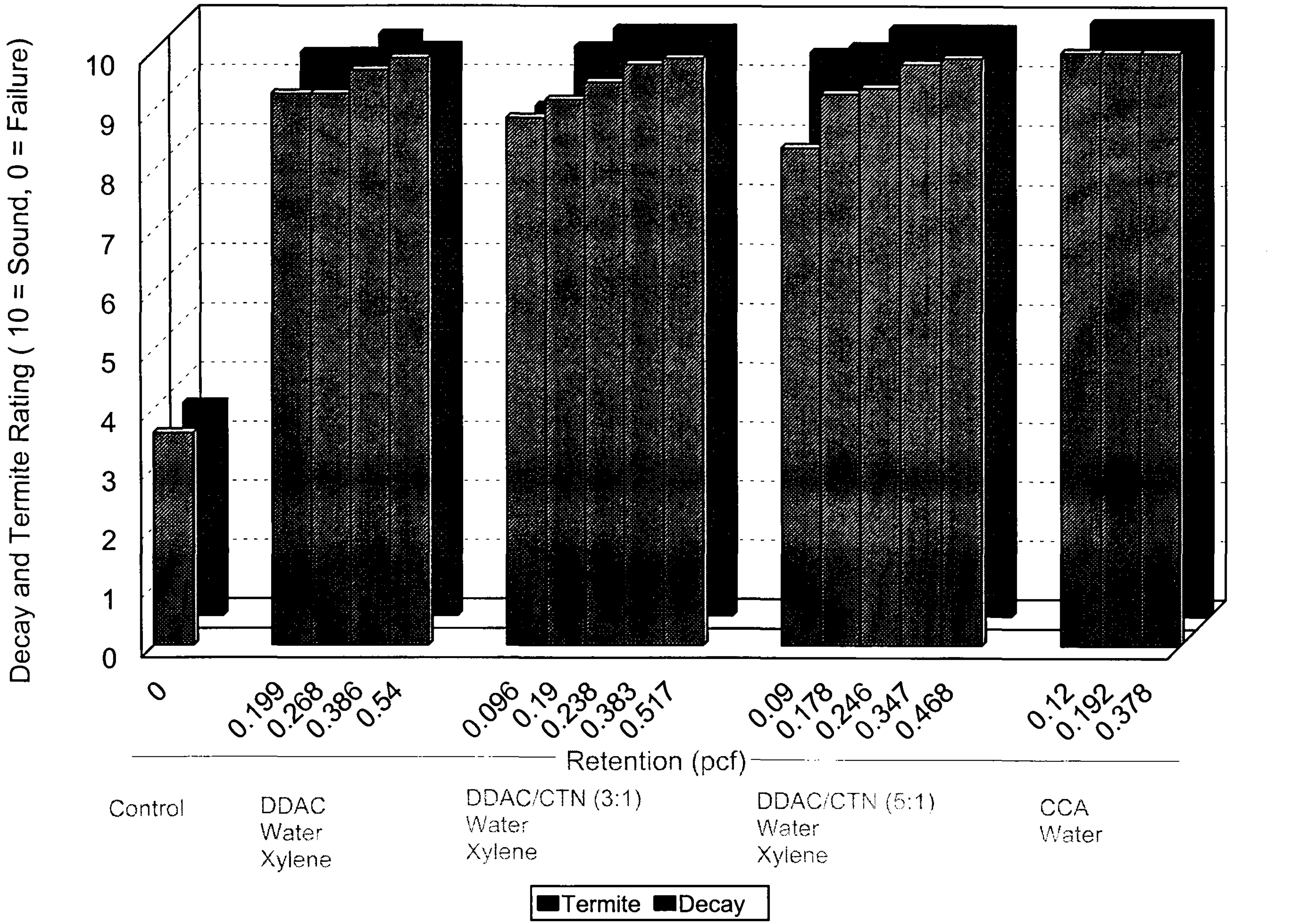


Figure 4.4.4.2. Average Decay and Termite Ratings for Water-borne DDAC:Chlorothalonil and CCA Treated Field Stakes After 2-Years Exposure at Saucier.

