CedarTreat™ Wood Stabilizer™

Scientific Data Compilation

Report KES-100

1 April 2007
(Report Issue Date)

kes.tech

KES Technologies Corporation

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Scientific Data Compilation

Report KES-100
Issued April 1, 2007

Manufacturer: CedarCide Industries, Inc. **2119 Old Ox Road** **Spring, Texas 77396** **www.cedarcide.com**	**Product: CedarTreat™ Wood Stabilizer™** **Division: Wood and Plastics** **Section: Wood Treatment**

SUMMARY

An evaluation of Cedar Treat™ Wood Sabilizer™ products was conducted by KES Technologies Corporation at the request of the manufacturer, CedarCide Industries, Inc. of Spring, Texas.

Based on our review of the evidence provided by the manufacturer and the scientific literature brought to our attention by the manufacturer, we conclude that there is evidence that supports the manufacturer's claims for improved dimensional stability of treated products, and resistance to attack by wood-destroying insects, including subterranean termites.

We also found there is evidence of flame retardency, and water repellency (beading of water on treated surfaces), and resistance to certain molds.

Furthermore, there exists some references in the literature to certain preservatives and their resistance to fungal decay in wood. In addition, the manufacturer has accumulated similar evidence of decay resistance for treated samples that have been exposed to the outdoor conditions, at a location near its place of business. However, this evidence is not yet considered conclusive. For that reason we do not at this time express an opinion concerning Cedar Treat™ Wood Sabilizer™ and decay resistant properties in wood treated with the product.

With the exception duly noted in the above paragraph, it is our opinion that the evidence reviewed supports a finding that building materials treated with Cedar Treat™ Wood Sabilizer™ (a) complies with building codes requiring termite resistance, and (b) meets or exceeds strength requirements.

Report Date April 1, 2007

1.0 **SUBJECT**

CedarTreat™ Wood Stabilizer™ wood treatment products

2.0 **APPLICATION**

Stabilized wood products for construction and building applications

3.0 **DESCRIPTION**

3.1 **General**

CedarTreat™ is a proprietary "wood-stabilizing" formulation that can be applied to building and structural materials required to be protected under applicable municipal Codes* and/or construction protocols, or where such protection is desired.

CedarTreat™ Wood Stabilizer™ products provide protection against wood-eating insects, moisture absorption and provide dimensional stability and enhanced wood strength. CedarTreat™ treated woods are appropriate for use in above-ground, ground contact, and fresh water contact applications, and are effective against subterranean termites, including the Formosan termite.

CedarTreat™ Wood Stabilizer™ products are manufactured by CedarCide Industries, Inc., Houston, Texas, and distributed through independent wood treatment providers, who infuse the product into various wood species, bamboo and other cellulose-based building materials. These providers operate under agreement to apply CedarTreatTM products in accordance with manufacturer's established Quality Control Standards and Procedures.

3.2 **Preservative System**

CedarTreat™ Wood Stabilizer™ is a hydrocarbon-carried formulation of essential oil of cedar ("cedar oil"), and silane used for wood members that are required by applicable standards to be protected against moisture and termites. The formulation penetrates green, air and kiln-dried woods, when applied in accordance with manufacturer's recommended procedures.

CedarTreat™ Wood Stabilizer™ formulations are composed of natural and organic compounds identified within the EPA minimum risk pesticide ruling, subsequently the Food Quality Protection Act dated March, 1996, and referred to in the Federal Register as 152.25b compounds. Components of the formulations are EPA, FDA, and/or GRAS List, approved, food-grade actives and 4a inerts, considered to be of low toxicity, and not requiring registration when claiming insect control properties.

3.3 **Materials**

CedarTreat™ Wood Stabilizer™ products are used to treat the following materials as specified in the CedarTreat™ Wood Stabilizer™ Quality Control Manual:

3.3.1 Dimensional lumber and timbers of the following ***sapwood*** species: Southern Yellow Pine, White Pine, Short Leaf Pine, Ponderosa Pine, Red Pine, Radiata Pine, and Caribbean Pine.

3.3.2 Dimensional lumber and timbers of the following ***heartwood*** species: Douglas Fir, Western Hemlock, Hem Fir, Lodgepole Pine, Jack Pine, Redwood, and Black and Blue Spruce.

3.3.3 Plywood comprised of Southern Pine and Douglas Fir.

3.3.4 Round and cut posts and building poles of Southern Pine, Ponderosa Pine, Red Pine, and Short Leaf Pine, Spruce, Douglas Fir, Hem Fir and Western Hemlock.

3.4 Treatment and Processing

The manufacturer recommends CedarTreat™ Wood Stabilizer™ products be applied to building materials prior to construction. The manufacturer recommends pre vacuum, pressure and post vacuum, with vapor recovery as described in the CedarCide Industries, Inc. **Standard Applications Procedural Manual Issue No. CT-10I**, and addressed herein to produce CedarTreat™ Wood Stabilizer™ products.

Furthermore, the manufacturer approves the use of spray, brush, roller, submersion, or other direct pressure methods when carried out in compliance with federal, state and local air emission regulations.

Schedule A: Formulation Mixture and Recommended Treatment Applications located at Section 6.4(A) in the Appendix of this report provides the reader with a comprehensive matrix of product formulations, contents, coverage and various treatment levels. Table 1, below, is an illustrative abstract of that schedule.

TABLE 1
Formulation Mixtures and
Recommended Treatment Applications[B]

Level	Dilution Ratio	Mixture (gals)	Carrier (gals)	Actives (gals)	Coverage (board ft)[A]	Treatment Applications per Level
I	9:1	1,000	900	100	125,000	**I. Ground Contact** • Deck & Floor Support, Piers, Poles & Posts **II. Above Ground** • Flooring, Trim, Fascia, Sill Plates, Docks **III. Exposed** • Structural & Millwork IV. Recreational & Yard Structures • Deck, Fence, Gazebos, Playground Equip **V. Wood Drying & 180 Day Construction Window**
	10:1	1,000	909	91	125,000	
II	11:1	1,000	917	83	125,000	
	12:1	1,000	923	77	125,000	
III	13:1	1,000	929	71	125,000	
	14:1	1,000	933	67	125,000	
IV	15:1	1,000	937	63	125,000	
V	19:1	1,000	950	50	125,000	

[A] Coverage based on application rate of 8 gallons of formulation per 1,000 board foot of wood media.
[B] Table illustrates 1,000 gallon formula mixtures only, see Section 6.4(A); Appendix A, for larger, and smaller volumes.

3.5 Quality Assurance

Treatment of materials is conducted in accordance with CedarTreat™ Quality Control Standards and Procedures with inspections by a KES Technologies Corporation, or other CedarCide Industries, Inc. approved third party inspection agency.

3.6 Corrosion

No adverse reaction with any common fastener materials have been noted form contact with CedarTreat™ Wood Stabilizer™ treated woods.

3.7 AWPA Standards

CedarTreat™ Wood Stabilizer™ products and treatments are novel materials and applications for which the standards and specifications published by the American Wood Preservers' Association (AWPA) and other such industry organizations established for certification of water soluble copper compounds, and certain polychloronated hydrocarbons, have no relevance in evaluating the performance of CedarTreat™ products. The specifications set forth by CedarCide Industries, Inc. are proprietary and differ from AWPA standards. At present CedarTreat™ Wood Stabilizer™

is not marketed as a wood decay preventative pending completion of an evaluation of the decay resistance of materials treated with the product.

4.0 INSTALLATION

4.1 General

CedarTreat™ Wood Stabilizer™ treated woods are installed as dimensionally-stabilized lumber, timbers and plywood in accordance with the requirements of applicable Code.

The manufacturer's published installation instructions for wood and pressure-treated wood and this report shall be strictly adhered to and a copy of these instructions shall be available at all times on the job site during installation.

The instructions within this report govern if there are any conflicts between the manufacturer's instructions and this report.

4.2 Applications

CedarTreat™ Stabilized Wood Products are permitted in locations where wood is used and/or in locations required by the applicable Code to be fungal decay and/or termite resistant. The treated wood members are listed for use only in ground contact, above-ground, and exposed applications, and for wood drying and use with building materials during the “180 day construction window”. Typical product applications are listed in Table 2.

TABLE 2
Structural Applications

Level	Installation	Structural Applications
I	Ground Contact	Piers, deck support & fence posts, poles
II	Above Ground	Framing, flooring, trim and fascia, rails, sill plates, spindles, docks
III	Exposed	Structural and Millwork
IV	Recreation & Yard Structures	Decks, fences, gazebos, playgrounds & trellises
V	Wood Drying & 180 Day Construction Window	Framing, joists, rafters, general construction materials

4.3 Fasteners

Appropriate fasteners should be used in accordance with the instructions for use provided by the supplier of the fastener.

4.4 Structural

The maximum load duration factor allowed for structural members treated with CedarTreat™ Wood Stabilizer™ Products shall be 1.6 in accordance with section 2.3 of the **AFPA, National Design Specification for Wood Construction.**

5.0 IDENTIFICATION

Each piece of CedarTreat™ Wood Stabilizer™ treated lumber, timber and plywood shall be labeled with the manufacturer's name and/or trademark, address, the product name, grade mark,

third party inspection label; KES TECHNOLOGIES CORPORATION (KES 186). Sample Labels see Figure 1 of this report.

6.0 EVIDENCE SUBMITTED

6.1 Manufacturer-provided Documents

6.1.1 Cedarcide Industries, Inc., Treatment Protocol No. KES-500, including "General Use QC Procedures & Standards".

6.1.2 "Analytical Standards for Cedar Oil and Silane Preservatives". KES Technologies Corporation

6.2 Reports of Treatments Evaluation

6.2.1 "Laboratory Tests to Determine Durability of Wood Treated with CedarCide Formulations"; Dr. Terry F. Amburgey and Ms. S.V. Parikh, Mississippi State University, (2006)

6.2.2 "An Evaluation of the Product Claims for CedarShield™ from a Scientific Perspective", January, 2006; George M. Jenkins, M.Sc., University of New Brunswick, Canada,

6.2.3 Wood Moisture Tests (2007); KES Technologies Corporation (Dr. M. McGregor)

6.2.4 "Analytical & Antimicrobial Test Results", May, 2006; Aegis Laboratories International

6.3 Technical Information on the nature of active ingredients in CedarTreat™ Wood Stabilizer™ Products.

6.3.1 Activity against Insects

(a) "Termiticidal Activities in Heartwood, Bark/Sapwood and Leaves of Juniperus Species in the United States", Dr. Robert Adams, Baylor U.; Biochemical Systematics and Ecology, Vol. 16 No. 5, 1988

(b) Letter dated April 4, 2000; Dr. Arthur Appel, Professor of Entomology, Auburn University

6.3.2 Activity against Microorganisms

(a) "Cedar Wood Oil - Analysis & Properties"; Dr. Robert P. Adams, Springer-Verlag; (1991)

(b) "Antimicrobial Properties of Heartwood, Bark/Sapwood and Leaves of Juniperus Species"; Drrs. Robert P. Adams and Alice M. Clark; Phytotherapy Research, Vol. 4 No. 1, (1990)

6.3.3 Corrosivity

(a) "Corrosivity of wood treated with CedarCide Wood Protection Products", Memo July 24, 2006; Dr. Terry Amburgey, TaskPro

6.4 Appendix

A. Schedule A: Formulation Mixture and Recommended Treatment Applications

7.0 CONDITIONS OF USE

KES Technologies Corporation finds that the CedarTreat™ Wood Stabilizer™ treated wood, as described in this report, is an acceptable alternative to other wood protection methodologies currently employed, demonstrating dimensional stability, water repellency, and insect resistance. Furthermore, said treated wood complies with the 2000 International Building Code, the 2000 International Residential Code', the 2001 Supplement to the International Codes*, the BOCA National Building Code/1999, the 1999 Standard Building Code*, the 1997 Uniform Building Code, and the 1998 International One and Two Family Dwelling Code' subject to the following conditions:

7.1 This Scientific Data Compilation (Report KES-100) and the manufacturer's published installation instructions, when required by the code official, shall be submitted at the time of permit application.

7.2 CedarTreat™ Wood Stabilizer™ products are limited to the wood species and minimum retentions noted under Section 3.3 and Table 1 above.

7.3 The treatment process complies with this report and CedarCide Industries, Inc. Quality Control Standards and Procedures for CedarTreat™ Wood Stabilizer™ products.

7.4 The treatment process is carried out at the manufacturing facilities of the listees noted in this report, under a quality control program with periodic inspections by a KES Technologies Corporation representative(s).

7.5 CedarTreat™ Wood Stabilizer™ Products may be used to treat LVL, OSB, or FRTW wood products.

7.6 In areas where a soil treatment/barrier termiticide treatment is required by the applicable Code or local code official, CedarTreatTM Wood StabilizerTM treated woods are used only as supplemental protection from termites and are not a replacement for required treatments or barriers.

7.7 Wood treated with CedarTreat™ Wood Stabilizer™ products have not been evaluated for exposure to fresh or salt water.

7.8 This report is subject to periodic re-examination. For information on the current status of this report, contact KES Technologies Corporation or CedarCide Industries, Inc., for current updates and exhibits.

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Treatment Protocol

Report KES-500
Issued April 1, 2007

Manufacturer: CedarCide Industries, Inc. **P. O. Box 549** **Spring, Texas 77383** **www.cedarcide.com**	**Product: CedarTreat™ Wood Stabilizer™** **Division: Wood and Plastics** **Section: Wood Treatment** **Criteria: Building & Structural Materials**

This procedural report, issued by KES Technologies Corporation (KES), is based upon performance features of the (a) Uniform, and (b) International, "family of codes". The primary charging sections upon which evaluation reports are issued include:

- 1997 Uniform Building Code™ (UBC): Section 104.2.8
- 2000 International Building Code™ (IBC) Section 104.11
- 2000 International Residential Code™ (IRC) Section R104.11

For example, Section 104.2.8 of the UBC reads as follows:

> The provisions of this code are not intended to prevent the use of any material, alternate design or method of construction not specifically prescribed by this code, provided any alternate has been approved and its use authorized by the building official.
>
> The building official may approve any such alternate, provided the building official finds that the proposed design is satisfactory and complies with the provisions of this code and that the material, method or work offered is, for the purpose intended, at least the equivalent of that prescribed in this code in suitability, strength, effectiveness, fire resistance, durability, safety and sanitation.
>
> The building official shall require that sufficient evidence or proof be submitted to substantiate any claims that may be made regarding its use. The details of any action granting approval of an alternate shall be recorded and entered in the files of the code enforcement agency.

Note: Similar provisions are located in the IBC (Sec. 104.11) and the IRC Sec.R104.11

The Treatment Protocol criteria has been issued to provide all interested parties with guidelines on implementing performance features of the applicable code(s) referenced in the acceptance criteria. The criteria was developed and from industry research conducted by the KES Technologies Corporation Technical Committee, and is effective on the date indicated herein. All reports issued or reissued an or after the effective date must comply with this criteria, while reports issued prior to this date may be in compliance with this criteria or with the previous edition. If the criteria is an updated version from a previous edition, it will be so noted in the margin within the criteria indicates a technical change, addition, or deletion from the previous edition. A notation is also indicated in the margin where a paragraph has been deleted due to a "technical change". This criteria may be further revised as the need dictates.

KES Technologies Corporation may consider alternate criteria, provided the proponent submits valid data demonstrating that the alternate criteria are at least equivalent to the attached criteria and otherwise meet the applicable performance requirements of the codes. Notwithstanding that a material, type or method of construction, or equipment, meets the attached acceptance criteria, or that it can be demonstrated that valid alternate criteria are equivalent and otherwise meet the applicable performance requirements of the codes, if the material, product, system or equipment is such that either unusual care with its installation or use must be exercised for satisfactory performance, or malfunctioning is apt to cause unreasonable property damage or personal injury or sickness relative to the benefits to be achieved by the use thereof, KES Technologies Corporation retains the right to refuse to issue or renew ay such procedural report or evaluation document.

Report Date April 1, 2007

TREATMENT PROTOCOL
CedarTreat™ Stabilizer™ Wood Protection Products

1.0 INTRODUCTION

1.1 Purpose:

The purpose of this Treatment Protocol is to establish minimum requirements for CedarTreat™ Wood Stabilizer™ Products and their application for use in (all) above ground applications including, but not limited to, Deck, Dock, Fence and Outdoor Structures. The subject products are recognized in KES Technologies Corporation's "Scientific Data Compilation" (KES-100), supportive of guidelines referenced in the *1997 Uniform Building Code™* ("UBC"), the *2000 International Building Code™* ("IBC"), and the *2000 International Residential Code™* ("IRC").

1.2 Scope:

CedarTreat™ Wood Stabilizer™ Products are designed to be used for treatment of timber components used as building materials. Timber treated in accordance with this criteria is intended for use only in above ground components that may or may not be exposed to the weather.

This criteria is established for use of CedarTreat™ Wood Stabilizer™ Products in connection with treatment of the following:

- **Heartwood species**: Douglas Fir, Hem-Fir, Western Hemlock, Lodgepole Pine, Jack Pine, Redwood, and Black and Blue Spuce.
- **Sapwood species**. Southern Yellow Pine, Ponderosa Pine, Red Pine ,Radiata Pine, Short Leaf Pine and Carribean Pine.

1.3 Reference Standards:

1.3.1 1997 Uniform Building Code™ (UBC), International Conference of Building Officials.

1.3.2 2000 International Building Code™ (IBC),International Code Council.

1.3.3 2000 International Residential Code™ (IRC), International Code Council.

1.3.4 American Wood-Preservers' Association (AWPA) Book of Standards:

1.3.5 ASTM D 4442-92 (1997), Test Methods for Direct Moisture Content Measurement of Wood and Wood-based Materials, American Society for Testing and Materials.

1.3.6 ASTM D 4444-92 (Reapproved 1998), Standard Test Method for Use and Calibration of Hand-held Moisture Meters, American Society for Testing and Materials.

1.4 Definitions:

1.4.1 CedarTreat™ Wood Stabilizer™:
A proprietary formulation that contains active ingredients of internally-modified essential oil of Cedar and silane, suspended in an inert hydrocarbon carrier, in a 9:1 to 20:1 inert to active dilution ratio.

1.4.2 Product Composition: CedarTreat™ Wood Stabilizer™ solution shall have the following composition:

- Cedar Oil, as identified on the EPA's GRAS (Generally Regarded as Safe) list of active ingredients,
- Silane Fluid, and
- Low viscosity, parrafinic, mineral oil solvent

Dilution Ratio	CedarTreat™ (in Gallons)	Solvent (in Gallons)	Total Solution (in Gallons)
9:1	10	90	100
15:1	10	150	160
20:1	10	200	210

1.4.3 Product Formulation: The treating solution shall contain Cedar Oil and Silane compounds as identified by the manufacturer CedarCide Industries Inc. and shall use a hydrocarbon solvent in the range of C-10 to C-12 as the carrier. The products shall be labeled as to their total content of active ingredients. Testing to establish conformity with the foregoing requirements shall be done in accordance with the standard methods provided by the manufacturer of the technical solution.

The composition of the CedarTreat™ components in the treating solution may deviate from the limits specified in the above table subject to the usage objective of the treatment. Higher dilutions provide less retention of active ingredients in the treated timber. Lower dilution ratios provide heavier loads of active ingredients and subsequently enhanced results.

2.0 BASIC INFORMATION

2.1 General:

The following information must be submitted:

2.1.1 Product Description: Complete information concerning material specifications, compositions and manufacturing process.

2.1.2 Application Instructions: Application details and limitations.

2.1.3 Packaging and Identification: A description of the method of packaging and identification of the products. Identification shall include the name and address of the treatment facility, the K ES Technologies evaluation report number and the name or logo of the quality control agency. Each board shall bear a stamp or label, or both, indicating "Stabilized with CedarTreat™"

2.2 Testing Laboratories:

Testing laboratories shall comply with the KES Technologies Acceptance Criteria for Laboratory Accreditation.

2.3 Test Reports and Product Sampling:

Test reports and test specimen sampling shall comply with the KES Acceptance Criteria for Test Reports and Product Sampling . All reports shall be issued or certified by a KES accredited test laboratory. Product for testing must be sampled in accordance with KES directives.

3.0 TEST AND PERFORMANCE REQUIREMENTS

3.1 General:

CedarTreat™ Wood Stabilizer™ solutions (products and formulations) shall conform to the compositions described in Section 1.4 and to the manufacturers applicable analytical standards. No alternative or substitute components are permitted save and except those that apply to the hydrocarbon solvent carrier.

3.2 Lumber Material:

There are no limitations as to the dimensions of lumber and construction material treated with CedarTreat™ Wood Stabilizer™ Products. Decking lumber shall include 5 / 4 , 2 inches (50 mm) or less in nominal thickness and 8 inches (200 mm) or less in nominal width or any other applicable size approved for Deck, Dock, Fence and structural integrity.

The treatment of "green wood" is encouraged, and generally results in enhanced preservative retention. Air and kiln dried, naturally aged wood, and previously treated woods may also be treated with CedarTreat™ Wood Stabilizer™ Products. However, extended treatment times are usually required for drier wood treatment protocols.

CedarTreat™ Wood Stabilizer™ treated lumber is specified to be dry within 30 days of treatment completion at which time the active moisture content of the material shall be deemed " zero active moisture".

3.3 Incising:

Although not prohibited, incising ("scoring") timber, wood or lumber prior to treatment IS NOT considered necessary when using CedarTreat™ Wood Stabilizer™ Products.

3.4 Treatment Process:

The pressure-treating process for CedarTreat™ Wood Stabilizer™ solutions is defined as vacuum-pressure-vacuum and includes but is not limited to 15 minute cycles. Work solutions may be heated to a maximum of 150- F (66- C), to enhance penetration and trigger the subsequent exodus of free and bound water from the cellular structure. Moisture exhumed from the timber will cling to the wood surface until the carrier is evacuated from the vessel and subsequent vaporization to atmosphere of the water is triggered. Sun or induced heat will promote immediate completion of drying with in several hours. Excess moisture content

accumulating in the treatment solution will vaporize from heated solutions or can be discarded by draining from the bottom of the storage reservoir.

3.5 Solution Strength Testing:

The manufacturer recommends the Refraction method of testing solution strength be utilized, and generally follow the procedure below:

3.5.1 Sampling: Check a sample of solution which has been left to stand for a period in the room (the water temperature should be the same as the room temperature) regardless of the measuring temperature. Set the boundary line to zero by using the adjusting screw for calibration. Then measure the sample, and note the scale reading which can be taken as the true value.

Variations in room temperature may cause an error, so it is recommended that the zero-setting be checked at intervals of 20 minutes using the test water mentioned above.

3.5.2 Precautions:

a. Hold the refractometer between the thumb and finger tips of the left hand and use the right hand for
adjusting the eyepiece and manipulating the sample. Do not hold the refractometer by enveloping the entire tube with the palm of the hand.

b. When the sample is severely turbid or colored, the field of vision darkens and the boundary line may become unclear or completely disappear. In such cases, try reading in direct sunlight or bright light.

c. Since the refractometer is an optical instrument, do not drop it or handle it roughly.

d. Since the prism has a relatively soft surface, be careful not to scratch it.

e. After use, clean the prism surface and daylight plate with a soft cloth soaked in water and wipe off the moisture with a dry cloth.

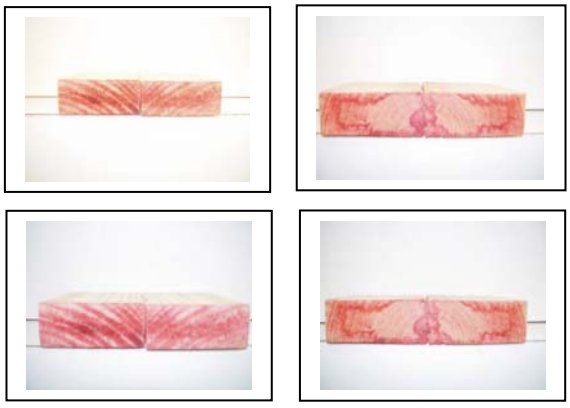
f. If the prism surface is smeared with oil or similar liquids it will repel the sample and obstruct the measurement. Wipe off the oil smear or contaminant with warm water.

3.6 Results of Treatment:

All timber subject to treatment with CedarTreat™ Wood Stabilizer™ Products should periodically be checked for treatment penetration levels. This is done by cutting a treated specimen and the dusting of the severed ends with a solvent compatible dye provided by CedarCide Industries, Inc. The results of this application will reveal the penetration level of the treatment. This process should be practiced on freshly treated timber and prior to the solvent flash off (curing) of the CedarTreat™ Wood Stabilizer™ solution. Various levels of treatment will indicate delivery amounts of different magnitudes. This is observed by the reagent dye and its reaction to the solvent level achieved in the treatment process.

Typical CedarTreat™ penetration of Soft and Hardwood timber species:

Normal **Abnormal**



4.0 QUALITY CONTROL

4.1 General:

Regular use of CedarTreat™ Wood Stabilizer™ will require periodic quality control ("QC"). The program shall be conducted and monitored by the Treater. The manufacturer shall assist Treater in establishing an ongoing QC program customized for the physical plant and predicated on the treatment protocols required by Treater. A jointly developed quality control format and manual can be created to memorialize a program dictating a series of events applicable to this agenda. The publication shall be reviewed and acknowledged by KES Technologies prior to institution.

4.2 Testing Treated Materials:

4.2.1 Introduction: As an ongoing part of a treatment plants quality assurance plan, regular sampling will confirm that the required penetration has been achieved on a piece by piece basis.

4.2.2 Sampling Frequency: CedarCide Industries, Inc. suggests all commercial treatment plants using CedarTreat™ Wood Stabilizer™ Products sample their treated products periodically in an effort to clearly define treatment levels of the ongoing production.

4.2.3 Penetration and Retention Sampling Requirements: Samples should be taken in clear, straight-grained wood away from knots, splits, checks or other defects and at a minimum distance from the end or edge of pieces as indicated in the table below. Samples shall be representative of the charge, but where mixed charges occur, sampling shall be directed at the produce considered to be the most difficult to treat.

4.2.4 Penetration and Retention Tolerance: Penetration and retention requirements will relate directly to the objective of the treatment. Total bulking of the timber should be observed for in ground use where as lesser amounts are used for above ground applications and should be reflected in a minimum of 90% of the samples in observed.

4.2.5 Substandard Treatments: Wood treatment cycles represented by samples not meeting the requirement should be re-branded for the proper classification or in the alternative labeled for construction window protection only.

4.2.6 Penetration Tests: Penetration spot-tests are to be performed on-site using a reagent method. This is performed by dusting of a severed portion of a sampling with the CedarCide™ Red Dye Reagent. The solvent compatible dye will reveal the penetration levels of the treatment.

4.2.7 Retention Tests: Sampling requirements for various treatment levels are published in other sections of this manual. Retention tests are to be conducted by KES Technologies or a subsequently approved laboratory.

4.2.8 Timber Samples: It is suggested that a plant takes sawn samples or increment borings of its treated timber. From these specimen drops or cores a treatment level can be determined.

Sawn Samples: Permit examination of the full cross-section of treatment level. It is suggested that a representative wafer of the test wood be held for a period of time and the cut-off can be discarded. Retained portion should be kept in a sealed jar or air tight container to preserve the reagents reaction.

Increment Borings: Shall be taken at the center of the specimen and at right angles to the annual rings directed toward the pith of round produce or towards the center of sawn timbers.

All holes created as a result of sampling should be tightly plugged with dowels treated with a suitable preservative at a retention loading equivalent to or greater than the produce sampled.

4.2.9 Minimum Sampling: All charges should have a minimum of one sample taken. All details relating to penetration tests conducted shall be recorded on the relevant charge sheet. All samples shall be indelibly labeled with the charge number and shall be held for not less than three months.

Note: Samples that are to be analyzed for retention shall be in addition to the samples retained for in-house use and should not be spot-tested prior to dispatch to the laboratory.

4.3 Plant Responsibility:

Treatment Plant management shall designate an employee trained in quality control procedures, as the plant Quality Control Supervisor ("QCS"). This person shall be responsible for conformance of all trademarked products to the requirements of the applicable standards. This person shall be charged with the following

specific responsibilities, and shall have the authority to correct any action resulting from product nonconformance:

4.3.1 Plant Equipment: The treatment plant shall have equipment for producing, indicating, controlling, and recording pressure and vacuum within the limits specified by KES Technologies Corporation and CedarCide Industries, Inc. The plant QCS shall ensure that this equipment is calibrated and maintained in acceptable working condition. The authorized treating plant shall maintain a laboratory on the plant premises, or in the alternative submit samples periodically to KES Technologies Corporation for analyzing treatment results. It is suggested that a pre-treat and post-treat monitored weight sample of no less than 12 inches in length be recorded from each vessel. Observance of the specimen weight increase will acknowledge fluid uptake and confirm levels of treatment.

4.3.2 Moisture Content: The plant QCS shall monitor and record the moisture content of the scheduled treatment and adjust the elapsed treatment times accordingly. The following chart provide the suggested vessel time based upon moisture content in the wood media:

Suggested Treatment Vessel Time & Standard Settings

Moisture Content	Pretreatment Vacuum	Pressure Treatment	Post Treatment Vacuum
5% to 10%	15 minutes	30 minutes **Min**	5 minutes
10% to 30%	15 minutes	15 minutes **Max**	15 minutes
30% to 100%	15 minutes	30 minutes **Min**	5 minutes

(a) Vacuum 15 to 28 HG
(b) Pressure: 120 to 175 PSI
(c) Temperature: 78-150^{o} F

4.3.3 Record Keeping: The QCS shall keep records of each charge, showing charge number, date treated, material description, and material volume expressed in cubic feet; solution concentration; treating conditions; and net retention expressed in pcf, pbf (or kf) The quality control supervisor shall also keep the records of results of penetration and retention sampling. All records shall be retained for one year. Additionally, each unit of lumber and plywood shall be marked with the charge number.

4.3.4 Sampling for Penetration: The QCS shall sample each charge to establish compliance with penetration standards listed in the approved quality control manual, using methods provided by KES Technologies Corporation.

4.3.5 Frequency: The QCS shall sample charges for retention at a frequency of not less than one charge in every 20 charges. Greater frequency may be required when so determined by the quality control agency and the evaluation report applicant.

6. EVIDENCE SUBMITTED

6.1 Manufacturer-provided Documents

6.1.1 **Standard Applications Procedure Manual** No. CC-101

6.1.2 **CedarTreat™ Wood Stabilizer™ Quality Control Manual** No. CT-001
CedarTreat™ Deck, Dock & Fenced PREtreat Manual No. CT-201

6.1.3 **CedarTreat™ Wood Stabilizer™ Product Control Manual** No. CC-002

6.1.4 **Analytical Standards for Cedar Oil and Silane Preservatives**

6. EVIDENCE SUBMITTED (Continued)

6.2 Reports of Treatment Evaluations

6.2.1 "Laboratory Tests to Determine Durability of Wood Treated with CedarCide Formulation"

Dr. Terry F. Amburgey and Ms. S.V. Parikh, Mississippi State University (2006)

6.2.2 "An Evaluation of the Product Clams for CedarShield™ from a Scientific Perspective"

George M. Jenkins, M.SC., University of New Brunswick, Canada (2006)

6.2.3 "Wood Moisture Tests of Various Wood Species Treated with CedarTreat™ Wood Stabilizer™"

KES Technologies Corporation, The Woodlands, Texas (2007)

6.2.4 "Analytical & Antimicrobial Test Results of Wood Treated with CedarTreat™"

Aegis Laboratories International, xxxxxxxxxx, Michigan (2006)

FOREST AND WILDLIFE RESEARCH CENTER

FOREST PRODUCTS DEPARTMENT

LABORATORY TESTS TO DETERMINE THE DURABILITY OF WOOD TREATED WITH CEDARCIDE FORMULATIONS

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Section 6.2.1

LABORATORY TESTS TO DETERMINE THE DURABILITY OF WOOD TREATED WITH CEDARCIDE FORMULATIONS

The purpose of this study was to determine resistance of wood treated with the CedarCide formulations to brown-rot and white-rot decay fungi and subterranean termites in laboratory bioassays. CedarCide Industries, Inc. has supplied five ready-to-use (RTU).formulations.

Soil Blocks Test - No. 1

Method:

The decay tests were conducted according to procedures given in American Wood Preserves' Association (AWPA) Standard E10-01 with some modifications.

Decay fungi:

Brown-rot fungus – *Gloeophyllum trabeum* (*G. trabeum*) ATCC 11539
White-rot fungus – *Trametes versicolor* (*T. versicolor*) ATCC 42462

Formulations and concentrations:

Formulation	% Cedar Oil	% Silane	% Solvent
1	0	5	95
2	2	2	94
3	2	5	93
4	5	5	90
5	10	10	80

And ACQ treated at 0.25 pcf.

Species and Size:

Replications of 10 of southern yellow pine (SYP) sapwood blocks (0.75" cubes) per formulation were used for brown rot fungus.
Replications of 10 of sweetgum blocks (0.75" cubes) were used for white rot fungus.
In addition, 20 blocks of SYP treated with ACQ formulation (@0.25 pcf) were used for both brown-rot and white-rot fungi as positive control.
Untreated SYP and sweetgum blocks also were used as controls.
Blocks of both wood species were cut from kiln dried stock.

Conditioning:

Five blocks for each formulation and each fungus were leached prior to exposure to the fungi.
Five blocks were unleached for each formulation and each fungus.

Treatment:

The treatment procedure (vacuum/soak method) and the leaching procedure were conducted according to AWPA Standard E -10-01.
Blocks were conditioned at 22 – 23C prior to treatment to obtain equilibrium weights.
Blocks were placed in a vacuum for 5 minutes while under solution and kept in the solution for 30 minutes at atmospheric pressure. All blocks remained under the solution after weights restraining them were removed.
Bocks were removed from solution and air-dried for 17-18 days.
All blocks were then conditioned to constant weight at temperature 22-23C prior to sterilization by autoclaving at 121C for 15 minutes and exposure to test fungi. At the end of 12 weeks, all blocks were removed, air dried, conditioned at temperature22-23 C, and weighed.

Results:

Table 1 presents a summary of individual weight losses of the treated and untreated SYP sapwood blocks after exposure to a brown-rot fungus, *G. trabeum,* for 12 weeks.
Table 2 presents a summary of individual weight losses of the treated and untreated sweetgum blocks after exposure to a white-rot fungus, (*T. versicolor*) for 12 weeks.

Table 1 Weight losses of the treated and untreated SYP sapwood blocks after exposure to a brown-rot fungus *G. trabeum* for 12 weeks.

Formulation #	Conditioning[a]	Block #	Retention (pcf)			W3 g	W4 g	% Weight. Loss
			Formulation[b] #	Cedar Oil (a.i.)[c]	Silane[d] (a.i.)			
1 Cedar Oil-(0%) Silane (5.0%)	NL	1	29.49	----	1.47	3.79	2.69	29.02
		2	31.48	----	1.57	3.56	2.33	34.55
		3	27.86	----	1.39	3.55	2.11	40.56
		4	29.13	----	1.46	3.73	2.57	31.10
		5	28.32	----	1.42	3.76	2.89	23.14
		Average	29.26		1.46			31.68
	L	6	35.55	----	1.78	4.82	3.31	31.33
		7	25.69	----	1.28	4.72	3.39	28.18
		8	24.52	----	1.23	4.32	3.16	26.85
		9	30.04	----	1.50	4.06	2.75	32.27
		10	22.98	----	1.15	5.15	4.68	9.13
		Average	27.76		1.39			25.55
2 Cedar Oil-(2.0%) Silane (2.0%)	NL	11	25.87	0.52	0.52	3.96	2.76	30.30
		12	25.06	0.50	0.50	4.27	2.95	30.91
		13	29.76	0.60	0.60	3.49	2.55	26.93
		14	28.95	0.58	0.58	3.93	2.91	25.95
		15	35.55	0.71	0.71	3.72	2.92	21.51
		Average	29.04	0.58	0.58			27.12
	L	16	34.74	0.69	0.69	4.26	3.07	27.93
		17	28.32	0.57	0.57	4.41	3.04	31.07
		18	28.59	0.57	0.57	4.56	3.30	27.63
		19	25.87	0.52	0.52	4.76	3.85	19.12
		20	24.88	0.50	0.50	4.73	3.63	23.26
		Average	28.48	0.57	0.57			25.80
3	NL	21	26.87	0.54	1.34	3.82	3.01	21.20

Formulation #	Conditioning[a]	Block #	Retention (pcf)			W3 g	W4 g	% Weight. Loss
			Formulation[b] #	Cedar Oil (a.i.)[c]	Silane[d] (a.i.)			
Cedar Oil-(2.0%) Silane (5.0%)	NL	22	30.40	0.61	1.52	4.05	3.25	19.75
		23	29.04	0.58	1.45	4.01	3.29	17.96
		24	26.42	0.53	1.32	4.38	3.08	29.68
		25	25.96	0.52	1.30	4.62	3.08	33.33
		Average	27.74	0.55	1.39			24.39
	L	26	25.42	0.51	1.27	4.35	3.49	19.77
		27	29.31	0.59	1.47	4.77	3.29	31.03
		28	27.59	0.55	1.38	4.50	3.23	28.22
		29	29.31	0.59	1.47	4.13	2.95	28.57
		30	26.15	0.52	1.31	4.58	3.27	28.60
		Average	27.56	0.55	1.38			27.24
4 Cedar Oil-(5.0%) Silane (5.0%)	NL	31	29.40	1.47	1.47	4.63	3.11	32.83
		32	31.57	1.58	1.58	4.48	3.38	24.55
		33	28.32	1.42	1.42	4.29	3.49	18.65
		34	24.52	1.23	1.23	5.02	3.91	22.11
		35	30.40	1.52	1.52	4.24	3.19	24.76
		Average	28.84	1.44	1.44			24.58
	L	36	25.78	1.29	1.29	5.02	3.11	38.05
		37	32.12	1.61	1.61	4.48	3.38	24.55
		38	22.80	1.14	1.14	5.26	3.75	28.71
		39	30.76	1.54	1.54	4.24	3.42	19.34
		40	27.77	1.39	1.39	4.94	3.62	26.72
		Average	27.85	1.39	1.39			27.47
5 Cedar Oil-(10.0%) Silane (10.0%)	NL	41	27.59	2.76	2.76	4.75	3.62	23.79
		42	31.30	3.13	3.13	4.26	3.12	26.76
		43	29.13	2.91	2.91	4.31	3.40	21.11
		44	29.40	2.94	2.94	4.26	3.64	14.55
		45	30.04	3.00	3.00	4.21	3.04	27.79

Formulation #	Conditioning[a]	Block #	Retention (pcf)			W3 g	W4 g	% Weight. Loss
			Formulation[b] #	Cedar Oil (a.i.)[c]	Silane[d] (a.i.)			
		Average	29.49	2.95	2.95			22.80
Cedar Oil- (10.0%) Silane (10.0%)	L	46	32.21	3.22	3.22	4.65	3.17	31.83
		47	27.05	2.70	2.70	5.29	4.18	20.98
		48	28.23	2.82	2.82	5.09	3.95	22.40
		49	36.64	3.66	3.66	5.33	4.31	19.14
		50	31.12	3.11	3.11	4.47	3.07	31.32
		Average	31.05	3.10	3.10			25.13
ACQ (0.25 pcf)	NL	61		0.25		3.69	3.66	0.81
		62				3.82	3.77	1.31
		63				3.68	3.68	0.00
		64				3.78	3.76	0.53
		65				3.83	3.79	1.04
		Average						0.74
	L	66				4.13	4.11	0.48
		67				3.89	3.86	0.77
		68				4.27	4.23	0.94
		69				3.80	3.77	0.79
		70				3.80	3.77	0.79
		Average						0.75
Control	NL	51		-----		4.47	2.24	49.89
		52				3.80	2.33	38.68
		53				3.35	1.75	47.76
		54				3.32	1.85	44.28
		55				3.95	2.35	40.51
		Average						44.22
	L	56		-----		3.87	2.25	41.86
		57				3.98	2.30	42.21
		58				3.55	1.90	46.48

Formulation #	Conditioning[a]	Block #	Retention (pcf)			W3 g	W4 g	% Weight. Loss
			Formulation[b] #	Cedar Oil (a.i.)[c]	Silane[d] (a.i.)			
		59		-----		3.44	2.25	34.59
Control		60				3.50	2.00	42.86
		Average						41.60

[a:] Conditioning: L= Leached and NL = Unleached
[b:] The retention is based on the Formulation pounds per cubic foot
[c:] The retention is based on the active ingredients of Cedar Oil.
[d:] The retention is based on the active ingredients of Silane
[e:] The weight of the block before exposure to fungus.
[f:] The weight of the block after exposure to fungus.