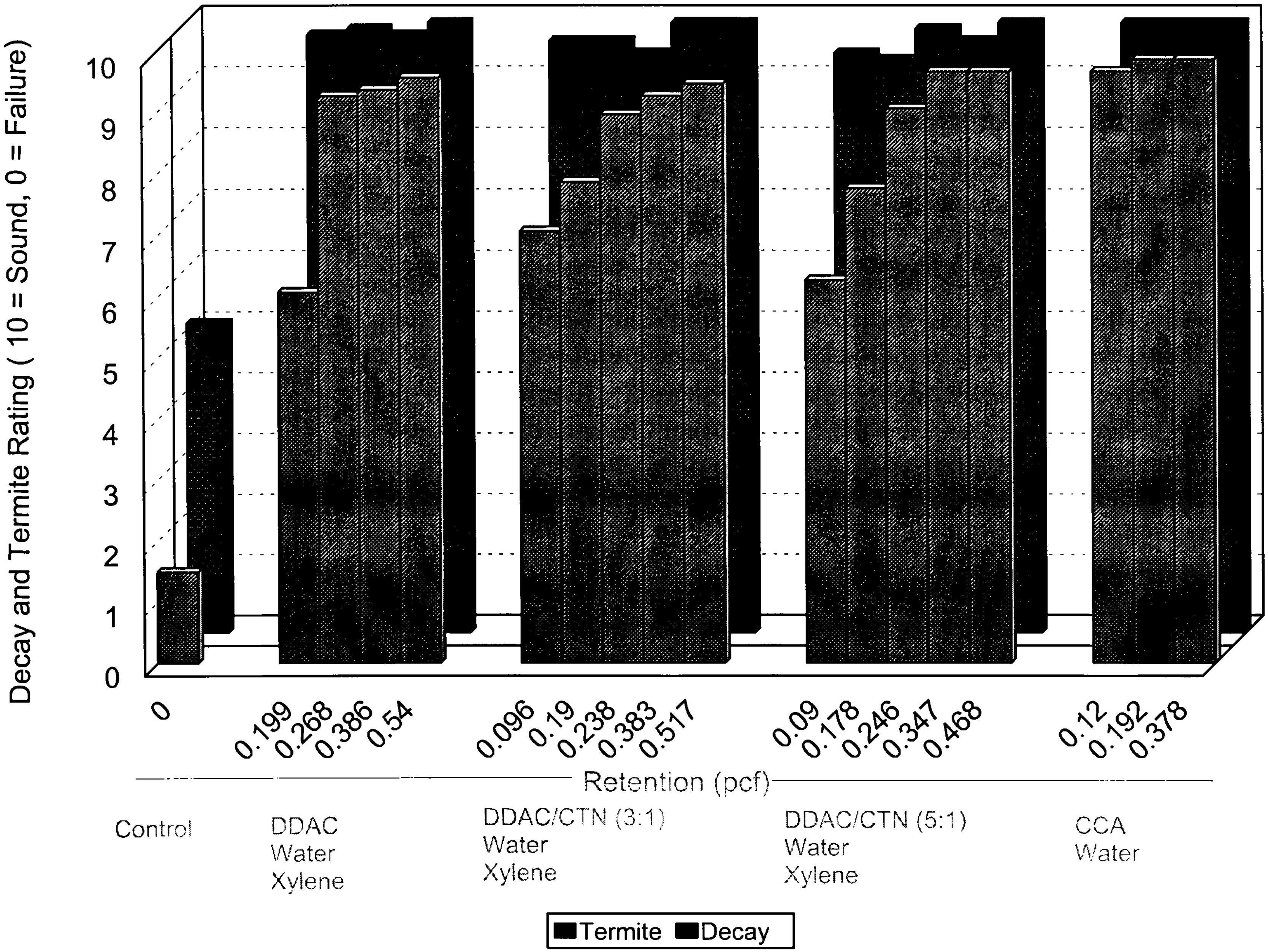


Figure 4.5.2.1. Average Decay Ratings for DDAC:Sodium Omadine and CCA Treated L-Joints After 2.5-Years Exposure at Hilo.

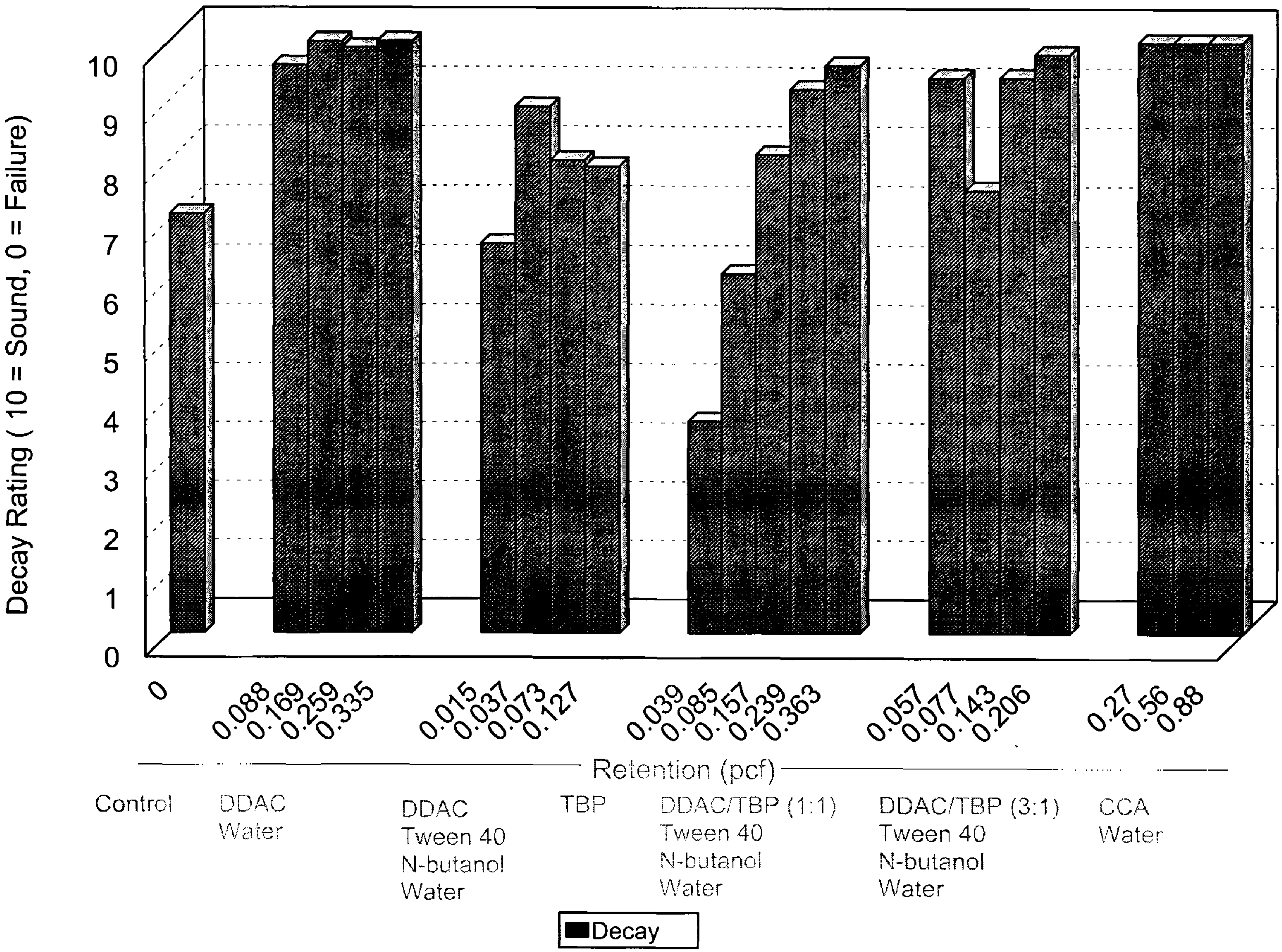