Table 2 Weight losses of the treated and untreated sweetgum blocks after exposure to a white-rot fungus, (*T. versicolor)*, for 12 weeks.

Formulation #	Conditioning[a]	Block #	Retention (pcf)			W3 g	W4 g	% Weight. Loss
			Formulation[b] #	Cedar Oil (a.i.)[c]	Silane[d] (a.i.)			
1 Cedar Oil-(0%) Silane (5.0%)	NL	1	23.78	----	1.19	4.62	3.15	31.82
		2	19.31	----	0.97	4.93	4.00	18.86
		3	23.39	----	1.17	4.71	3.90	17.20
		4	20.49	----	1.02	5.27	4.00	24.10
		5	19.70	----	0.99	5.76	4.80	16.67
		Average	21.33		1.07			21.73
	L	6	20.80	----	1.04	5.16	2.07	59.88
		7	19.78	----	0.99	5.34	1.28	76.03
		8	21.51	----	1.08	5.23	1.87	64.24
		9	18.99	----	0.95	4.98	1.24	75.10
		10	19.23	----	0.96	4.82	1.96	59.34
		Average	20.06		1.04			66.92
2 Cedar Oil-(2.0%) Silane (2.0%)	NL	11	20.64	0.41	0.41	5.23	3.18	39.20
		12	19.31	0.39	0.39	4.92	2.81	42.89
		13	23.15	0.46	0.46	4.58	2.84	37.99
		14	15.70	0.31	0.31	5.02	2.29	54.38
		15	20.25	0.41	0.41	5.16	2.89	43.99
		Average	19.81	0.40	0.40			43.69
	L	16	19.94	0.40	0.40	5.10	0.89	82.55
		17	20.49	0.41	0.41	5.10	2.17	57.45
		18	19.23	0.38	0.38	4.86	1.91	60.70
		19	20.09	0.40	0.40	5.17	2.28	55.90
		20	15.54	0.31	0.31	4.81	2.05	57.38

Formulation #	Conditioning[a]	Block #	Retention (pcf)			W3 g	W4 g	% Weight. Loss
			Formulation[b] #	Cedar Oil (a.i.)[c]	Silane[d] (a.i.)			
		Average	19.06	0.38	0.38			62.80
3 Cedar Oil-(2.0%) Silane (5.0%)	NL	21	15.62	0.31	0.78	4.92	1.86	62.20
		22	20.17	0.40	1.01	5.11	2.75	46.18
		23	25.51	0.51	1.28	4.63	2.54	45.14
		24	15.78	0.32	0.79	5.10	3.03	40.59
		25	23.08	0.46	1.15	4.72	2.25	52.33
		Average	20.03	0.40	1.00			49.29
	L	26	21.04	0.42	1.05	5.19	2.41	53.56
		27	15.62	0.31	0.78	4.70	2.24	52.34
		28	23.15	0.46	1.16	4.96	1.95	60.69
		29	20.33	0.41	1.02	5.64	2.91	48.40
		30	19.94	0.40	1.00	5.09	1.57	69.16
		Average	20.01	0.40	1.00			56.83
4 Cedar Oil-(5.0%) Silane (5.0%)	NL	31	15.93	0.80	0.80	5.06	4.31	14.82
		32	16.09	0.80	0.80	6.40	5.60	12.50
		33	16.25	0.81	0.81	5.41	4.22	22.00
		34	22.45	1.12	1.12	5.08	4.24	16.54
		35	16.64	0.83	0.83	5.50	4.06	26.18
		Average	17.47	0.88	0.88			18.41
	L	36	19.86	0.99	0.99	5.31	4.25	19.96
		37	15.93	0.80	0.80	4.83	4.39	9.11
		38	20.41	1.02	1.02	5.61	4.36	22.28
		39	15.62	0.78	0.78	4.97	4.30	13.48
		40	16.25	0.81	0.81	5.24	4.10	21.76
		Average	17.61	0.88	0.88			17.32
5 Cedar Oil-(10.0%)	NL	41	24.88	2.49	2.49	5.55	4.15	25.23
		42	16.17	1.62	1.62	5.11	2.56	49.90

Formulation #	Conditioning[a]	Block #	Retention (pcf)			W3 g	W4 g	% Weight. Loss
			Formulation[b] #	Cedar Oil (a.i.)[c]	Silane[d] (a.i.)			
Silane (10.0%)		43	22.29	2.23	2.23	5.21	2.00	61.61
		44	22.29	2.23	2.23	5.41	3.75	30.68
		45	21.43	2.14	2.14	5.82	3.31	43.13
		Average	21.41	2.14	2.14			42.11
	L	46	16.48	1.65	1.65	5.38	2.87	46.65
		47	22.53	2.25	2.25	4.99	4.20	15.83
		48	20.72	2.07	2.07	5.42	3.40	37.27
		49	22.53	2.25	2.25	5.67	4.10	27.69
		50	21.04	2.10	2.10	5.58	2.92	47.67
		Average	20.66	2.07	2.07			35.02
ACQ-0.25 pcf	NL	61		0.25		3.69	3.66	0.81
		62				3.82	3.77	1.31
		63				3.68	3.68	0.00
		64				3.78	3.76	0.53
		65				3.83	3.79	1.04
		Average						0.74
	L	66				4.13	4.11	0.48
		67				3.89	3.86	0.77
		68				4.29	4.23	1.40
		69				3.80	3.77	0.79
		70				3.80	3.77	0.79
		Average						0.85
Control	NL	51		----		5.03	2.42	51.89
		52				4.25	1.66	60.94
		53				5.03	2.33	53.68
		54				4.84	1.75	63.84
		55				5.05	2.41	52.28

Formulation #	Conditioning[a]	Block #	Retention (pcf)			W3 g	W4 g	% Weight. Loss
			Formulation[b] #	Cedar Oil (a.i.)[c]	Silane[d] (a.i.)			
Control		Average						56.53
	L	56		----		5.21	2.40	53.93
		57				4.43	1.12	74.72
		58				4.45	2.20	50.56
		59				4.37	2.23	48.97
		60				4.51	1.36	69.84
		Average						59.61

[a:] Conditioning: L= Leached and NL = Unleached
[b:] The retention is based on the Formulation pounds per cubic foot
[c:] The retention is based on the active ingredients of Cedar Oil.
[d:] The retention is based on the active ingredients of Silane
[e:] The weight of the block before exposure to fungus.
[f:] The weight of the block after exposure to fungus.

Subterranean Termite test

This report covers the termite test results for treated southern yellow pine (SYP) wafers treated with Cedarcide formulations. The termite test was conducted according to procedures given in AWPA Standard (AWPA) E1-97, Section 1.1.1 for **No choice test**.

Test organisms:
Field collected native subterranean termites, *Reticulitermes flavipes (R. flavipes)*

Formulations and concentrations:

Formulation	% Cedar Oil	% Silane	% Solvent
1	0	5	95
2	2	2	94
3	2	5	93
4	5	5	90
5	10	10	80

Species and Size:

Replications of 10 of southern yellow pine (SYP) sapwood wafers (1" x1" x o.25") per formulation were used.
In addition, 10 SYP wafers of treated with ACQ formulation (@0.25 pcf) were used as positive control.

Conditioning:

Five blocks per formulation were leached,
Five blocks per formulation were unleached.

Treatment:

The treatment procedure (vacuum/soak method) and the leaching procedure were conducted according to AWPA Standard E-10-01.
Blocks were conditioned at 22 – 23C prior to treatment to obtain equilibrium weights.
Blocks were placed in a vacuum for 5 minutes while under solution and kept in the solution for 30 minutes at atmospheric pressure.
Blocks were removed from solution and air-dried for 17-18 days.
All blocks were conditioned to constant weight at temperature 22-23C prior to exposure to termites.
Termite test was conducted according to procedures given in AWPA Standard E 1-97. All wafers were conditioned to constant weight at temperature 22-23C prior to exposure to termites. At the end of 4 weeks, all blocks were removed, air dried, conditioned at temperature 50^0 C, and weighed.

Results:

Table 3 presents a summary of individual weight losses and the block ratings of the treated and untreated SYP sapwood wafers after exposure to subterranean termites, *Reticulitermes flavipes*, *(R. flavipes)*, for 4 weeks.

In this test, a block rating of 7.0 or less represents a questionable level of durability.

Table 3: Summary of individual weight losses and block ratings for treated southern yellow pine sapwood and untreated SYP wafers as control (25 mm square by 6 mm radial direction) after exposure to subterranean (*Reticulitermes flavipes*) for four weeks. (**No Choice Method**).

							Visual Inspection[e]						Block[f]
Formulation	Conditioning	Block[a] #	Retention[b]	W1[c] g	W2[d] g	Wt. loss	1st week			4th week			ratings
			pcf			(%)	T	P	M	T	P	M	
1 Cedar Oil- (0%) Silane (5.0%)	NL	1	25.91	1.91	1.77	7.33	+	d	s	+	-	x	8
		2	26.91	1.81	1.72	4.97	+	d	s	+	-	x	8
		3	25.91	1.70	1.64	3.53	+	d	s	+	-	x	8
		4	26.41	1.84	1.74	5.43	+	d	s	+	-	x	8
		5	25.07	1.72	1.66	3.49	+	d	s	+	d	h	9
		Average	26.04			4.95							8
	L	6	26.91	1.76	1.53	13.07	+	d	s	+	u/d	s	7
		7	25.40	1.64	1.16	29.27	+	d	s	+	u/d	s	6
		8	27.58	1.77	1.37	22.60	+	d	s	+	u/d	s	6
		9	26.07	1.77	1.36	23.16	+	d	s	+	u/d	s	6
		10	25.57	1.96	1.60	18.37	+	d	s	+	u/d	s	7
		Average	26.31			21.29							6
2 Cedar Oil- (2.0%) Silane (2.0%)	NL	11	25.57	2.01	1.80	10.45	+	d	s	+	u/d	m	9
		12	25.40	2.05	1.97	3.90	+	d	s	+	-	x	10
		13	33.93	1.75	1.68	4.00	+	d	s	+	-	x	8
		14	25.57	1.73	1.58	8.67	+	d	s	+	-	x	7
		15	25.74	1.90	1.39	26.84	+	d	s	+	u/d	s	4
		Average	27.24			10.77							8
	L	16	25.24	1.80	1.55	13.89	+	d	s	+	u/d	m	7
		17	26.41	1.83	1.61	12.02	+	d	s	+	u/d	m	7
		18	23.90	1.61	1.10	31.68	+	d	s	+	u/d	s	6
		19	25.74	1.75	1.40	20.00	+	d	s	+	u/d	s	7
		20	25.40	1.94	1.42	26.80	+	d	s	+	u/d	s	4

Formulation	Conditioning	Block[a] #	Retention[b]	W1[c] g	W2[d] g	Wt. loss	Visual Inspection[e] 1st week			Visual Inspection[e] 4th week			Block[f] ratings
			pcf			(%)	T	P	M	T	P	M	
		Average	25.34			20.88							6
3 Cedar Oil-(2.0%) Silane (5.0%)	NL	21	27.41	1.82	1.73	4.95	+	d	s	+	-	x	10
		22	27.41	1.96	1.87	4.59	+	d	s	+	-	x	10
		23	25.24	2.01	1.93	3.98	+	d	s	+	-	x	10
		24	27.08	1.89	1.81	4.23	+	d	s	+	-	x	9
		25	26.91	1.84	1.79	2.72	+	d	s	+	-	x	10
		Average	26.81			4.09							9
	L	26	25.74	1.97	1.93	2.03	+	d	s	+	-	x	9
		27	24.40	1.75	1.59	9.14	+	d	s	+	u	h	8
		28	24.40	1.96	1.65	15.82	+	d	s	+	u/d	m	7
		29	25.57	2.12	2.06	2.83	+	d	s	+	-	x	9
		30	28.25	1.94	1.90	2.06	+	d	s	+	-	x	10
		Average	25.67			6.38							9
4 Cedar Oil-(5.0%) Silane (5.0%)	NL	31	26.74	1.95	1.85	5.13	+	d	s	+	-	x	10
		32	24.74	1.92	1.81	5.73	+	d	s	+	-	x	10
		33	24.90	2.19	2.15	1.83	+	d	s	+	-	x	10
		34	25.40	2.02	1.96	2.97	+	d	s	+	-	x	10
		35	25.24	2.17	2.04	5.99	+	d	s	+	-	x	10
		Average	25.40			4.33							10
	L	36	27.24	1.99	1.96	1.51	+	d	s	+	-	x	10
		37	26.74	1.78	1.74	2.25	+	d	s	+	-	x	10
		38	25.57	1.96	1.92	2.04	+	d	s	+	-	x	9
		39	25.40	1.89	1.88	0.53	+	d	s	+	-	x	10
		40	26.07	1.80	1.78	1.11	+	d	s	+	-	x	10
		Average	26.21			1.49							10
5 Cedar Oil-	NL	41	27.74	2.06	1.92	6.80	+	d	s	+	-	x	10
		42	27.41	2.04	1.93	5.39	+	d	s	+	-	x	10

Formulation	Conditioning	Block[a] #	Retention[b]	W1[c] g	W2[d] g	Wt. loss	Visual Inspection[e] 1st week			Visual Inspection[e] 4th week			Block[f] ratings
			pcf			(%)	T	P	M	T	P	M	
(10.0%) Silane (10.0%)		43	27.58	2.13	1.97	7.51	+	d	s	+	-	x	10
		44	25.74	1.91	1.81	5.24	+	d	s	+	-	x	10
		45	27.41	2.12	1.98	6.60	+	d	s	+	-	x	10
		Average	27.18			6.31							10
	L	46	27.74	1.88	1.84	2.13	+	d	s	+	-	x	10
		47	26.24	1.90	1.88	1.05	+	d	s	+	-	x	10
		48	27.58	1.88	1.83	2.66	+	d	s	+	-	x	10
		49	24.23	1.88	1.87	0.53	+	d	s	+	-	x	10
		50	28.25	1.88	1.83	2.66	+	d	s	+	-	x	10
		Average	26.81			1.81							10
ACQ (O.20pcf)	NL	61	0.20	1.69	1.66	1.78	+	d	s	+	-	x	10
		62		1.81	1.80	0.55	+	d	s	+	-	x	10
		63		1.70	1.68	1.18	+	d	s	+	-	x	9
		64		1.86	1.86	0.00	+	d	s	+	-	x	10
		65		1.91	1.88	1.57	+	d	s	+	-	x	9
		Average				1.01							9
	L	66	0.20	2.03	2.01	0.99	+	d	s	+	-	x	10
		67		1.97	1.97	0.00	+	d	s	+	-	x	10
		68		1.77	1.77	0.00	+	d	s	+	-	x	10
		69		1.75	1.74	0.57	+	d	s	+	-	x	10
		70		1.85	1.83	1.08	+	d	s	+	-	x	10
		Average				0.53							10
Control SYP	L	51	----	1.79	1.14	36.31	+	d	s	+	d	s	0
		52		1.78	1.24	30.34	+	d	s	+	d	s	4
		53		1.80	1.02	43.33	+	d	s	+	d	s	0
		54		1.70	1.07	37.06	+	d	s	+	d	s	0

Formulation	Conditioning	Block[a] #	Retention[b]	W1[c] g	W2[d] g	Wt. loss	Visual Inspection[e] 1st week			Visual Inspection[e] 4th week			Block[f] ratings
			pcf			(%)	T	P	M	T	P	M	
Control SYP	-----	55		1.80	1.28	28.89	+	d	s	+	d	s	4
		Average				35.19							2
	L	56	----	1.94	1.32	31.96	+	d	s	+	d	s	0
		57		1.63	0.92	43.56	+	d	s	+	d	s	0
		58		1.79	1.13	36.87	+	d	s	+	d	s	0
		59		1.74	1.11	36.21	+	d	s	+	d	s	4
		60		1.76	1.02	42.05	+	d	s	+	d	s	0
		Average				38.13							1

[a:] SYP BLOCKS ARE CONTROL AND BLOCK NUMBERS WITH "L" ARE LEACHED BLOCKS, "NL" = NONLEACHED

[b:] THE RETENTION IS NOT BASED ON ACTIVE INGREDIENTS (a.i). PCF = POUNDS PER CUBIC FOOT.

[c:] W1: WEIGHT OF THE BLOCK BEFORE EXPOSURE TO TERMITES AND CONDITIONED AT TEMPERATURE 50^{O} C.

[d:] W2: WEIGHT OF THE BLOCK AFTER EXPOSURE TO TERMITES AND CONDITIONED AT TEMPERATURE $50^{0C.}$

[e:] VISUAL INSPECTION:

T = TUNNELING - "+" = YES; "-" = NO

P = MAJORITY TERMITE POSITION - "u" ON SURFACE and "d" BENEATH SURFACE

M = APPROXIMATE TERMITE MORTALITY - "s" = SLIGHT (0% TO 33%)

"m" = MODERATE (34% TO 66%)

"h" = HEAVY (67% TO 99%)

"x" = COMPLETE (100%) AND "-" NO EVIDENCE.

[f:] BLOCK RATINGS:

10 = SOUND, TRACE, SURFACE NIBBLES PERMITTED

9 =SLIGHT ATTACK

7 = MODERATE ATTACK, PENETRATION

4 = VERY SEVERE ATTACK

0 = FAILURE

Laboratory Leach Test

This report covers the laboratory leaching procedure for the treated southern yellow pine cubes (o.75") treated with the Cedarcide formulations. The leaching test was conducted according to AWPA Standard E11-06. The treating procedure was conducted according to the AWPA Standard E10-01, Section 9.

Formulations and concentrations:

Formulation	% Cedar Oil	% Silane	% Solvent
2	2	2	94
3	2	5	93
4	5	5	90

Species and Size:

Replications of 12 of southern yellow pine (SYP) sapwood blocks (0.75" cubes) per formulation were used for the leaching test.
From each retention level, the six blocks with the most uniform retention levels were used for the leach test. All blocks were conditioned to constant weight at temperature 23ºC prior to exposure to leach test. At the end of 2 weeks, all blocks were air dried, and conditioned to constant weight at temperature 23^0 C.