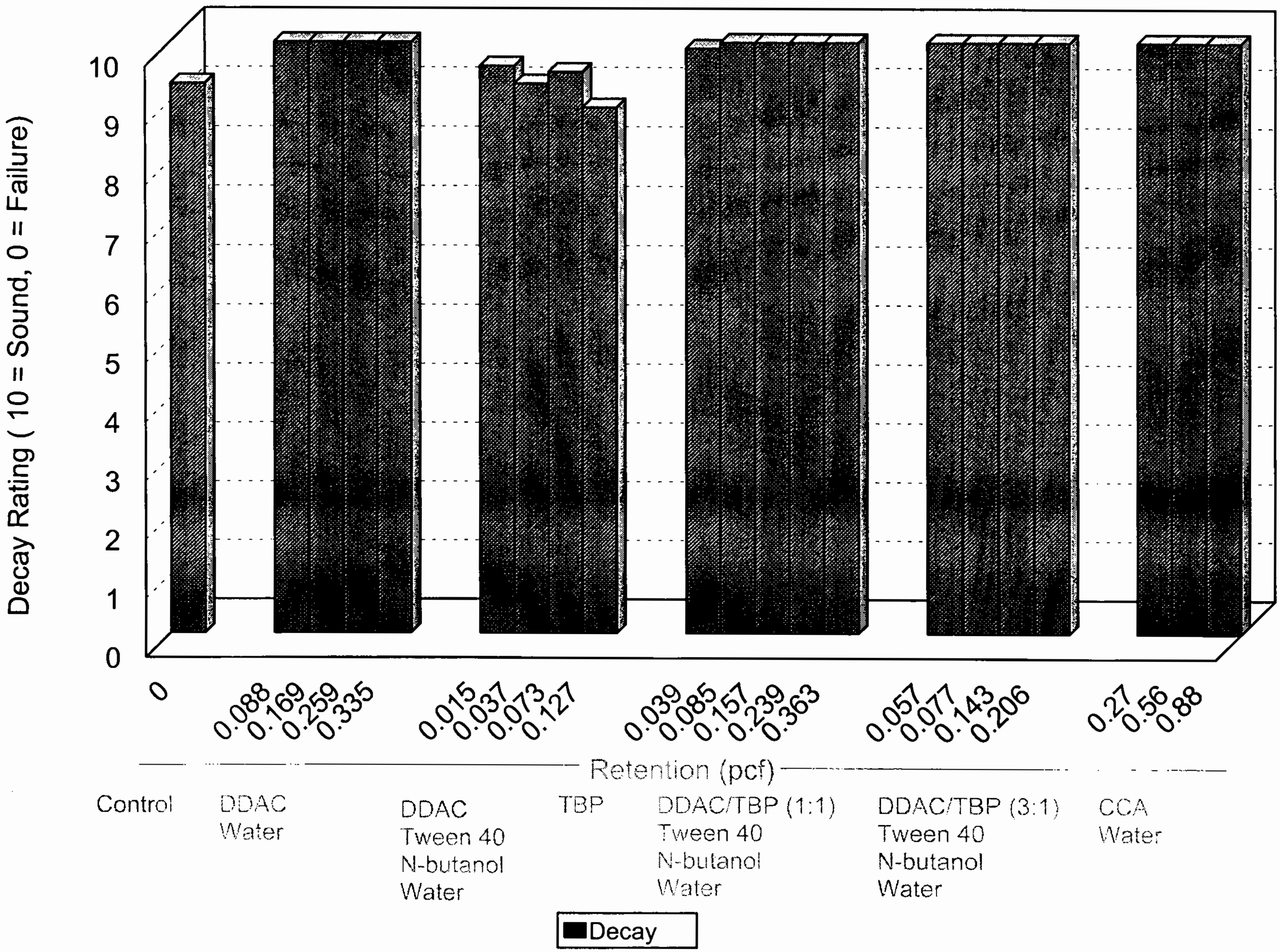


Figure 4.5.2.2.. Average Decay Ratings for DDAC:Sodium Omadine and CCA Treated L-Joints After 2.5-Years Exposure at Saucier.



APPENDIX D

QUALITY CONTROL RESULTS

QUALITY CONTROL RESULTS

Several different tests were used in this research project. The QAPP procedures and results for each of these tests are outlined below.

SAMPLE TREATMENT

Wood samples for the agar block, soft-rot, L-joint, and field stake tests were treated by a vacuum/pressure process. The vacuum and pressure gauges were calibrated in accordance with the QAPP and found to be satisfactory (see Log A).

AGAR BLOCK TEST

In this test an autoclave was used for sterilization and the tests were carried out in an incubator cabinet. Logs for time/temperature/pressure calibrations were developed for the autoclave and for the incubator cabinet thermometer calibrations were maintained. All calibration measurements were found to be satisfactory (see Log B).

SOFT-ROT TEST

The amount of decay in the wood samples was determined by periodically measuring the bending stiffness (MOE) after exposure to unsterile soil. The bending test apparatus was calibrated periodically with a standard metal bar in accordance with the QAPP. The test apparatus was found to be within the specified limits in all cases (see Log C).

L-JOINT AND FIELD STAKE EVALUATION

These test units were randomly arranged in the test plot and periodically evaluated visually. The ratings were recorded on a data sheet without any knowledge of the treatments or previous ratings. Both positive and untreated controls were included for comparison.

BIOCIDE DEPLETION

The amount of CCA and Chlorothanlonil leading from test specimens was determined by analyzing treated wood samples by x-ray fluorescence. The instrument was calibrated periodically with standard pellets for CCA and chlorine. All of the calibrations were found to be in accordance with the QAPP (see Log D).

The amount of DDAC and Tribromophenol leaching from test specimens was determined by HPLC analysis. The HPLC was calibrated using a series of prepared standards consisting of 50, 100, 200, 400, and 600 ppm DDAC. Following this, test samples were extracted and run in triplicate according to the QAPP. The DDAC recovery from treated sample controls was determined with each set of samples submitted. The range of recovery was found to be 78 to 114% (see Log E) which we considered to be satisfactory.

Attempts were made to measure the amount of sodium salt of omadine remaining in the wood, using a HPLC method provided by the manufacturer (Olin Corp.). Unfortunately, while a sodium omadine peak was observed in the standard samples, no sodium omadine was detected in either the exposed or unexposed L-joint samples. Based on discussions with Olin Corp., we concluded that the sodium omadine monomer was probably oxidized to the dioxide dimer (based on the acidity of the wood which will neutralize the salt, and the ease of oxidation of the phenol).

Therefore, to estimate the level of omadine remaining in the samples, selected samples were submitted for elemental sulfur analysis with the sulfur content then converted to omadine levels. However, since trace sulfur analysis is inherently difficult and inaccurate, some sulfur is normally present in wood at levels of about 70 to 300 ppm (Roger Patterson, USDA-Forest Products Lab, Madison, WI), and any oil contamination can easily affect the results. Therefore, this alternate method should only be used to give a rough estimate of the omadine level present. Since sulfur levels were higher in wood treated with DDAC:Sodium Omadine than with DDAC alone, this does suggest that some omadine remains in the wood in some form.

Log A. Phase I and II Treatment.