Change of leachate water:

After 6, 24, 48, and there after at 48 hour intervals, 50 ml of the leachate was removed from each retention level and replaced with an equal amount of fresh distilled water. At the end of 2 weeks, total volume of the leachate for each retention level was 450 ml (9 cycles). All leachate samples were sent to the **CedarCide Industries, Inc.**

Table 4: The summary of the retention of the individual southern yellow sapwood (0.75") cubes use in the leaching test.

Formulation #	Block [a]:#	W1[b]: g	W2[c]g	Retention [d] pcf
2	61	3.58	6.65	27.77
Cedar Oil-(2.0%)	62x	3.56	6.81	29.40
Silane (2.0%)	63x	3.06	6.34	29.67
	64x	3.36	6.67	29.94
	65	3.69	6.75	27.68
	66x	3.56	6.71	28.50
	67	3.83	6.73	26.24
	68	3.64	6.74	28.05
	69	3.09	6.62	31.94
	70	3.83	6.99	28.59
	71x	3.45	6.58	28.32
	72x	3.36	6.66	29.85
	Average			28.83
3	73x	3.53	6.75	29.13
Cedar Oil-(2.0%)	74	2.79	6.88	37.00
Silane (5.0%)	75x	3.42	6.83	30.85
	76x	3.95	7.37	30.94
	77x	3.78	6.75	26.87
	78x	4.19	7.35	28.59
	79	3.14	6.8	33.11
	80	2.98	6.76	34.20
	81	2.81	6.74	35.55
	82	5.04	7.59	23.07
	83x	3.33	6.66	30.13
	84x	3.66	6.82	28.59
	Average			30.67
4	85	2.35	6.41	36.73
Cedar Oil-(5.0%)	86x	3.65	6.86	29.04
Silane (5.0%)	87x	3.88	7.09	29.04
	88x	3.89	7.11	29.13
	89	2.55	6.5	35.73
	90x	4.01	7.24	29.22
	91x	3.84	7.02	28.77
	92	2.15	7.41	47.59
	93	4.25	7.02	25.06
	94x	3.95	7.22	29.58
	95	4.23	7.24	27.23
	96	3.95	7.08	28.32
	Average			31.29

[a] block number with "x " mark was selected for leaching.
[b]: W1: Weight of the block before treatment.
[c]: W2: Weight of the block before treatment.
[d]: The retention is based on the formulations not on active ingredients.

Soil Block, Test - No. 2

Method:

The decay tests were conducted according to procedures given in AWPA Standard E10-01.

Decay fungi:

Brown-rot fungus – *Gloeophyllum trabeum* (*G. trabeum*) ATCC 11539
White-rot fungus – *Trametes versicolor* (*T. versicolor*) ATCC 42462

Formulations and concentrations:

Formulation	% Cedar Oil	% Silane	% Solvent
1	0	5	95
2	2	2	94
3	2	5	93
4	5	5	90
5	10	10	80

And ACQ treated at 0.25 pcf.

Species and Size:

Replications of 10 per formulation of southern yellow pine (SYP) sapwood blocks (0.75" cubes) were used for brown rot fungus.
Replications of 10 per formulation of sweetgum blocks (0.75" cubes) were used for white rot fungus.
In addition, 20 blocks of SYP treated with ACQ formulation (@0.25 pcf) were used for both brown-rot and white-rot fungi as positive control. All blocks were cut from kiln dried stock. Untreated blocks served as controls.

Conditioning:

Five blocks for each formulation and each fungus were leached prior to use in decay tests..
Five blocks were unleached for each formulation and each fungus.

Treatment:

Blocks were conditioned at 22 – 23C prior to treatment to obtain equilibrium weights.
Blocks were placed in a vacuum for 5 minutes while under solution and kept in the solution for 30 minutes at atmospheric pressure.
Bocks were removed from solution and air-dried for 17-18 days.
Blocks were conditioned at 22-23C and 45%RH to constant weight to obtain treated weight.

The soil block tests were conducted according to procedures given in AWPA Standard E 10-01. All blocks were sterilized by immersion in boiling water for 30 seconds..
All blocks were conditioned at 22-23C and relative humidity 44-45% prior to expose to test fungi. At the end of 12 weeks, all blocks were removed; air dried, conditioned at 22-23C and relative humidity 44-45%, and weighed.

Results:

Table 5 gives treatment data for southern yellow pine blocks
Table 6 presents a summary of individual weight losses of the treated and untreated SYP sapwood blocks after exposure to a brown-rot fungus, *G. trabeum,* for 12 weeks.
Table 7 gives treatment data for sweetgum blocks
Table8 presents a summary of individual weight losses of the treated and untreated sweetgum blocks after exposure to a white-rot fungus, *T. versicolor,* for 12 weeks.
Table 9 gives comparative data for blocks in soil-block tests 1 and 2 that were exposed to a brown-rot fungus
Table 10 gives comparative data for blocks in soil-block tests 1 and 2 that were exposed to a white-rot fungus.

Table 5 Treatment data for Southern yellow pine sapwood blocks

				Retention[c] (pcf)		
Formulation #	Block #	W1[a] g	W2[b] g	Formulation	Cedar	Silane
1 Cedar OIL (0%) Silane (5%)	1	3.83	6.76	26.51	---	1.33
	2	4.41	7.24	25.60	---	1.28
	3	4.16	7.31	28.50	---	1.42
	4	3.71	6.70	27.05	---	1.35
	5	3.45	6.76	29.94	---	1.50
	6	4.06	6.87	25.42	---	1.27
	7	3.33	6.59	29.49	---	1.47
	8	3.46	6.77	29.94	---	1.50
	9	3.48	6.59	28.14	---	1.41
	10	2.52	6.58	36.73	---	1.84
	Average			28.73		1.44
2 Cedar OIL (2%) Silane (2%)	11	4.66	7.48	25.51	0.51	0.51
	12	3.49	6.76	29.58	0.59	0.59
	13	3.63	6.89	29.49	0.59	0.59
	14	3.74	6.72	26.96	0.54	0.54
	15	3.74	6.84	28.05	0.56	0.56
	16	3.68	6.87	28.86	0.58	0.58
	17	3.45	6.82	30.49	0.61	0.61
	18	4.17	7.39	29.13	0.58	0.58
	19	3.35	6.58	29.22	0.58	0.58
	20	4.54	7.16	23.70	0.47	0.47
	Average			28.10	0.56	0.56
3 Cedar OIL (2%) Silane (5%)	21	3.71	6.87	28.59	0.57	1.43
	22	3.98	7.10	28.23	0.56	1.41
	23	3.28	6.41	28.32	0.57	1.42
	24	3.77	7.09	30.04	0.60	1.50
	25	3.24	6.73	31.57	0.63	1.58
	26	3.24	6.62	30.58	0.61	1.53
	27	4.05	7.05	27.14	0.54	1.36
	28	3.68	6.67	27.05	0.54	1.35
	29	3.89	6.74	25.78	0.52	1.29
	30	4.13	7.05	26.42	0.53	1.32
	Average			28.37	0.57	1.42
4 Cedar OIL (5%) Silane (5%)	31	3.52	6.94	30.94	1.55	1.55
	32	3.83	6.76	26.51	1.33	1.33
	33	4.10	7.35	29.40	1.47	1.47
	34	3.08	6.48	30.76	1.54	1.54
	35	3.91	6.95	27.50	1.38	1.38
	36	4.40	7.28	26.05	1.30	1.30
	37	3.19	6.70	31.75	1.59	1.59
	38	4.41	7.05	23.88	1.19	1.19
	39	4.26	6.58	20.99	1.05	1.05

				Retention[c] (pcf)		
Formulation #	Block #	W1[a] g	W2[b] g	Formulation	Cedar	Silane
4	40	3.76	6.82	27.68	1.38	1.38
	Average			27.55	1.38	1.38
5 Cedar OIL (10%) Silane (10%)	41	3.41	6.81	30.76	3.08	3.08
	42	4.25	7.39	28.41	2.84	2.84
	43	3.94	7.16	29.13	2.91	2.91
	44	4.49	7.43	26.60	2.66	2.66
	45	4.36	6.90	22.98	2.30	2.30
	46	4.09	7.03	26.60	2.66	2.66
	47	3.77	6.95	28.77	2.88	2.88
	48	4.33	7.30	26.87	2.69	2.69
	49	3.92	7.07	28.50	2.85	2.85
	50	3.83	6.54	24.52	2.45	2.45
	Average			27.31	2.73	2.73

[a;] W1 = Weight of the block before treatment
[b:] W2 = Weight of the block after treatment
[c:] pcf = pounds per cubic foot.

Table 6 Weight losses of the treated and untreated SYP sapwood blocks after exposure to a brown-rot fungus *G. trabeum* for 12 weeks (**Soil block test-2)**.

Formulation #	Conditioning[a]	Block #	Retention (pcf)			W3 g	W4 g	% Weight. Loss
			Formulation[b] #	Cedar Oil (a.i.)[c]	Silane[d] (a.i.)			
1 Cedar Oil-(0%) Silane (5.0%)	NL	1	26.51	----	1.33	4.51	3.47	23.06
		2	25.60	----	1.28	4.83	4.00	17.18
		3	28.50	----	1.42	4.43	4.14	6.55
		4	27.05	----	1.35	4.40	3.33	24.32
		5	29.94	----	1.50	3.74	3.21	14.17
		Average	27.52		1.38			17.06
	L	6	25.42	----	1.27	4.79	3.41	28.81
		7	29.49	----	1.47	4.15	2.97	28.43
		8	29.94	----	1.50	4.36	2.90	33.49
		9	28.14	----	1.41	4.18	2.92	30.14
		10	36.73	----	1.84	3.94	3.03	23.10
		Average	29.94		1.50			28.79
2 Cedar Oil-(2.0%) Silane (2.0%)	NL	11	25.51	0.51	0.52	5.07	4.34	14.40
		12	29.58	0.59	0.50	4.22	2.81	33.41
		13	29.49	0.59	0.60	4.46	3.09	30.72
		14	26.96	0.54	0.58	4.42	2.95	33.26
		15	28.05	0.56	0.71	4.21	3.21	23.75
		Average	27.92	0.56	0.58			27.11
	L	16	28.86	0.58	0.58	4.52	2.77	38.72
		17	30.49	0.61	0.61	4.55	3.06	32.75
		18	29.13	0.58	0.58	4.98	3.16	36.55
		19	29.22	0.58	0.58	4.00	2.66	33.50
		20	23.70	0.47	0.47	4.91	3.42	30.35
		Average	28.28	0.57	0.57			34.37

Formulation #	Conditioning[a]	Block #	Retention (pcf)			W3 g	W4 g	% Weight. Loss
			Formulation[b] #	Cedar Oil (a.i.)[c]	Silane[d] (a.i.)			
3 Cedar Oil-(2.0%) Silane (5.0%)	NL	21	28.59	0.57	1.43	4.35	3.46	20.46
		22	28.23	0.56	1.41	4.72	3.41	27.75
		23	28.32	0.57	1.42	4.16	2.81	32.45
		24	30.04	0.60	1.50	4.51	3.26	27.72
		25	31.57	0.63	1.58	3.71	3.05	17.79
		Average	29.35	0.59	1.47			25.23
	L	26	30.58	0.61	1.53	4.18	2.78	33.49
		27	27.14	0.54	1.36	4.83	3.43	28.99
		28	27.05	0.54	1.35	4.62	2.92	36.80
		29	25.78	0.52	1.29	4.71	3.10	34.18
		30	26.42	0.53	1.32	4.86	3.42	29.63
		Average	27.39	0.55	1.37			32.62
4 Cedar Oil-(5.0%) Silane (5.0%)	NL	31	30.94	1.55	1.55	4.58	3.44	24.89
		32	26.51	1.33	1.33	5.06	3.55	29.84
		33	29.40	1.47	1.47	5.31	4.23	20.34
		34	30.76	1.54	1.54	4.31	2.41	44.08
		35	27.50	1.38	1.38	4.83	3.56	26.29
		Average	29.02	1.45	1.45			29.09
	L	36	26.05	1.30	1.30	5.83	3.80	34.82
		37	31.75	1.59	1.59	4.92	2.72	44.72
		38	23.88	1.19	1.19	5.74	3.92	31.71
		39	20.99	1.05	1.05	4.61	3.10	32.75
		40	27.68	1.38	1.38	4.68	3.15	32.69
		Average	26.07	1.30	1.30			35.34
5 Cedar Oil-(10.0%) Silane (10.0%)	NL	41	30.76	3.08	2.76	4.44	3.43	22.75
		42	28.41	2.84	3.13	4.99	4.26	14.63
		43	29.13	2.91	2.91	4.77	3.40	28.72

Formulation #	Conditioning[a]	Block #	Retention (pcf)			W3 g	W4 g	% Weight. Loss
			Formulation[b] #	Cedar Oil (a.i.)[c]	Silane[d] (a.i.)			
5 Cedar Oil-(10.0%) Silane (10.0%)	NL	44	26.60	2.66	2.94	5.09	3.62	28.88
		45	22.98	2.30	3.00	4.82	3.51	27.18
		Average	27.57	2.76	2.95			24.43
	L	46	26.60	2.66	3.22	4.81	2.93	39.09
		47	28.77	2.88	2.70	4.49	2.91	35.19
		48	26.87	2.69	2.82	4.89	3.42	30.06
		49	28.50	2.85	3.66	4.39	2.72	38.04
		50	24.52	2.45	3.11	4.06	2.92	28.08
		Average	27.05	2.70	3.10			34.09
ACQ (0.25 pcf)	NL	61	0.25			3.69	3.66	0.81
		62	0.25			3.82	3.77	1.31
		63	0.25			3.68	3.68	0.00
		64	0.25			3.78	3.76	0.53
		65	0.25			3.83	3.79	1.04
		Average	0.25					0.74
	L	66	0.25			4.13	4.11	0.48
		67	0.25			3.89	3.86	0.77
		68	0.25			4.27	4.23	0.94
		69	0.25			3.80	3.77	0.79
		70	0.25			3.80	3.77	0.79
		Average	0.25					0.75
Control	NL	51	-----			3.91	1.25	68.03
		52	-----			2.93	1.72	41.30
		53	-----			3.56	1.75	50.84
		54	-----			4.15	1.35	67.47
		55	-----			4.65	3.33	28.39
		Average						51.21

Formulation #	Conditioning[a]	Block #	Retention (pcf)			W3 g	W4 g	% Weight. Loss
			Formulation[b] #	Cedar Oil (a.i.)[c]	Silane[d] (a.i.)			
Control	L	56	-----			3.93	1.94	50.64
		57	-----			3.83	1.57	59.01
		58	-----			3.32	1.23	62.95
		59	-----			3.93	1.90	51.65
		60	-----			3.27	1.27	61.16
		Average						57.08

[a:] Conditioning: L= Leached and NL = Unleached
[b:] The retention is based on the Formulation pounds per cubic foot
[c:] The retention is based on the active ingredients of Cedar Oil.
[d:] The retention is based on the active ingredients of Silane
[e:] The weight of the block before exposure to fungus.
[f:] The weight of the block after exposure to fungus.

Table 7 Treatment data for sweetgum blocks

				Retention (pcf)		
Form. #	Block #	W1 g	W2 g	Formulation	Cedar	Silane
1 Cedar OIL (0%) Silane (5%)	41	4.09	6.43	18.37	----	0.92
	42	3.85	6.53	21.04	----	1.05
	43	3.25	5.97	21.35	----	1.07
	44	3.4	6.22	22.13	----	1.11
	45	3.85	6.38	19.86	----	0.99
	46	3.39	6.34	23.15	----	1.16
	47	3.96	6.53	20.17	----	1.01
	48	4.28	6.85	20.17	----	1.01
	49	3.83	6.39	20.09	----	1.00
	50	3.6	6.50	22.76	----	1.14
	Average			20.91		1.05
2 Cedar OIL (2%) Silane (2%)	51	3.61	6.33	21.35	0.43	0.43
	52	3.8	6.50	21.19	0.42	0.42
	53	3.48	6.29	22.06	0.44	0.44
	54	3.54	6.31	21.74	0.43	0.43
	55	3.41	6.21	21.98	0.44	0.44
	56	4.23	6.75	19.78	0.40	0.40
	57	3.51	6.25	21.51	0.43	0.43
	58	4.03	6.59	20.09	0.40	0.40
	59	4.17	6.70	19.86	0.40	0.40
	60	3.64	6.41	21.74	0.43	0.43
	Average			21.13	0.42	0.42
3 Cedar OIL (2%) Silane (5%)	61	3.96	6.65	21.11	0.42	1.06
	62	3.52	6.36	22.29	0.45	1.11
	63	3.37	6.22	22.37	0.45	1.12
	64	3.6	6.26	20.88	0.42	1.04
	65	4.15	6.78	20.64	0.41	1.03

				Retention (pcf)		
Form. #	Block #	W1 g	W2 g	Formulation	Cedar	Silane
	66	3.49	6.16	20.96	0.42	1.05
	67	3.42	6.35	23.00	0.46	1.15
	68	3.93	6.33	18.84	0.38	0.94
	69	4.04	6.50	19.31	0.39	0.97
	70	3.4	6.23	22.21	0.44	1.11
	Average			21.16	0.42	1.06
4 Cedar OIL (5%) Silane (5%)	71	3.8	6.40	20.41	1.02	1.02
	72	3.45	6.37	22.92	1.15	1.15
	73	3.5	6.44	23.08	1.15	1.15
	74	3.46	6.30	22.29	1.11	1.11
	75	3.45	6.23	21.82	1.09	1.09
	76	3.87	6.59	21.35	1.07	1.07
	77	3.87	6.71	22.29	1.11	1.11
	78	4.00	6.68	21.04	1.05	1.05
	79	3.33	6.24	22.84	1.14	1.14
	80	3.39	6.29	22.76	1.14	1.14
	Average			22.08	1.10	1.10
5 Cedar OIL (10%) Silane (10%)	81	3.86	6.36	19.62	1.96	1.96
	82	4.08	6.65	20.17	2.02	2.02
	83	3.93	6.66	21.43	2.14	2.14
	84	3.89	6.67	21.82	2.18	2.18
	85	3.54	6.38	22.29	2.23	2.23
	86	5.34	8.06	21.35	2.13	2.13
	87	5.27	8.12	22.37	2.24	2.24
	88	5.05	7.72	20.96	2.10	2.10
	89	4.48	7.69	25.19	2.52	2.52
	90	5.02	7.68	20.88	2.09	2.09
	Average			21.61	2.16	2.16

[a;] W1 = Weight of the block before treatment. [b:] W2 = Weight of the block after treatment. [c:] pcf = pounds per cubic foot.

Table 8 Weight losses of the treated and untreated sweetgum blocks after expose to a white-rot fungus (*T. versicolor*) for 12 weeks **(Soil Block Test 2)**.

Formulation #	Conditioning[a]	Block #	Retention (pcf)			W3 g	W4 g	% Weight. Loss
			Formulation[b] #	Cedar Oil (a.i.)[c]	Silane[d] (a.i.)			
1 Cedar Oil-(0%) Silane (5.0%)	NL	1	18.37	----	0.92	4.18	2.12	49.28
		2	21.04	----	1.05	4.01	2.40	40.15
		3	21.35	----	1.07	3.34	1.92	42.51
		4	22.13	----	1.11	3.61	2.57	28.81
		5	19.86	----	0.99	4.08	3.64	10.78
		Average	20.55		1.03			34.31
	L	6	23.15	----	1.16	3.55	2.08	41.41
		7	20.17	----	1.01	4.36	3.03	30.50
		8	20.17	----	1.01	4.66	2.85	38.84
		9	20.09	----	1.00	4.18	2.42	42.11
		10	22.76	----	1.14	4.04	1.67	58.66
		Average	21.27		1.06			42.30
2 Cedar Oil-(2.0%) Silane (2.0%)	NL	11	21.35	0.43	0.43	3.84	2.29	40.36
		12	21.19	0.42	0.42	3.97	1.88	52.64
		13	22.06	0.44	0.44	3.59	1.65	54.04
		14	21.74	0.43	0.43	3.80	2.27	40.26
		15	21.98	0.44	0.44	3.57	1.83	48.74
		Average	21.66	0.43	0.43			47.21
	L	16	19.78	0.40	0.40	4.59	2.72	40.74
		17	21.51	0.43	0.43	3.98	3.21	19.35
		18	20.09	0.40	0.40	4.40	2.73	37.95
		19	19.86	0.40	0.40	4.59	2.81	38.78
		20	21.74	0.43	0.43	3.95	2.49	36.96
		Average	20.60	0.41	0.41			34.76
3	NL	21	21.11	0.42	1.06	4.19	2.73	34.84

Formulation #	Conditioning[a]	Block #	Retention (pcf)			W3 g	W4 g	% Weight. Loss
			Formulation[b] #	Cedar Oil (a.i.)[c]	Silane[d] (a.i.)			
Cedar Oil-(2.0%) Silane (5.0%)		22	22.29	0.45	1.11	3.70	1.98	46.49
		23	22.37	0.45	1.12	3.61	2.38	34.07
		24	20.88	0.42	1.04	3.81	2.51	34.12
		25	20.64	0.41	1.03	4.40	2.61	40.68
		Average	21.46	0.43	1.07			38.04
	L	26	20.96	0.42	1.05	3.73	2.24	39.95
		27	23.00	0.46	1.15	3.63	2.42	33.33
		28	18.84	0.38	0.94	4.44	2.73	38.51
		29	19.31	0.39	0.97	4.56	3.06	32.89
		30	22.21	0.44	1.11	3.68	2.17	41.03
		Average	20.86	0.42	1.04			37.14
4 Cedar Oil-(5.0%) Silane (5.0%)	NL	31	20.41	1.02	1.02	4.22	2.90	31.28
		32	22.92	1.15	1.15	3.99	3.26	18.30
		33	23.08	1.15	1.15	4.19	3.40	18.85
		34	22.29	1.11	1.11	4.06	3.07	24.38
		35	21.82	1.09	1.09	4.02	2.98	25.87
		Average	22.10	1.11	1.11			23.74
	L	36	21.35	1.07	1.07	4.37	2.86	34.55
		37	22.29	1.11	1.11	4.67	3.47	25.70
		38	21.04	1.05	1.05	4.86	3.58	26.34
		39	22.84	1.14	1.14	4.19	3.18	24.11
		40	22.76	1.14	1.14	4.10	2.89	29.51
		Average	22.06	1.10	1.10			28.04
5 Cedar Oil-(10.0%) Silane (10.0%)	NL	41	19.62	1.96	1.96	4.03	1.39	65.51
		42	20.17	2.02	2.02	4.31	2.43	43.62
		43	21.43	2.14	2.14	4.18	2.52	39.71
		44	21.82	2.18	2.18	4.16	2.62	37.02
		45	22.29	2.23	2.23	3.80	2.40	36.84

Formulation #	Conditioning[a]	Block #	Retention (pcf)			W3 g	W4 g	% Weight. Loss
			Formulation[b] #	Cedar Oil (a.i.)[c]	Silane[d] (a.i.)			
		Average	21.07	2.11	2.11			44.54
	L	46	21.35	2.13	2.13	5.56	3.46	37.77
		47	22.37	2.24	2.24	5.56	3.83	31.12
		48	20.96	2.10	2.10	5.33	2.80	47.47
		49	25.19	2.52	2.52	4.92	2.77	43.70
		50	20.88	2.09	2.09	5.34	2.40	55.06
		Average	22.15	2.21	2.21			43.02
ACQ-0.25 pcf	NL	61		0.25		3.69	3.66	0.81
		62		0.25		3.82	3.77	1.31
		63		0.25		3.68	3.68	0.00
		64		0.25		3.78	3.76	0.53
		65		0.25		3.83	3.79	1.04
		Average		0.25				0.74
	L	66		0.25		4.13	4.11	0.48
		67		0.25		3.89	3.86	0.77
		68		0.25		4.29	4.23	1.40
		69		0.25		3.80	3.77	0.79
		70		0.25		3.80	3.77	0.79
		Average		0.25				0.85
Control	NL	51		----		4.54	2.62	42.29
		52		----		5.15	2.59	49.71
		53		----		5.14	1.94	62.26
		54		----		5.08	2.76	45.67
		55		----		4.52	2.15	52.43
		Average						50.47
	L	56		----		4.92	2.55	48.17
		57		----		4.93	2.40	51.32
		58		----		5.13	1.70	66.86

Formulation #	Conditioning[a]	Block #	Retention (pcf)			W3 g	W4 g	% Weight. Loss
			Formulation[b] #	Cedar Oil (a.i.)[c]	Silane[d] (a.i.)			
		59		----		5.81	2.85	50.95
		60		----		5.22	2.27	56.51
		Average						54.76

[a:] Conditioning: L= Leached and NL = Unleached
[b:] The retention is based on the Formulation pounds per cubic foot
[c:] The retention is based on the active ingredients of Cedar Oil.
[d:] The retention is based on the active ingredients of Silane
[e:] The weight of the block before exposure to fungus.
[f:] The weight of the block after exposure to fungus.

Table 9 Average weight losses after exposure to a brown-rot fungus (*G. trabeum*) **(Test 1 and Test 2.)**

Formulation #	Ingredients	Conditioning[a]	Test-1[b]		Test - 2[c]	
			Average		Average	
			Retention (pcf)	Weight Loss %	Retention (pcf)	Weight Loss %
1	Ceder Oil "0"% Silane "5" % Solvent "95"%	NL	29.26	31.68	27.52	17.06
		L	27.76	25.55	29.94	28.79
2	Ceder Oil "2"% Silane "2" % Solvent "96"%	NL	29.04	27.12	27.92	27.11
		L	28.48	25.80	28.28	34.37
3	Ceder Oil "2"% Silane "5" % Solvent "93"%	NL	27.79	24.39	29.35	25.23
		L	27.56	27.24	27.37	32.62
4	Ceder Oil "5"% Silane "5" % Solvent "90"%	NL	28.84	24.58	29.02	29.09
		L	27.85	27.47	26.07	35.34
5	Ceder Oil "10"% Silane "10" % Solvent "80"%	NL	29.49	22.80	27.57	24.43
		L	31.05	25.13	27.05	34.09
ACQ		NL	0.25	0.74		0.74
		L	0.25	0.75		0.75
Control		NL	----	44.22		51.21
		L	----	41.60		57.08

[b:] The retention is based on the Formulation pounds per cubic foot.
[c:] The retention is based on the active ingredients of Cedar Oil.
[d:] The retention is based on the active ingredients of Silane

Table 10; Average weight losses after exposure to a white-rot fungus (*T.versicolor*) **(Test 1 and Test 2.)**

Formulation #	Active Ingredients	Conditioning[a]	Test-1[b] Average		Test - 2[c] Average	
			Retention (pcf)	Weight Loss %	Retention (pcf)	Weight Loss %
1	Ceder Oil "0"% Silane "5" % Solvent "95"%	NL	21.33	45.28	20.55	34.31
		L	20.06	66.72	21.27	42.30
2	Ceder Oil "2"% Silane "2" % Solvent "96"%	NL	19.81	43.69	21.66	47.21
		L	19.06	62.80	20.60	34.76
3	Ceder Oil "2"% Silane "5" % Solvent "93"%	NL	20.03	49.29	21.46	38.04
		L	20.01	56.83	20.86	37.14
4	Ceder Oil "5"% Silane "5" % Solvent "90"%	NL	17.47	18.41	22.10	23.74
		L	17.61	17.50	22.06	28.04
5	Ceder Oil "10"% Silane "10" % Solvent "80"%	NL	21.41	42.11	21.07	44.54
		L	20.66	35.42	22.15	43.02
ACQ		NL	0.25	0.00	0.25	0.74
		L	0.25	0.10	0.25	0.85
Control		NL	---	56.53	---	50.47
		L	---	59.61	---	54.76

[b:] The retention is based on the Formulation pounds per cubic foot.
[c:] The retention is based on the active ingredients of Cedar Oil.
[d:] The retention is based on the acive ingredients of Silane

REPORT

An Evaluation of the Product Claims for CedarShield from a Scientific Perspective

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1.0 BACKGROUND

Elsipogtog Economic Development (EED) is interested in becoming involved in supplying natural materials to consumers in a viable commercial basis. In particular, there is an interest in supplying natural materials for enhancing the value of wood products.

CedarCide Industries, Inc. (CCI) of Spring, Texas, USA, is in the business of manufacturing and supplying “wood stabilization products”. Some of their products contain natural oils extracted from a variety of natural sources. The claims of CCI with respect to some of its products put them ahead of competing products with respect to the treatment of wood.

EED has discussed developing a business relationship with CCI which includes the marketing of a CCI product named CedarShield. CedarShield is a wood stabilizer which CCI claims will render wood “perpetually, moisture, insect, mold and decay resistant”.

As part of a due diligence review by EED, the Wood Science and Technology Centre (WSTC) of the University of New Brunswick has been requested to carry out a scientific evaluation of the claims made by CCI with respect to the CedarShield product. This report is in response to that request.

2.0 OBJECTIVE

To review and evaluate the claims with respect to CedarShield and make conclusions as to whether these claims are reasonable from a scientific point of view.

3.0 OVERVIEW

The claims with respect to CedarShield are discussed in the following three sections and are divided into general comments, comments arising from the patents, and comments arising from the CCI website and other communications.

3.1 General

The CedarShield product claims to stabilize wood due to a chemical reaction which primarily occurs between a silicon containing compound and cellulose.
From a general scientific point of view, this is a reasonable expectation. Silicon is the major component of window glass which is primarily SiO_2. It is not unreasonable to suspect that certain silicon- containing compounds will react with other materials to form stable compounds which support the CedarShield claims. Having carried out no experiments one cannot be certain that CedarShield contains such compounds, but it is not unreasonable to expect that silicon-containing liquids will solidify on reacting with cellulose. Indeed, the reaction of silane gas, SiH_4, with oxygen, another gas, is one of the major reactions used to manufacture pure silicon dioxide, SiO_2, in the semiconductor industry. This reaction occurs spontaneously without any catalytic activity.

Furthermore, the petrification of wood, a fossilization process, often involves a reaction in which silicon replaces the carbon atoms in the wood forming a hard glass coloured by trace minerals. This process can occur relatively quickly, i.e., days or months, in nature and in the lab. It would not be unreasonable then to expect the silicon-containing compounds in the CedarShield to react with the components of wood to form a stable complex. The claims of CCI with respect to CedarShield indicate this does occur. The proof that it does occur can only be confirmed by experiment. The level of experimental support for those claims is discussed in the next section.

3.2 Comments on Patent Applications

CCI has provided WSTC with a binder containing copies of patent applications related to their products. Three of the patents are particularly relevant and have been reviewed in detail.

The patent applications reviewed were identified as:

1. Attorney Docket 87-0-PCT, Methods and Compositions of Matter for Treatment of Cellulose
2. Attorney Docket 87-6-PCT, Pest Protection Methods and Compositions
3. Attorney Docket 87-3-CIP-1, Methods for Preventing Warping in Wood Products

The abstract filed with each of these patents is attached (see Attachments 1-3).

Essentially these applications describe a process in which wood is contacted with “at least one” of the following: (1) an organic solvent with 7-16 carbons, (2) a natural product oil, (3) a silicone polymer that forms a film in the presence of a catalyst and water. The third item obviously requires the application of a catalyst as part of the treating solution or in some other manner. Apparently, another silicon-containing compound, called a cross linker may or may not be used.

It is scientifically reasonable to expect that most, if not all, of the claims made in these patent applications are reasonable. This does not mean the claims are technically and economically viable. Furthermore, some of the statements in the patents are grammatically unclear and in at least one instance totally incorrect. On page 9, line 5, of the first patent listed above it states, “The weight of the water in wet wood can be twice that in wood that is oven dry.” This statement is neither a grammatically nor typographical error, but is scientifically irrelevant. By definition, oven-dry wood has 0% moisture content. Any moisture content above that is infinitely greater, not merely twice as great.

From a scientific point of view, the experimental results quoted in the patents lack sufficient numbers of test specimens to be statistically reliable. This does not mean the results quoted are incorrect, but that testing must be done under rigorously controlled conditions with a significant number of samples to accurately validate and quantify the results claimed.

For instance, in Example 2, page 14, of the first patent listed above, the tangential dimensional change of a piece of treated wood “over the humidity range of 0 to 100% humidity change in the ambient air” is reported to be less than 0.03 mm per 25 mm. Not only is the term “humidity” erroneously used instead of the correct term “relative humidity” but the experimental results are compared to literature values for untreated wood. A more scientifically appropriate procedure would have been to subject several treated and untreated pieces of wood to the same ambient conditions of temperature and relative humidity and compare the results.

It was stated that the CCI process will work with oils from as many as 34 different plants. It is also claimed to work with synthetically prepared compounds without the presence of compounds obtained from natural sources. Indeed, it is stated that in some cases the use of the essential oil, whether natural or synthetic, is not necessary for the process to work.

One wonders whether the essential oil is there primarily, or solely, as a marketing tool. This approach may be valid and reasonable economically, but from a scientific point of view it may be simply adding unnecessary compounds to the process.

In essence, the conclusion arising from a consideration of the above and other parts of the patent applications is that a series of tests which will definitively confirm the claims made should be conducted before advancing further with this venture.

4.0 COMMENTS ON THE WEBSITE, WWW.CEDARCIDE.COM

These comments relate to CedarCide products #2001 and #8008, CedarShield, as described in the products section of the website. These descriptions are included as Attachments 4 and 5.

The first scientific observation is that CedarShield is a "chemical-free wood preservative". Webster defines "chemical" as "a substance used for producing a chemical effect; a reagent." It is certainly incorrect to say that CedarShield is "chemical free" when it contains compounds which undergo chemical change as part of the treatment process. Specifically, the website claims the CedarShield "modifies the molecular make up of wood" (see Attachment 6). Whatever the motivation for claiming CedarShield is "chemical free", it is certainly scientifically incorrect to do so.

It is also claimed in Attachment 5 that CedarShield will provide "complete penetration in less than 30 minutes [and] will eliminate all moisture in the wood [and] provide a decay, water and termite proof media that will last indefinitely." Considering the fact that the solvent must migrate to the center of the wood and the water must migrate out, this does not seem a likely occurrence. If for no other reason than it requires 540 cal to evaporate every gram of water; i.e., 970 BTU to evaporate one pound of water. Somehow that heat must be injected into the system, but there seems to be no provision for doing so. Yet not only is it claimed that there will be complete penetration of the CedarShield within 30 minutes, but the water will be eliminated too.

In Attachment 7 the claim is taken even further. On page 1 of Attachment 7 it says, "Penetration with the proprietary hydrocarbon solvent displaces existing moisture content in the wood which results in Kiln-less Drying, an instant evacuation and exodus of H_2O compounds from the media." In the opinion of the author, this is not what would be expected based on current knowledge of the drying of wood. The migration of water out of the wood at 130°F is not expected to be instantaneous. Furthermore, it is claimed on page 1 of Attachment 7 that the CedarShield seals the "annular growth rings" with a "waxy like substance in the media cellular structure". It is not clear what the last phrase means, however if CedarShield seals the wood to keep water out after treatment does it not also inhibit the migration of water out of the wood during treatment.

CCI was questioned about what happens to the water and heat for vaporization (see

Attachment 8). The response was that the water expelled from the wood clings to the wood until it is removed from the treatment vessel at which time it either evaporates or runs off the wood “in the drying process or during the removal process”. One wonders what this drying process is. Reading the literature suggests drying happens as part of the treatment process. This answer still begs the question, “Where does the energy come from to evaporate the water?” They may not call it a kiln, but if they require an additional process which supplies heat (970 BTU/lb) to remove water they effectively have a kiln.

5.0 CONCLUSIONS AND RECOMMENDATIONS

The concept of reacting silicon compounds with wood to stabilize it is scientifically reasonable.

The concept of adding essential oils like cedar to the stabilization treatments to inhibit fungal growth and invasion by pests is scientifically reasonable.

The concept of treating wood by rolling or brushing on a mixture of hydrocarbon and silicon containing substances thus drying green wood and eliminating “all moisture” in the wood in 30 minutes at 130°F is not, in the opinion of the author, scientifically reasonable.

Before advancing further with this venture it is recommended that specific tests be carried out to determine how the claims stand up to rigorous testing. Treating twenty 2" x 4" pieces of green black spruce and green balsam fir and measuring the properties after the 30-minute treatment will answer how well the treatment works on green wood.

Provided the above treatment works as claimed, it is then recommended that a series of standard tests be carried out to quantify the effectiveness of the treatment in other areas of interest to EED. If the treatment does not work as claimed, EED may choose to work with CCI to improve the product or move on to other ventures.

Customer: Internal TS (Cedarcide)

Date Received: 01/31/06

Date Reported: 05/25/06

AEM Project Number: 3636 Addendum

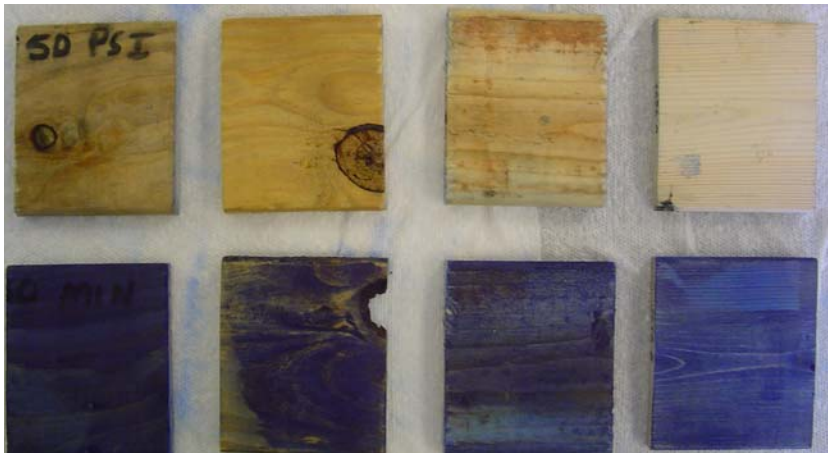
Description All AEM Treatments applied at 100 mg actives/sq.ft.	Microbiological Analysis		Chemical Analysis
	ACTM 0622 20 day reading	ACTM 0622 78 day reading	% Uniformity
Control – no treatment	7	8	No Color
Control with AEM	5	6	Very Good
Hemlock with Cedar-cide	3	6	No Color
Hemlock with Cedar-cide & AEM	3	0	Very Good
Southern Yellow Pine with Cedar-cide	0	3	No Color
Southern Yellow Pine with Cedar-cide & AEM	0	1	Good
Douglas Fir with Cedar-cide	0	7	No Color
Douglas Fir with Cedar-cide & AEM	0	0	Excellent

ACTM 0622
Environmental Chamber Test
Aspergillus niger / Penicillium spp.