Vacuum Gauge Calibration Log

Date	Dial Gauge Reading (In Hg)	Manometer Vacuum Reading (In Hg)	Within Calibration Standard (±5%)
29 August 1994	29	29	Yes
23 November 1994	29	30	Yes
12 April 1995	29	29	Yes
28 June 1995	29	29	Yes
27 September 1995	29	29	Yes

Pressure Gauge Calibration Log

Date	Dial Gauge Reading (psig)	Calibration Set Reading (psig)	Within Calibration Standard (±5%)
29 August 1994	148	150	Yes
23 November 1994	152	150	Yes
12 April 1995	147	150	Yes
28 June 1995	150	150	Yes
27 September 1995	148	150	Yes

Log B. Phase 1 Agar Plate Test.

Autoclave Calibration Log

Date	Autoclave Time/Temperature/psig	Standard Time/Temperature/psig	Within Standard
20 May 1994	30 min @ 126^{c} / 16 psig	20 min @100^{c}/15psig	Yes

Low temperature Incubator Cabinet Calibration Log

Date	Digital Thermometer Reading (°C)	NIST Certified Thermometer (°C)	Within Calibration Standard ($\pm 2^{\circ}$ C)
21 June 1994	28	28	Yes
24 June 1994	28	28	Yes
25 June 1994	28	28	Yes
27 June 1994	28	28	Yes
28 June 1994	28	28	Yes

Log C. Phase I Bending Stiffness Apparatus Calibration.

Date	Maximum Bending Stiffness (grams)	Steps Used for Calibration	Within Calibration Standard (1135±10 grams)
6 June 1995	1138	12	Yes
7 June 1995	1139	14	Yes
18 July 1995	1135	13	Yes
19 July 1995	1144	14	Yes
20 July 1995	1145	14	Yes
21 July 1995	1145	14	Yes
24 July 1995	1144	14	Yes
26 July 1995	1136	14	Yes
27 July 1995	1145	14	Yes
23 August 1995	1141	12	Yes
28 August 1995	1139	14	Yes
29 August 1995	1142	14	Yes
30 August 1995	1142	4	Yes
31 August 1995	1142	4	Yes
1 September 1995	1138	4	Yes
5 September 1995	1139	4	Yes
6 September 1995	1138	4	Yes
7 September 1995	1144	4	Yes
4 January 1996	1133	10	Yes
8 January 1996	1145	10	Yes
9 January 1996	1137	10	Yes
10 January 1996	1132	9	Yes
11 January 1996	1135	10	Yes

Log C. Phase I Bending Stiffness Apparatus Calibration.

Date	Maximum Bending Stiffness (grams)	Steps Used for Calibration	Within Calibration Standard (1135 ± 10 grams)
24 January 1996	1137	10	Yes
25 January 1996	1140	9	Yes
26 January 1996	1140	10	Yes
29 January 1996	1142	10	Yes
31 January 1996	1144	10	Yes
5 February 1996	1143	10	Yes
7 February 1996	1136	10	Yes
9 February 1996	1143	9	Yes
12 February 1996	1139	9	Yes
13 February 1996	1135	9	Yes
14 February 1996	1140	10	Yes
15 February 1996	1135	9	Yes
16 February 1996	1141	9	Yes
2 May 1996	1143	10	Yes
3 May 1996	1144	10	Yes
6 May 1996	1138	10	Yes
7 May 1996	1144	5	Yes
8 May 1996	1144	6	Yes
9 May 1996	1144	7	Yes
10 May 1996	1135	5	Yes
14 May 1996	1135	6	Yes
15 May 1996	1143	10	Yes
16 May 1996	1136	9	Yes
21 May 1996	1144	4	Yes
22 May 1996	1144	7	Yes

Log C. Phase I Bending Stiffness Apparatus Calibration.

Date	Maximum Bending Stiffness (grams)	Steps Used for Calibration	Within Calibration Standard ($\pm$ 10 grams)
23 May 1996	1140	9	Yes
28 May 1996	1140	9	Yes
28 May 1996	1144	6	Yes
29 May 1996	1135	5	Yes
30 May 1996	1142	6	Yes
31 May 1996	1143	7	Yes
14 June 1996	1142	5	Yes
15 July 1996	1139	8	Yes
16 July 1996	1144	10	Yes
26 July 1996	1136	9	Yes
29 July 1996	1136	9	Yes
30 July 1996	1142	9	Yes
3 September 1996	1141	5	Yes
4 September 1996	1135	5	Yes
5 September 1996	1138	5	Yes
6 September 1996	1135	5	Yes
9 September 1996	1143	6	Yes
10 September 1996	1138	5	Yes
12 September 1996	1145	6	Yes
17 September 1996	1135	8	Yes
22 November 1996	1139	5	Yes
25 November 1996	1138	7	Yes
26 November 1996	1140	10	Yes
27 November 1996	1140	10	Yes
2 December 1996	1145	8	Yes

Log C. Phase I Bending Stiffness Apparatus Calibration.

Date	Maximum Bending Stiffness (grams)	Steps Used for Calibration	Within Calibration Standard (1135±10 grams)
3 December 1996	1137	9	Yes
4 December 1996	1139	8	Yes
6 January 1997	1144	10	Yes
12 February 1997	1142	8	Yes
17 February 1997	1135	6	Yes
18 February 1997	1142	6	Yes
19 February 1997	1141	6	Yes
21 February 1997	1144	9	Yes
25 February 1997	1133	7	Yes
3 March 1997	1141	7	Yes
18 March 1997	1136	7	Yes
19 March 1997	1139	7	Yes
20 March 1997	1138	5	Yes
21 March 1997	1145	5	Yes
23 March 1997	1141	8	Yes
6 June 1997	1137	9	Yes
9 June 1997	1139	10	Yes
10 June 1997	1144	7	Yes
11 June 1997	1141	6	Yes
12 June 1997	1137	6	Yes
13 June 1997	1136	7	Yes
23 September 1997	1140	6	Yes
24 September 1997	1142	6	Yes
25 September 1997	1137	5	Yes
30 September 1997	1145	9	Yes

Log C. Phase I Bending Stiffness Apparatus Calibration.

Date	Maximum Bending Stiffness (grams)	Steps Used for Calibration	Within Calibration Standard (1135±10 grams)
1 October 1997	1145	10	Yes
2 October 1997	1143	9	Yes
8 October 1997	1143	9	Yes
9 October 1997	1142	6	Yes
13 October 1997	1145	6	Yes
14 October 1997	1138	9	Yes
22 October 1997	1142	9	Yes

Log D. Phase I and II Asoma X-ray Apparatus Calibration.

Date	External Standard Used	Calibration (pcf)	Within Calibration Standard
20 March 1996	CCA	0.998	Yes
21 March 1996	CCA	1.034	Yes
21 March 1996	Chlorothalonil	0.984	Yes
22 March 1996	Chlorothalonil	1.001	Yes
1 April 1996	Chlorothalonil	0.999	Yes
2 April 1996	CCA	0.978	Yes
2 April 1996	Chlorothalonil	0.988	Yes
16 July 1996	CCA	1.054	Yes
18 July 1996	CCA	1.011	Yes
26 August 1996	CCA	0.981	Yes
27 August 1996	Chlorothalonil	0.997	Yes
28 August 1996	CCA	0.949	Yes
29 August 1996	CCA	0.985	Yes
12 September 1996	CCA	0.988	Yes
13 September 1996	CCA	1.014	Yes
16 September 1996	Chlorothalonil	1.013	Yes
17 September 1996	Chlorothalonil	1.021	Yes
8 November 1996	CCA	1.007	Yes
8 November 1996	Chlorothalonil	0.992	Yes
12 November 1996	Chlorothalonil	0.981	Yes
13 November 1996	CCA	0.996	Yes
14 November 1996	CCA	1.003	Yes
15 November 1996	CCA	0.999	Yes
25 November 1996	Chlorothalonil	0.989	Yes
22 September 1997	Chlorothalonil	1.003	Yes

Log D. Phase I and II Asoma X-ray Apparatus Calibration.