Observed Growth	Grade
No Growth	0
1-10%	1
11-20%	2
21-30%	3
31-40%	4
41-50%	5
51-60%	6
61-70%	7
71-80%	8
81-90%	9
91-100%	10

ÆGIS BPB Direct Stain (DS):
3"x4" sample
0.025% BPB dH_2O solution
20 minute exposure

Bromophenol Blue Direct Stain Results



Initial results submitted by:

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Operations Manager

Additional results submitted by:

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Research Assistant

This project has been reviewed and approved by:

James Back
Laboratory Manager

6. EVIDENCE SUBMITTED (Continued)

6.3 Technical Information on the Nature of Active Ingredients in CedarTreat™ Wood Stabilizer™

6.3.1 Activity Against Insects

(a) "Termiticidal Activities in Hearwood, Bark/Sapwood and Leaves of Juniperus Species in the United States"
Dr. Robert Adams, Baylor University;
Biochemical Systematics and Ecology, Vol 16, No. 5 (1988)

(b) Letter dated April 4, 2000 to CedarCide Industries, Inc.
Dr. Arthur Appel, Professor of Entomology, Auburn University

6.3.2 Activity Against Microorganisms

(a) "Cedar Wood Oil – Analysis & Properties"
Dr. Robert Adams, Baylor University;
Springer-Verlag (1991)

(c) "Antimicrobial Properties of Hearwood, Bark/Sapwood and Leaves of Juniperus Species";
Dr. Robert Adams, Baylor University and Dr. Alice M. Clark, Mississippi University
Phytotherapy Research Vol 4, No. 1 (1990)

6.3.3 Corrosivity

(a) "Corrosivity of Wood Treated with CedarCide Wood Protection Products"
Memo dated July 24, 2006; Dr. Terry F. Amburgey, TASKpro, xxxxx, Mississippi

Biochemical Systematics and Ecology, Vol. 16, No. 5, pp. 453–456, 1988.
Printed in Great Britain.

0305–1978/88 $3.00+0.00

Termiticidal Activities in the Heartwood, Bark/Sapwood and Leaves of *Juniperus* Species from the United States

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Key Word Index—*Juniperus*; cupressaceae; termiticides; insecticides.

Abstract—Twelve taxa of *Juniperus* from the United States were investigated for termiticidal activities of the heartwood, bark/sapwood and leaves. All taxa exhibited termiticidal activities for the fresh heartwood sawdusts. All except *Juniperus scopulorum* showed high termiticidal activities for the bark/sapwood sawdusts. The activity in the sawdusts could be removed by washing with hexane followed by methanol for about half of the taxa. Both hexane and methanol (sequential) extracts of the heartwoods showed termiticidal activities. Hexane and methanol (sequential) extracts of intact leaves displayed termiticidal activities for most of the taxa.

Introduction

Juniper wood is the domestic source of cedarwood oil for the United States but the junipers are also known to contain natural wood preservatives [1]. The control of wood rot and termites is a perennial problem in much of the world. Many of the methods for wood preservation have used arsenic and/or chlorinated hydrocarbons which may present some environmental hazards. Carter [2] has found that the subterranean termite *Reticulitermes flavipes* Kollar could not survive on sawdust from *J. virginiana* nor could they survive on filter paper treated with a pentane extract of the *J. virginiana* sawdust.

Oda *et al.* [3] conducted insecticidal screening of individual components of the sesquiterpenoids from the wood of *J. recurva* Buch., which has been used as an insecticide by the natives in Nepal against household insects. They found the highest insecticidal activity in thujopsene (widdrene) (LD_{50} mg/mosquito = 4.5) and 8-cedren-13-ol (LD_{50} mg/mosquito = 6.6), with less activity by cedrol and alpha-cedrene.

The two sources of domestically produced cedarwood oil for the United States are central Texas (*J. ashei*, 'Texas cedarwood oil') and the eastern United States (*J. virginiana* L., 'Virginia cedarwood oil'). In many parts of the United States the weedy junipers have invaded abandoned fields and overgrazed rangelands. They often occur in almost continuous stands for hundreds of kilometres. The most important weedy junipers of the United States are *J. ashei* Buch., *J. californica* Carr., *J. erythrocarpa* Cory, *J. deppeana* Steud., *J. monosperma* (Engelm.) Sarg., *J. occidentalis* Hook., *J. osteosperma* (Torr.) Little, *J. pinchotii* Sudw. and *J. virginiana* L. These species have invaded millions of acres of grasslands and old fields. In Texas alone, there are an estimated 21.5 million acres of juniper-invaded grasslands [4]. Ranchers are paid (USDA–ASCS) for juniper removal to improve the range conditions. The opening of the shade canopy appears to be very important for foliage production [5]. Thus, a natural renewable source of termiticides may be available from plants that are currently not utilized.

The purpose of this study was to determine the termiticidal activities of heartwood, bark/sapwood and leaves of the dominant Juniper species in the United States as part of the evaluation of the commercial potential of plants that are now considered to be a noxious tree species in rangelands.

Results and Discussion

The first test conducted to determine the bioassay for termiticidal activity used fresh

(*Received* 25 *April* 1988)

sawdust. Both the heartwood and bark/sapwood sawdusts had extremely high activity except for the bark/sapwood of *J. scopulorum* (62 and 57% survival, Table 1). There were essentially no survivors when the heartwood of any juniper was used.

In order to determine if the active components could be removed from the sawdust, heartwood sawdust was extracted 10 times (by shaking) with hexane and then 10 times with acetone. This did not remove all of the termiticidal activity from any species (Table 2). Several of the heartwood sawdusts were still 100% lethal (Table 2) but about half of the species lost most of their bio-active components (Table 2).

Additional samples of heartwood were Soxhlet extracted with hexane and the hexane soluble material was bioassayed (Table 3). The hexane extracts proved to be highly active. The termites did not survive for more than one week on most extracts (Table 3). However, at these low concentrations one can begin to see differences among the species. At 1 ml/pad there is some survival on the extracts of *J. monosperma* and *J. osteosperma* and considerable survival on *J. californica* extracts (Table 3).

TABLE 1. RATES OF SURVIVAL FOR TERMITES FED ON JUNIPER HEARTWOOD AND SAPWOOD/BARK SAWDUSTS.

Species	Material	Per cent survival at 4 weeks* Trial 1	Trial 2
J. ashei	Heartwood	0 (0.5)	0 (0.5)
	Bark/sapwood	5	3
J. californica 'A'	Heartwood	0 (2.5)	0 (2.5)
	Bark/sapwood	1	0 (3.0)
J. californica 'B'	Heartwood	0 (3.0)	0 (3.0)
	Bark/Sapwood	0 (3.5)	0 (3.5)
J. deppeana	Heartwood	0 (1.5)	0 (1.5)
	Bark/sapwood	0 (3.0)	0 (3.0)
J. erythrocarpa	Heartwood	0 (0.5)	0 (0.5)
	Bark/sapwood	0 (3.5)	0 (3.5)
J. monosperma	Heartwood	0 (2.0)	0 (0.5)
	Bark/sapwood	0 (3.5)	17
J. occidentalis	Heartwood	0 (1.5)	0 (1.5)
var. *occidentalis*	Bark/sapwood	0 (3.0)	0 (3.0)
J. occidentalis	Heartwood	0 (0.5)	0 (0.5)
var. *australis*	Bark/sapwood	2	0 (4.0)
J. osteospmera	Heartwood	0 (3.0)	0 (3.0)
	Bark/sapwood	0 (4.0)	0 (3.5)
J. pinchotii	Heartwood	0 (4.0)	10
	Bark/sapwood	0 (3.5)	1
J. scopulorum	Heartwood	0 (0.5)	0 (0.5)
	Bark/sapwood	62	57
J. virginiana	Heartwood	0 (0.5)	0 (0.5)
	Bark/sapwood	0 (3.5)	35

*Values in parentheses are the number of weeks when all the termites had died.

TABLE 2. RATE OF SURVIVAL FOR TERMITES FED ON JUNIPER HEARTWOOD SAWDUSTS SEQUENTIALLY EXTRACTED WITH HEXANE FOLLOWED BY ACETONE

Species	Per cent termites surviving at 4 weeks*
J. ashei	0 (3.5)
J. californica 'A'	0 (3.0)
J. californica 'B'	0 (3.5)
J. deppeana	0 (3.5)
J. erythrocarpa	0 (3.5)
J. monosperma	10
J. occidentalis	11
J. occidentalis var. *australis*	10
J. osteosperma	48
J. pinchotii	38
J. scopulorum	50
J. virginiana	46
Control	93
Sand	0 (2.5)

*Values in parentheses are the number of weeks when all the termites had died in the text.

TABLE 3. RATE OF SURVIVAL FOR TERMITES FED ON PAPER CONTAINING HEXANE OR METHANOL EXTRACTS FROM JUNIPER HEARTWOOD

Species	Per cent termites surviving at 4 weeks* Hexane extract† 1 ml/pad	2 ml/pad	Methanol extract‡ 1 ml/pad
J. ashei	0 (1.0)	0 (1.0)	36
J. californica 'A'	88	0 (1.0)	0 (1.5)
J. californica 'B'	84	84	0 (3.0)
J. deppeana	0 (1.0)	0 (1.0)	4
J. erythrocarpa	0 (1.0)	0 (1.0)	32
J. monosperma	23	20	48
J. occidentalis	0 (1.0)	0 (1.0)	0 (0.5)
var. *australis*	0 (1.0)	0 (1.0)	0 (1.5)
J. osteosperma	20	0 (1.0)	0 (3.5)
J. pinchotii	NT	NT	8
J. scopulorum	0 (1.0)	0 (1.0	0 (2.0)
J. virginiana	0 (1.0)	0 (0.5)	0 (1.5)
Control	96	100	100

*Values in parentheses are the number of weeks when all the termites in the test had died.

†Hexane extracts applied at 1 mg ml^{-1} concentration except for *J. californica* 'A' and 'B', *J. occidentales* and *J. occidentalis* var. *australis* for which 0.5 mg ml^{-1} was used.

‡Methanol extracts were applied at 10 mg ml^{-1} concentration.

NT = Not tested.

A sequential Soxhlet extraction of the heartwood using methanol (following hexane) removed the more polar components. The bioassay of the polar fraction revealed considerable activity for most of the extracts (Table 3). However, *J. ashei, J. erythrocarpa* and *J. monosperma* methanol extracts showed reduced activity (Table 3).

Based on the aforementioned series of experiments, several factors seem to be indicated. Not all of the bioactivity could be removed by simple hexane/acetone extraction (Table 2). A non-polar fraction that has a high termiticidal activity exists in all species (Table 3) except *J. californica.* Our investigation of the antitermitic activities of the *J. virginiana* heartwood extractives (McDaniel, C. A., Klocke, J. A. and Balandrin, M. F., unpublished results) indicated that the most toxic components were the sesquiterpene alcohols, cedrol and widdrol. The sesquiterpene hydrocarbons showed considerably less toxicity.

A correlation between the toxicity data generated in this study and the analysis of the major extractive components of the heartwoods of the *Juniperus* species [6] allows some conclusions to be drawn.

A comparison of Tables 2 and 3 indicates that the antitermitic properties of *J. californica* are not contained in the hexane extractable material, but are a result of more polar compounds which are found in the methanol extract. The low yield of steam distillable material found by Adams [6] for this species indicates that the antitermitic components are not likely to be the same as those from *J. virginiana.*

The toxicities of the methanol extracts from the other species may indicate that hexane simply does not completely extract the sesquiterpenes and sesquiterpene alcohols; or they may indicate the presence of additional, more polar toxic components. Further investigations are needed to ascertain the identities of these components.

Due to the large volume of leaves that could be obtained during harvesting, it seemed appropriate to assay the leaf extracts for bioactivity. The hexane leaf extracts of about half of the species had high termiticidal activity (Table 4). It is interesting to note that the two chemical races (based on their volatile leaf oils) of *J. californica*, 'A' and 'B', behaved quite differently in this assay with type 'A' showing little activity and type 'B' displaying considerable activity (Table 4).

TABLE 4. RATE OF SURVIVAL FOR TERMITES FED PAPER CONTAINING HEXANE OR METHANOL EXTRACTS OF UNGROUND JUNIPER LEAVES

Species	Per cent termites surviving at 4 weeks* Hexane extract†	Methanol extract
J. ashei	0 (3.5)	66
J. californica 'A'	84	0 (2.5)
J. californica 'B'	0 (1.5)	0 (2.5)
J. deppeana	88	97
J. erythrocarpa	80	41
J. monosperma	0 (2.5)	0 (3.0)
J. occidentalis	0 (1.5)	83
var. *australis*	0 (2.5)	41
J. osteosperma	88	25
J. pinchotii	96	51
J. scopulorum	36	0 (0.5)
J. virginiana	0 (1.5)	0 (0.5)
Control	100	95

*Values in parentheses are the number of weeks when all the termites in the test had died.

†1 ml of hexane extract (diluted to 10 mg ml^{-1}) was added to each paper pad.

The methanol soluble components from the leaves showed very high termiticidal activity in some of the species and reduced survival in others (Table 4). Only the *J. deppeana* methanol extract had essentially all termites surviving after four weeks. The hexane extract of this species also exhibited low toxicity. *Juniperus ashei, J. californica, J. monosperma, J. occidentalis, J. scopulorum* and *J. virginiana* each had termiticidal activity in one or both of the leaf extracts. Research efforts to date have concentrated on surveys of wood chemicals as sources of termiticides, presumedly because rot and insect resistant woods are often well known and one might expect a long co-evolution of plant chemical defenses against wood-eating insects. The discovery of very active termiticidal components in the leaves appears to be a serendipitous event. Since many tons of leaves can be harvested along with the wood, additional research should be directed toward the isolation and identification of the active components in the leaves.

Experimental

Samples of wood and herbarium vouchers were collected from *J. ashei* (Adams 5007–5009, 9 km west of Ozona,

Crockett Co., TX; 5010–5016, 2 km east of Junction, Kimble Co., TX) *J. californica* 'A' (Adams 5067–5071, 13 km northeast of I40, Granite Mountains, San Bernardino Co., CA) and *J. californica* 'B' (Adams 5072–5076, 30 km southeast of Yucca, Yuma Co., AZ), *J. erythrocarpa* (Adams 4987–4996, 32 km north of Alpine, Jeff Davis Co., TX), *J. deppeana* (Adams 4974–4983, 32 km northwest of Fort Davis, Jeff Davis Co., TX), *J. monosperma* (Adams 5027–5036, 2 km west of Santa Rosa, Guadalupe Co., NM), *J. occidentalis,* (Adams 5077–5086, 8 km west of Juntura, Malheur Co., OR), *J. occidentalis* var. *australis* (Adams 5057–5066, 2 km west of Sonora Junction, Mono Co., CA), *J. osteosperma* (Adams 5047–5056, 25 km west of Monticello, San Juan Co., UT), *J. pinchotii* (Adams 4997–5001, 28 km east of Fort Stockton, Pecos Co., TX; Adams 5002–5006, 10 km west of Sheffield, Pecos Co., TX), *J. scopulorum* (Adams 5037–5046, 5 km east of Clines Corner, Torrance Co., NM) and *J. virginiana* (Adams 5017–5025, 7 km west of Bastrop, Bastrop Co., TX). *Juniperus californica* 'A' and 'B' refer to the two chemical races discovered by Vasek and Scora [7] and reconfirmed by Adams, von Rudloff and Hogge [8] using the leaf volatile oils.

The samples consisted of: wood (section 20 cm long × 5–10 cm in diameter) and leaves (400 g). All samples were kept cool (February collections) in the field and then frozen in the laboratory until analysed.

The wood samples were separated into heartwood and bark/sapwood; each subsample was then kept separate. Portions of the heartwood, bark/sapwood and leaves were dried (48 h, 100°) to determine the per cent moisture. Extracts were obtained from fresh heartwood, bark/sapwood and leaves by Soxhlet extraction of each set of materials for 6 h [9]. In each case the first solvent used was hexane and the second (sequential) solvent used was methanol. The material was dried (4 h at 70°) after the hexane extraction to remove the hexane before extraction with methanol [10].

Fresh heartwood sawdusts, fresh bark/sapwood sawdusts and extracted materials were tested on externally undifferentiated termite workers from field-collected colonies of *Reticulitermes flavipes*. Fifty g of sand and 7 ml distilled water were placed into a plastic zipper case. Sawdust samples (1.5 g) were placed in the zipper case along with 100 termites (*R. flavipes*) and kept at 25°. Duplicate samples were run for each species and the bioassays terminated after 4 weeks. Hexane and methanol extracts were placed on filter paper and 25 termites were added. The hexane (Soxhlet) extracts of the heartwoods were initially diluted to a concentration of 10 mg ml^{-1} except for samples from *J. occidentalis, J. californica* 'A' and 'B' which contained 5 mg ml^{-1}. At these concentrations, all termites were dead within 3 days for all samples. Therefore, all the extracts were then diluted to 1 mg ml^{-1} except for *J. occidentalis* and *J. californica* 'A' and 'B' which contained 0.5 mg ml^{-1}. Two trials were prepared for each extract: 1 ml extract and 2 ml extract. The methanol extracts were prepared with 10 mg ml^{-1} extracted material and bioassayed as described previously, but with only one bioassay per extract; each filter pad was treated with 1 ml extract. The leaf sample extracts were diluted to 10 mg ml^{-1} for both the hexane and methanol extracts. Test results are reported as the per cent survival after 4 weeks.

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April 4, 2000

CedarCide Industries, Inc.
P.O. Box 549
Spring, TX 77383

Dear CedarCide:

As you know, we are in the process of testing your Texas red cedar products, both granules and liquid form, against a variety of pest insects. Based on our findings and those of other researchers, Texas red cedar is significantly repellent to a number of insect pests including cockroaches, fleas, silverfish, and mosquitoes. We are currently working with German cockroaches, the most common indoor cockroach pest, to determine the optimum amount of cedar granules to effectively repel these insects. Our next scheduled test will include the use of CedarCide liquid products.

Cedar and cedar products have a long history as safe and effective insect repellents. Please feel free to contact me if you have any questions.

Sincerely,

Arthur G. Appel
Professor of Entomology

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Section 6.3.1(b)

Cedar Wood Oils – Analysis & Properties (pps 159-173)
Authored by Robert P. Adams, Ph.D.

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Cedar Wood Oil — Analyses and Properties

R.P. ADAMS

1 Introduction

Cedarwood oil is an important natural product for components used directly in fragrance compounding or as a source of raw components in the production of additional fragrance compounds. The oil is used to scent soaps, technical preparations, room sprays, disinfectants, and similar products, as a clearing agent for microscope sections, and with immersion lenses (Guenther 1952).

The price varies but has generally been about $4.50/lb. for Virginia cedarwood oil, $3.50/lb. for Texas cedarwood oil and $1.50-$1.75/lb. for Chinese cedarwood oil. The Chinese cedarwood oil, although almost identical in composition, is less valued because its fragrance is very different from the Texas and Virginia cedarwood oils. The commercial cedarwood oils are obtained from three genera of the Cupressaceae: *Juniperus* (Texas and Virginia oils); *Cupressus* (China) and *Cedrus* (Morocco, India) according to Bauer and Garbe 1985. The heartwood oils of the Cupressaceae are well known for having the same components across the family (i.e., evolutionally conserved), so the occurrence of similar oils in different genera should not be surprising.

The world production (1984) has been reviewed by Lawrence (1985), who reported the following (source and metric tons): Texas (*J. ashei* Buch.)—1400; Virginia (*J. virginiana* L., S.E. United States)—240; China (*Cupressus funebris* Endl.)—450; India (Himalaya, *Cedrus atlantica* Menetti)—20; Morocco (Atlas Mtns., *Cedrus deodora* Loud.)— 7; Kenya (*J. procera* Endl.)— no production at present.