Date	External Standard Used	Calibration (pcf)	Within Calibration Standard
3 April 1998	CCA	0.988	Yes
6 April 1998	CCA	0.992	Yes
8 April 1998	CCA	1.011	Yes
9 April 1998	CCA	1.017	Yes

Log E. Phase I and II LC Analyses Calibration.

Date	LC Analyses of	Control			Meets Calibration Standard[1]
		1	2	3	
8 September 1995	DDAC	0.3879	0.3899	0.3927	Yes
3 April 1996	DDAC	0.3758	0.3659	0.3702	Yes
9 July 1996	DDAC	0.378	0.3777	0.4042	Yes
9 July 1996	DDAC	0.3961	0.3976	0.3922	Yes
9 July 1996	TBP	0.4186	0.4189	0.4199	Yes
9 August 1996	TBP	0.4619	0.4527	0.4545	Yes
9 August 1996	DDAC	0.3943	0.3979	0.3922	Yes
12 August 1996	DDAC	0.3392	0.3438	0.3369	Yes
14 November 1996	DDAC	0.2879	0.2898	0.2844	Yes
14 November 1996	TBP	0.4240	0.4208	0.4249	Yes
10 October 1997	DDAC	0.3433	0.3573	0.3485	Yes
10 October 1997	TBP	0.4178	0.4172	0.4237	Yes
12 August 1996	TBP	0.4653	0.4608	0.4643	Yes
22 May 1997	DDAC	0.3055	0.2917	0.2989	Yes
22 May 1997	TBP	0.4292	0.4321	0.4205	Yes
30 April 1996	DDAC	0.3197	0.2842	0.2804	Yes
11 November 1996	DDAC	0.2895	0.2942	0.2763	Yes
7 November 1996	DDAC	0.4129	0.3979	0.3968	Yes
22 May 1997	DDAC	0.3055	0.2917	0.2989	Yes

[1]Calibration range for DDAC is 0.25 - 0.36 pcf
Calibration range for TBP is 0.40 -0.50 pcf

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15. SUPPLEMENTARY NOTES

Project Officer: Paul M. Randall (513) 569-7673

16. ABSTRACT

The objective of this project was to evaluate the potential synergistic combinations of environmentally-safe biocides as wood preservatives. These wood preservatives could be potential replacements for the heavy-metal based CCA. Didecyldimethylammonium chloride (DDAC) was combined with either chlorothalonil (CTN), tribromophenol (TBP) or sodium omadine (NaO) to provide the synergistic mixtures. A total of five systems were examined; one oil-borne (DDAC:CTN) and four water-borne (oil-in-water emulsions) mixtures, including DDAC:NaO with a water repellant. Wood treated with these preservatives was evaluated in both soil contact and above-ground exposure, with CCA and pentachlorophenol (penta) treated wood used as positive controls. The treated wood was evaluated for both biocide efficacy and depletion. Because of project deadlines, the outdoor exposure time was limited to two- to three-years exposure, which is insufficient to fully evaluate the efficacy of most systems. The water-borne DDAC:TBP and DDAC:NaO formulations performed poorly in the field tests and, consequently, are not viable wood preservative systems. However, the addition of a water repellent to the DDAC:NaO system greatly improve the performance in above-ground tests, suggesting that this may be a good preservative for this application. The oil-borne DDAC:CTN formulation is performing very well and may be a viable wood preservative system. The water-borne DDAC:CTN formulation is performing moderately well at this time but appears to suffer from excessive CTN leaching; this deficiency probably can be corrected with a modified formulation.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Arsenic, Chlorothalonil, Chromated copper arsenate (CCA), Chromium, Didecyldimethyl-ammonium chloride (DDAC), Fungal degradation, Pentachlorophenol, Sodium omadine, Synergism, Termites, Tribromophenol, Wood, Wood degradation	Wood treating Wood preservation Pollution prevention	

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