Cedarwood oils have not been examined thoroughly or systematically. Many of the analyses of cedarwood oil were done by Runeberg (1960a-e, 1961) and associates (Pilo and Runeberg 1960; Pettersson and Runeberg 1961) (Table 1). For many years *J. ashei* was reported to contain only alpha-cedrene and cedrol (Guenther 1952; erroneously referred to as *J. mexicana* in Erdtman and Norin 1966 and Walker 1968, see Zanoni and Adams 1979 for nomenclatural discussion). However, more recently, Kitchens et al. (1971) reported beta-cedrene, thujopsene, widdrol, pseudocedrol, beta-chamigrene, prim cedrol, widdrene, isowiddrene, alpha-chamigrene, and cuparene (three isomers). Unfortunately, as is typical of most of the reports on identifications, not enough data were given by Kitchens et al. (1971) to allow confirmatory studies of their work.

Juniperus californica Carr.was reported (Pettersson and Runeberg 1961) to have cedrol as the major component (52%) of the heartwood volatile oils (Table 1) with a considerable amount of thujopsene (26%). A more recent study (Adams 1987) reported low yields (Table 1) of cedrol from two chemical races (A and B, Vasek and Scora 1967) of *J. californica*. It is presumed that Pettersson and Runeberg (1961) may have analyzed the wood of *J. occidentalis* Hooker instead of *J. californica*.

Juniperus communis L. was reported to have mostly thujopsene (37%); however, it is not clear how the author (Bredenberg 1961) arrived at these percentages

Table 1. Literature reports on the composition of the volatile wood oils of *Juniperus* species. Approximate percent concentration of key components was obtained when possible from the original literature cited

Species	[a]ACDR	BCDR	THJP	CPRN	CDRL	WDDL	Reference
J. ashei (=*J. mexicana* in part)	+	+	+	+	+	+	Guenther 1952; Windemuth 1945 Kitchens et al. 1971
J. ashei	1.8	1.6	60.4	2.8	19.0	1.1	Adams 1987
J. californica	2.6		26.0	1.0	52.0	0.2	Pettersson and Runeberg 1961
J. californica'A'	4.9	2.7	19.7	6.4	8.0	8.0	Adams 1987
J. californica'B'	3.9	1.9	18.7	4.7	9.3	9.2	Adams 1987
J. cedrus			82.4	3.7	2.2	2.6	Runeberg 1960a
J. chinensis			11.6	4.3	72.9	6.0	Pilo and Runeberg 1960
J. communis			37.0	3.0	2.0	1.0	Bredenberg 1961
J. conferta			+	+	+		Doi and Shibuya 1972
J. deppeana	16.9	3.9	14.9	3.9	26.4	1.0	Adams 1987
J. erythrocarpa	1.9	1.6	67.9	3.0	8.5	0.5	Adams 1987
J. excelsa					+		Rutowski and Vinogradova 1927
J. foetidissma	58.3				8.3	5.0	Runeberg 1961
J. horizontalis	+		+	+	+	+	Narasimhachari and von Rudloff 1961
J. monosperma	2.7	1.8	61.0	3.8	4.1	1.7	Adams 1987
J. occidentalis	+				+		Kurth and Lackey 1948
J. occidentalis var. *occidentalis*	8.8	2.6	18.9	1.5	38.9	1.6	Adams 1987
australis	3.3	1.3	20.1	1.5	38.2	1.6	Adams 1987
J. osteosperma (=*J. utahensis*)	12.7		47.8	12.5		13.5	Runeberg 1960b
J. osteosperma	4.0	1.8	40.0	2.6	13.2	1.5	Adams 1987
J. phoenicea			79.3	2.9	7.2	0.1	Runeberg 1960c
J. pinchotii	2.8	1.2	4.8	0.1	4.4	—	Adams 1987
J. procera	41.8			2.5	41.8		Pettersson and Runeberg 1961
J. recurva	3.5	0.9	5.1	1.8	49.0	16.7	Oda et al. 1977
J. semiglobosa		+			+		Goryaev et al. 1962
J. thurifera	23.3		15.5	3.9	27.1		Runeberg 1960d
J. scopulorum	4.3	2.4	57.9	6.1	6.1	3.0	Adams 1987
J. virginiana	35.0		30.0	2.0	4.0	2.0	Runeberg 1960e
J. virginiana	27.2	7.7	27.6	6.3	15.8	1.0	Adams 1987

[a]ACDR = alpha-cedrene; BCDR = beta-cedrene; THJP = thujopsene; CPRN = cuparene; CDRL = cedrol; WDDL = widdrol.

Juniperus horizontalis Moench is a prostrate plant that forms mats. Due to its low wood biomass, its oil composition is primarily of academic interest. Narasimhachari and von Rudloff (1961) reported that *J. horizontalis* contained alpha-cedrene, thujopsene, cuparene, cedrol, and widdrol, but relative concentrations were not reported (Table 1). *Juniperus occidentalis* was examined by Kurth and Lackey (1948), who merely reported that the wood contained alpha-cedrene and cedrol. A more recent analysis of both varieties (Table 1; Adams 1987) showed the varieties to be high in cedrol and thujopsene.

Juniperus osteosperma (referred to as *J. utahensis* Lemm. by Runeberg 1960b) had 47.8% thujopsene, with about equal amounts of alpha-cedrene, cuparene, and widdrol (Table 1). Adams (1987) found that the taxon was high in thujopsene, but reported that cedrol was also a major component (Table 1).

Juniperus virginiana L. wood was not directly analyzed by Runeberg (1960e). Using a commercial sample of cedarwood oil said to be from *J. virginiana*, he found mostly alpha-cedrene and thujopsene with a very small amount of cedrol (4%) (Table 1). However, the commercial cedarwood oil may have been precipitated or fractionally distilled to remove cedrol because Adams (1987) stated that *J. virginiana* wood (collected from native trees in Texas) contained about 16% cedrol (Table 1). Wenninger et al. (1967) analyzed the sesquiterpene hydrocarbons of American cedarwood oil (*J. virginiana*?) and reported that the oil contained 55-65% sesquiterpene hydrocarbons, with alpha-cedrene and thujopsene as the major components. Runeberg (1960e) stated that the highest yield of oil, about 3.5% of the wood (dry wt.?), was obtained from sawmill waste from older tree (i.e., trees with a greater ratio of heartwood to sapwood). Guenther (1952) obtained only a 0.2% yield by distilling sapwood of *J. virginiana*; he noted that young trees (commonly called sap cedars) yielded less than 1% oil, compared with older trees (commonly called virgin cedars), which yielded 3.5%.

2 Sample Collection

It is assumed that the reader is not only interested in the analysis of commercial cedarwood oil, but also in investigating the cedarwood oil from trees. In general, at least five trees should be sampled (obviously ten is preferred). Unfortunately, little is known about seasonal variation of wood oils. Depending on the local customs and laws, one may be faced with only a few options in collecting wood samples. I have even resorted to visiting a local woodworking shop in Ethiopia to obtain wood sample of *J. procera*. The ideal situation is to visit a site where trees are being cut for firewood, posts, lumber, etc. and obtain wood blocks directly. Failing this, one may look for broken limbs and cut off the stump section near the stem. I have also used a drill with a large wood bit (2 cm) to obtain wood from the trunk. One must be very careful to keep track of both sap- and heartwood shavings if biomass and yields are to be determined.

If a wood block is available, a wood planer is useful to produce fresh wood shavings for steam distillation. A power drill can also be used to produce wood

chips for distillation, but care must be taken so the bit does not get hot and cause a loss of the oil. Cedarwood oil appears to be very stable in intact wood blocks, as cedarwood cut in the 1930's is still being collected and distilled near Junction, Texas, with the oil being apparently acceptable.

3 Oil Extraction

Commercially, cedarwood oil is extracted in a variety of manners ranging from home-built stills to a newly designed process by Texarome Inc., Leakey, Texas (Figs. 1, 2). Distillation times vary from 8 h or more in traditional stills, but only 30 s in the Texarome process (K. E. Harwell, pers. commun). One should bear in mind that changing the distillation time, sizes of wood chips extracted or temperature and pressure of the steam can make vast differences in the cedarwood oil composition, so that comparisons of various commercial oils may vary as much by distillery as by region or species utilized.

For laboratory use, one should be most careful about placing the wood into water and boiling out the oil. Several studies (Fischer et al. 1987; Koedam and Looman 1980; Koedam et al. 1981; Schmaus and Kubeczca 1985) have shown that plants produce acidic conditions when boiled and this leads to terpene rearrange-

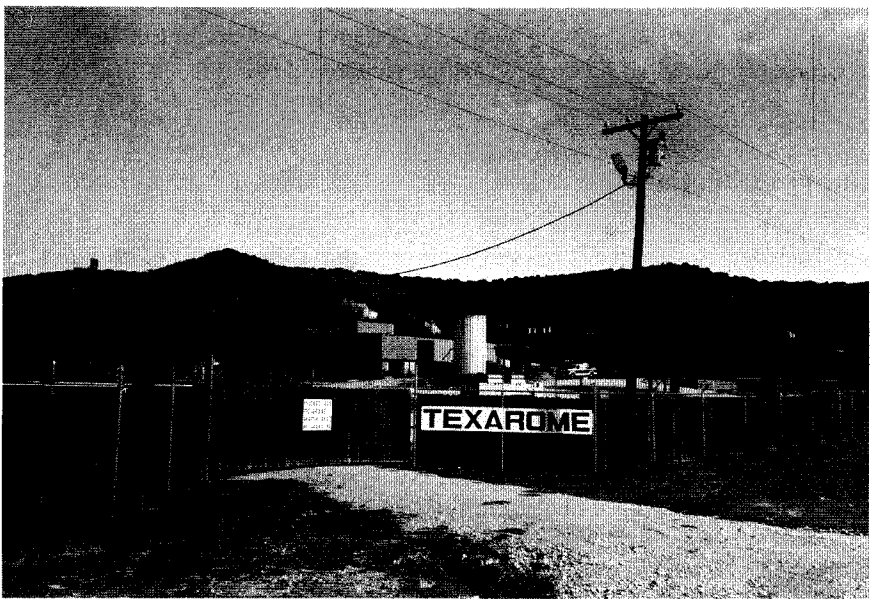

Fig. 1. Texarome's new cedarwood oil plant near Leakey, Texas. Note *Juniperus ashei* on the hillside in the background. (Photo courtesy Texarome, Inc.)

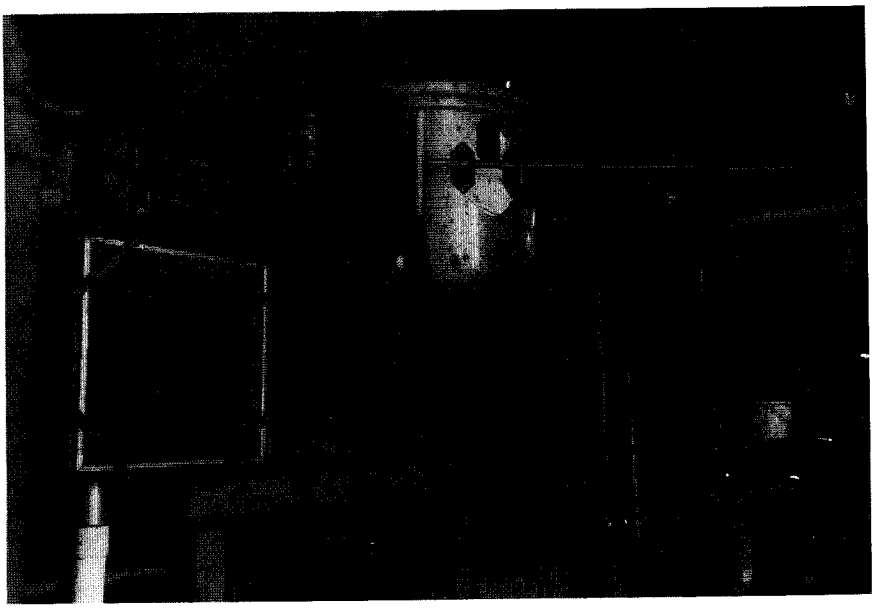

Fig. 2. Close-up of modern oil extraction equipment at Texarome, Inc. Residence time is 30 to 60 s. (Photo courtesy Texarome, Inc.)

ments and decompositions. This is shown for cedarwood oil in Fig. 3. The initial pH of the water in the boiling flask was 7.12. After 2 h boiling the wood chips directly in the flask the pH was 6.17 and the composition was quite changed (Fig. 3, upper). Steam distillation using an apparatus with the plant material suspended above the steam generator flask (Fig. 4) resulted in the chromatogram in Fig. 3 (lower). In this case, the pH of the water in the steam generator flask was 8.62 after steam distillation. The shift in the base line (Fig. 3, upper) is indicative of decomposition. Note particularly the low yield of α- and β-cedrenes (peaks 6, 7). There is a large increase in the oxygenated sesquiterpenoids (peaks 30 and upward).

Fischer et al. (1987) discuss the fact that the original (in situ) flavor components of marjoram may be quite different from those of the commercial oils. However, if one is to work within the legal and market framework that has already been established for cedarwood oil, it seems that practical work will be forced to use steam distillation extraction. Von Rudloff (1967) examined the use of direct distillation (plant material in boiling water), a Markham-type device, and a modified Clevenger-type circulatory apparatus. He preferred the modified Clevenger-type circulatory apparatus and that is essentially what I recommend (Fig. 4). I have added ball joints so the apparatus is easier to align and the ether trap can be adjusted. Notice that the plant material is placed in the cylindrical part so that only steam comes in contact with the plant material. An external heating jacket can be added to the cylindrical part to increase the distillation efficiency if

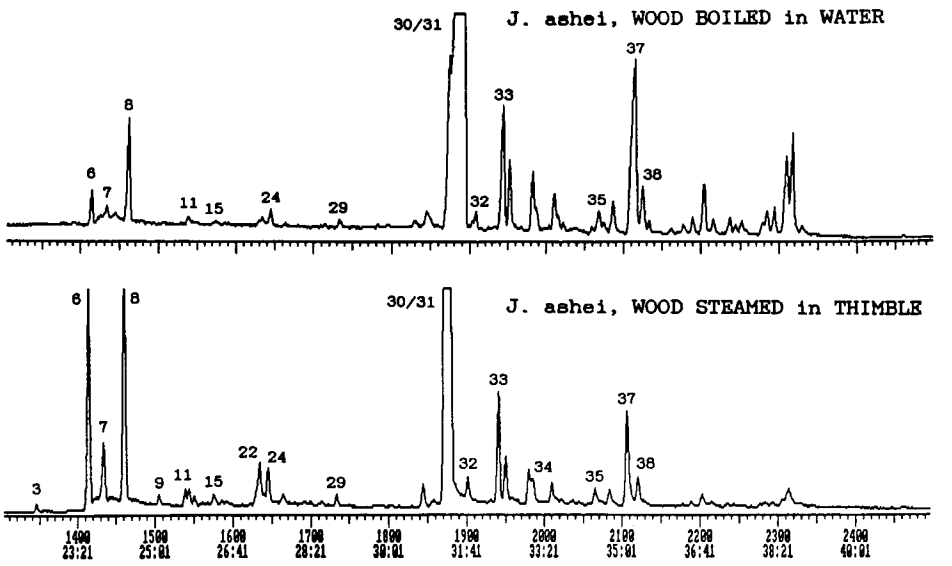

Fig. 3. Comparison of cedarwood oils obtained by hydrodistillation, boiling in water (*upper* chromatogram) and steamed in suspension (*lower* chromatogram). These and later chromatograms run on J & W DB5 silica capillary, 60–240 °C, 3°/min

desired. The condenser has also been modified so that the water jacket completely covers the ether trap area. This has resulted in much less loss of ether during distillation.

I prefer ether as the terpene trap because the ether can be evaporated by a stream of nitrogen in a hood and almost none of the terpenes are lost. Pentane could be substituted for ether. The use of hexane is discouraged because its higher boiling point results in the loss of volatile terpenes during concentration. The condenser (lower portion) should be filled with water until the water overflows into the distillation chamber. Then, the ether is placed on top of the water layer. As the distillate condenses, the oil is trapped in the ether (pentane) and the water condensate goes into the lower layer and thence back into the distillation chamber. The low density of ether allows one to trap oils that have a density greater than water. The apparatus can be run without attendance and any terpenes lost in the water are automatically volatilized as the condensate flows back into the distillation chamber.

When using the apparatus with finely ground or small wood chips, I have found it useful to place the ground wood into a sandwich of nylon screen (as used for window screens) and then place the elongated sandwich into the cylindrical chamber. If loose, finely ground material is placed directly into the cylindrical chamber, it will pack down and block the steam. Channels will form and the distillation will not proceed regularly. In addition, the distillate water, returning from the condenser, will accumulate on top of the plug and one faces the danger of

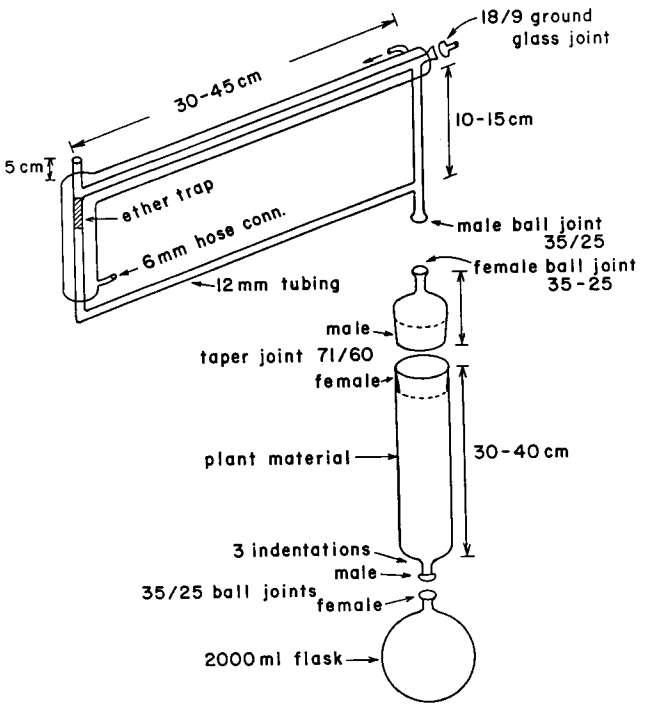

Fig. 4. Simplified Clevenger-type circulatory steam distillation apparatus recommended for cedarwood oil and general terpene extraction. Note the plant material is suspended during distillation and the oil is collected in an ether trap

running the steam generator flask to dryness. Care should be taken when handling the ether, and the entire apparatus should be placed in a well-ventilated hood when used.

The oil samples can be dried over anhydrous sodium sulfate to remove water in the ether if desired. We routinely preweigh our vials (with either compression or screw caps but in either case, using Teflon-coated caps), and evaporate the ether in a hood with nitrogen. A GC run is then used to determine the percent ether remaining in the sample and the final weight of the oil is then calculated. The samples should be stored at -20 °C or colder for long-term storage. Sealing the samples under nitrogen is also advisable for very long storage. Although decomposition of various oil samples has been mentioned to me by many colleagues, we have not experienced a problem over the past 25 years. Either our cedar and juniper oils are very stable or the aforementioned procedures mitigate decomposition. I expect that those who distill directly in water obtain oils that are quite acidic, and this may be the reason that oil decomposition is a problem. In any case, one can not assume that there will be no decomposition during long-term storage (months to years).

4 Chemical Analysis

Traditionally, cedarwood oils are defined (Walker 1968) on the basis of several physical properties: specific gravity at 15 °C (or 20 °C) 0.94-0.99; optical rotation –16 to –60°; refractive index at 20 °C 1.48-1.51; and solubility (at 20 °C) in 90 or 95% ethanol (varies with source). Although this treatment will focus on the individual chemical components, one should be aware of the practical use of the aforementioned physical properties.

4.1 Gas Chromatography

Gas chromatography has become an integral part of any essential oil analysis today. For a detailed discussion see Adams (Chap. 7, this Volume) for information on columns, carrier gases, sample injection, temperature programming and detection. All of our primary analyses are on a J & W fused silica capillary columns, DB-5, 30 m, 0.26 mm i.d., 0.25 micron coating thickness.

5 Identification

Early work on the identifications of terpenoids used component trapping from preparative GC, with subsequent liquid infrared (IR) spectral analysis for identification. The introduction of capillary columns have reduced the samples to the point that those techniques are no longer practical. The more recent development of vapor phase IR with on-the-fly analysis offers considerable promise as libraries are being compiled. However, the most practical method of identification is generally combined GC/MS or GC/MS/computer searches.

5.1 GC/MS

A large library of mass spectra is readily available from sources such as the US NBS (National Bureau of Standards, formerly the EPA/NIH data base) with thousands of spectra. Unfortunately, searches from these large data bases, with the current technology (i.e., simple matching coefficients and no retention data) do not yield reliable identifications (see Adams et al. 1979 for discussion). Although numerous papers have been written on analyses (see introduction), only the major components can be easily, unequivocally identified.

Analyses of the three major cedarwood oils are shown in Fig. 5 and a detailed list of components and retention times (on DB5) are given in Table 2. Notice that the three oils share the major components (α-cedrene, β-cedrene, thujopsene, cedrol, and widdrol). Although the minor components vary quantitatively among the oils, there is a remarkable uniformity. The off-flavor of the Chinese cedarwood oil (*C. funebris*) is apparently due to minor components.

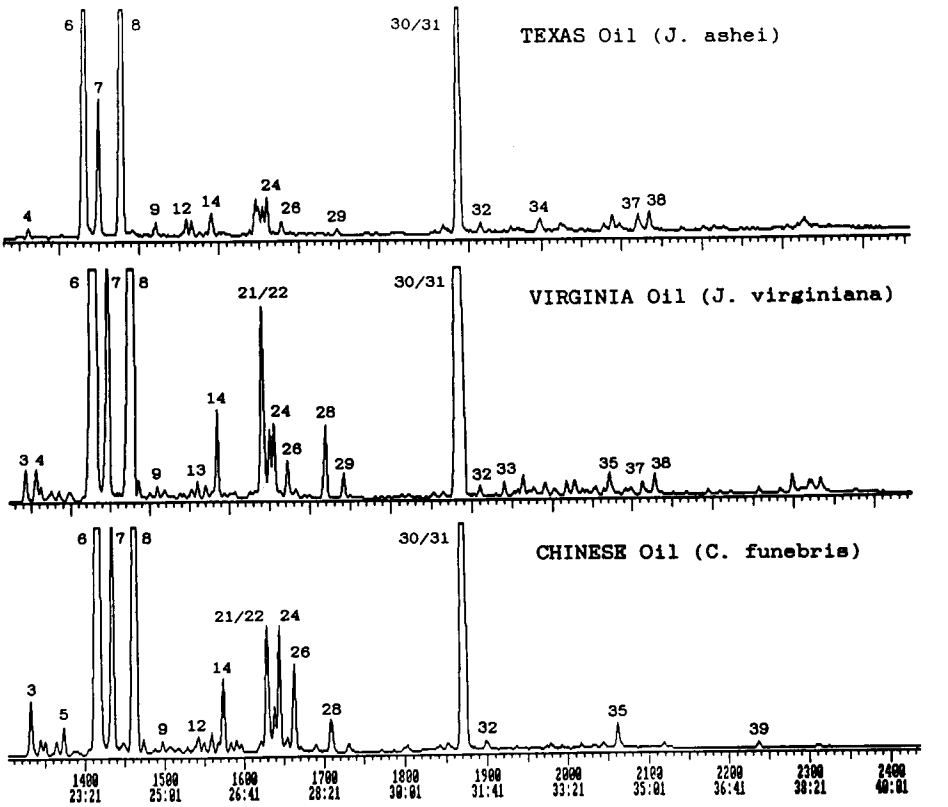

Fig. 5. Comparison of commercial cedarwood oils on a DB5 column. The *peak numbers* are identified in Table 2

Ion trap mass spectra (ITMS) for the major components are given in Figs. 6 and 7. Although the ITMS spectra are generally quite similar to quadrapole mass spectra (Adams 1989), there is a large reduction in ion 151 in both cedrol and widdrol on the ion trap. It might be noted that cedrol is very sensitive to space charging effects (overloading) and tuning on the ion trap. We use cedrol as a tuning standard on the ion trap due to its sensitivity (Adams 1989).

6 Properties

The general properties of cedarwood oils have been mentioned in the introduction. In this section, I would like to focus on several of the more unusual bioactivity properties.

Table 2. Cedarwood oil compositions from Texas (*Juniperus ashei*), Virginia (*J. virginiana*) and China (*Cupressus funebris*)

RT[a]	Compound	Texas	Virginia	China
1.	734 Camphor	0.2	—	—
2.	990 Carvacrol, methyl ether	—	—	0.7
3.	1341 Sesquiterpene	—	0.7	1.7
4.	1354 Sesquiterpene	0.3	0.7	0.5
5.	1384 Sesquiterpene	—	0.2	0.8
6.	1421 α-Cedrene	30.7	21.1	26.4
7.	1441 β-Cedrene	5.5	8.2	9.2
8.	1467 Thujopsene	25.0	21.3	29.9
9.	1507 α-Himachalene	0.5	0.2	0.2
10.	1538 cis-β-Farnesene	—	0.1	0.1
11.	1547 Thujopsadiene	0.1	—	—
12.	1551 α-Acoradiene	0.7	0.2	0.6
13.	1558 β-Acoradiene	0.6	0.3	0.3
14.	1581 β-Chamigrene	1.1	1.8	2.2
15.	1585 Γ-Himachalene	0.1	—	—
16.	1594 Γ-Curcumene	0.1	0.1	0.2
17.	1602 ar-Curcumene	0.1	0.1	0.4
18.	1608 β-Selinene	—	0.1	0.2
19.	1624 Valencene	0.1	0.1	—
20.	1631 (β-Alaskene)	0.2	0.1	0.1
21.	1633 α-Selinene + ?	1.5	3.0	3.1
22.	1643 β-Himachalene	1.4	2.1	1.4
23.	1646 (α-Chamigrene)	1.2	1.6	1.4
24.	1652 Cuparene	1.7	1.6	3.4
25.	1667 β-Bisabolene	—	—	0.4
26.	1675 α-Alaskene (=Γ-acoradiene)	0.7	0.9	2.6
27.	1701 *trans*-β-Farnesene	—	—	0.1
28.	1719 Sesquiterpene	—	1.6	1.1
29.	1739 Sesquiterpene alcohol	0.3	0.6	0.3
30.	1876 Cedrol	19.1	22.2	9.6
31.	1878 Widdrol	1.6	2.3	9.5
32.	1907 6-Isocedrol	0.4	0.2	0.1
33.	1944 Cubenol	0.2	0.1	—
34.	1966 *trans*-3-Thujopsanone	0.8	—	—
35.	2072 α-Bisabolol	0.4	0.6	0.8
36.	2085 8-Cedren-13-ol	0.9	—	—
37.	2116 Sesquiterpene alcohol	0.9	0.3	—
38.	2128 Sesquiterpene alcohol	0.8	0.6	—
39.	2246 Cedryl acetate	—	—	0.1
40.	2597 Cembrene	—	—	0.1
41.	2891 Abietadiene	—	—	0.3

[a]Compounds are listed in order of their retention times (RT) on a J β W DB5 capillary column. Compounds in parenthesis are tentatively identified.

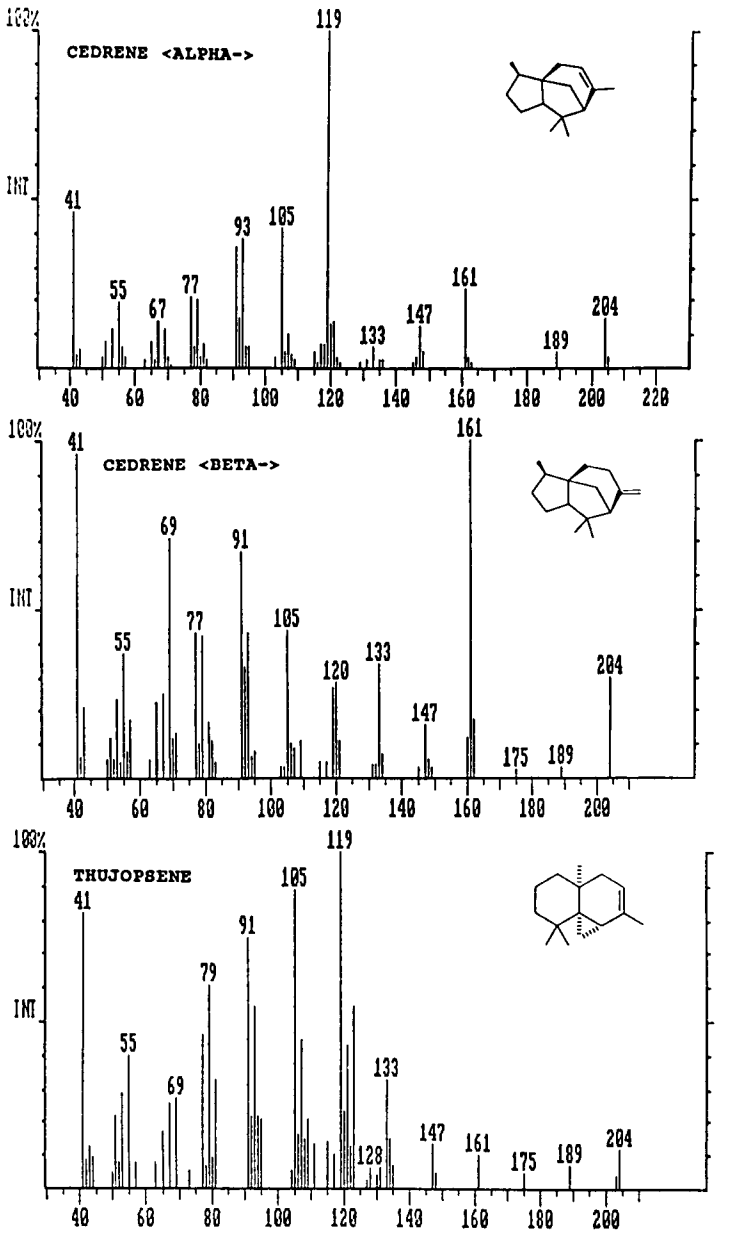

Fig. 6. Ion trap mass spectra of α-cedrene, β-cedrene, and thujopsene (*cis*)

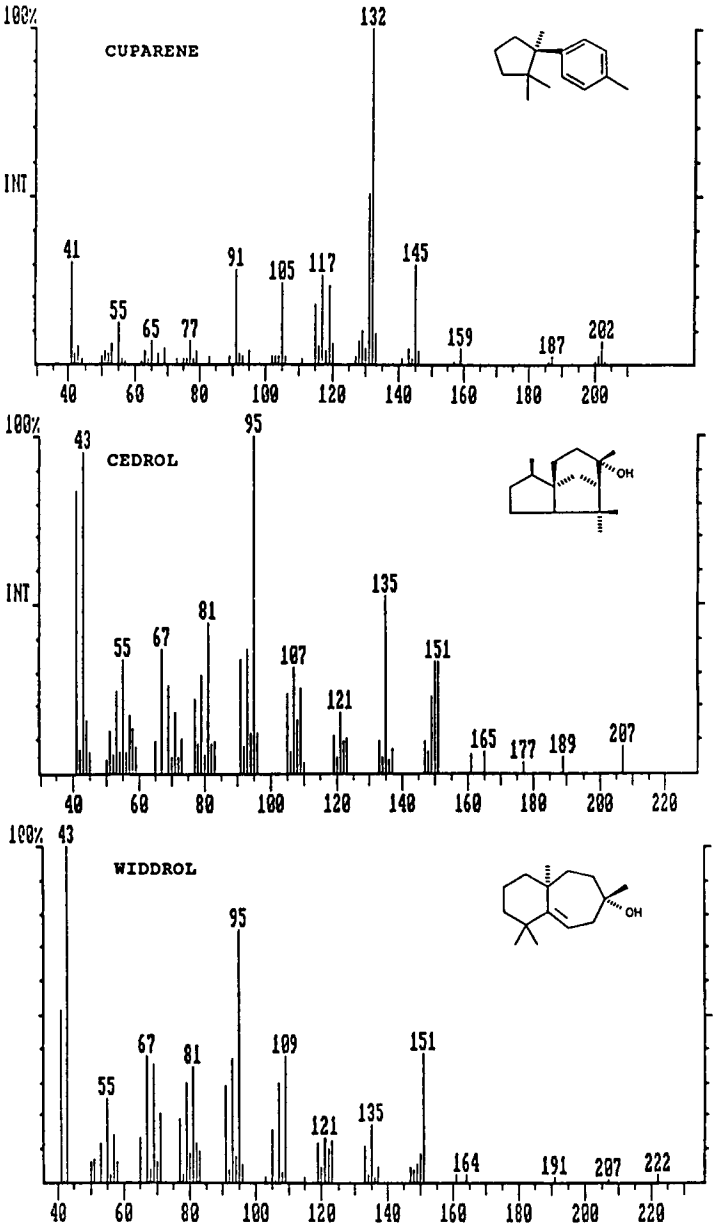

Fig. 7. Ion trap mass spectra of cuparene, cedrol, and widdrol

6.1 Antimicrobial Activities

Hexane and methanol extracts of heartwood, bark/sapwood, and leaves of 12 taxa of *Juniperus* from the United States were assayed for anti-fungal and anti-bacterial activities (Clark et al. 1990). The hexane extracts of the heartwood (which contains the cedarwood oil) of several junipers appear comparable in antibacterial activity to streptomycin. No anti-fungal activities comparable to amphotericin B were found in either the hexane or methanol extracts of heartwood. Additional research is needed to isolate and determine the anti-bacterial components.

6.2 Insecticidal Activities

Oda et al. (1977) examined the insecticidal activities of several extracts of the heartwood of *Juniperus recurva* from Nepal. The insecticidal activities were found in the steam volatile fraction(i.e., cedarwood oil). Detailed examination of individual components revealed the following LD_{50} μg/mosquito: α-cedrene— 33.5; β-cedrene— not active; thujopsene,— 4.5; acoradiene— not active; β-chamigrene— not active; curparene— not active; 8, 14-cedranoxide— 10.7; 8-cedren-13-al— not active; cedrol— 21.2; widdrol— not active; 8-cedren-13-ol acetate— not active; 8-cedren-13-ol- 6.6; 8S,13- and 14-cedrane-diols— not active. Clearly the most insecticidal components were thujopsene and 8-cedren-13-ol. Again, additional research is warranted on both *Juniperus* and *Cupressus* (and other Cupressaceae species) for natural insecticidal compounds to replace chlorinated pesticides of current usage.

6.3 Termiticidal Activities

The control of termites is a world wide problem. Current preservatives use arsenic, and chlorinated and copper-based products, all of which are toxic to humans and/or carcinogenic. Carter (1976) found that termites (*Reticulitermes flavipes*) could not survive on sawdust from *Juniperus virginiana* or on filter paper treated with a pentane extract (cedarwood oil) of *J. virginiana* sawdust.

Subsequently, Adams et al. (1988) found extremely high termiticidal activities in the heartwood sawdust from all 12 of the United States junipers examined. Hexane extracts of the heartwoods revealed that treated paper showed termiticidal activities for seven of the taxa. Additional research is continuing (McDaniel and Adams in prep.) to determine if the extracts are anti-feedants and/or toxic to termites. Because the junipers are used for posts in the United States, it is obvious that wood preservatives are in the wood. These same kinds of observations about wood rotting should be used to select promising species for additional termiticidal (and wood rotting) tests around the world (particularly in the Cupressaceae).

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Antimicrobial Properties of Heartwood, Bark/Sapwood and Leaves of *Juniperus* Species

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Hexane and methanol extracts of heartwood, bark/sapwood and leaves of twelve taxa of *Juniperus* from the United States were assayed for antifungal and antibacterial activities. The hexane extract of the heartwood of several junipers appeared comparable in antibacterial activity to streptomycin. Antibacterial activity of the hexane extracts from the bark/sapwood of *J. monosperma* and *J. californica* were comparable to streptomycin. No appreciable antibacterial activities were found in the leaf extracts from any species examined. No antifungal activities comparable to amphotericin B were found in either hexane or methanol extracts of the heartwood nor from the bark/sapwood. Antifungal activity against *Cryptococcus neoformans* comparable to amphotericin B was found in the hexane extract of the leaves of *J. occidentalis* var. *australis*. The methanol extracts from the leaves of *J. osteosperma* and *J. californica* had antifungal activities comparable to amphotericin B against *Trichophyton mentagrophytes*.

Keywords*: *Juniperus*; antifungal; antibacterial; *Cryptococcus neoformans*; *Trichophyton mentagrophytes

INTRODUCTION

Juniper wood is the domestic source of cedarwood oil for the United States but the Junipers are also known to contain natural wood preservatives (Guenther, 1952). In fact, the preferred status of juniper wood (cedar) for use as fence posts comes from a long history of its use in wet lands. The control of wood rot and termites is a perennial problem in most parts of the United States and the world. Many of the methods for wood preservation have used arsenic and/or chlorinated hydrocarbons which are environmentally hazardous. Carter (1976) has found that *Reticulitermes flavipes* Kollar (southern termite) could not survive on sawdust from *J. virginiana* nor could they survive on filter paper treated with a pentane extract of the *J. virginiana* sawdust.

Adams (1987) has recently reported on the yields of the heartwood volatile oils from 12 taxa of *Juniperus*, and noted that in addition to the two species currently utilized (*J. ashei* Buch. and *J. virginiana* L.), two additional species of juniper of the United States might be commercially harvested: *J. erythrocarpa* Cory and *J. scopulorum* Sarg. These species were also examined for their potential as sources of phytochemicals (Adams, 1987). Because plant materials were collected for these analyses an opportunity became available to examine the antibacterial and antifungal activities of the heartwood, bark/sapwood and leaves of these juniper taxa. Previous examination of the hexane and methanol soluble extracts of the leaves of *J. monosperma* revealed considerable bioactivity (McChesney and Adams, 1985).

The purposes of this study were to determine the antibacterial and antifungal activities of the heartwood, bark/sapwood and leaves of the principal *Juniperus* species of the United States.

MATERIALS AND METHODS

Samples of wood and herbarium vouchers were collected from *J. ashei* (*Adams 5007–5009*, 9 km W of Ozona, Crockett Co., TX; *Adams 5010–5016*, 2 km E of Junction, Kimble Co., TX); *J. californica* 'A' (*Adams 5067–5071*, 13 km NE of I-40, Granite Mtns., San Bernardino Co., CA) and *J. californica* 'B' (*Adams 5072–5076*, 30 km SE of Yucca, Yuma Co., AZ) ('A' and 'B' refer to the two chemical races discovered by Vasek and Scora (1967) and reconfirmed by Adams, von Rudloff, and Hogge (1983) using leaf volatile oils); *J. erythrocarpa* (*Adams 4987–4996*, 32 km N of Alpine, Jeff Davis Co., TX); *J. deppeana* (*Adams 4974–4983*, 32 km NW of Ft. Davis, Jeff Davis Co., TX); *J. monosperma* (*Adams 5027–5036*, 2 km W of Santa Rosa, Guadalupe Co., NM); *J. occidentalis* (*Adams 5077–5086*, 8 km W of Juntura, Malheur Co., OR); *J. occidentalis* var. *australis* (*Adams 5057–5066*, 2 km W of Sonora Jct., Mono Co., CA); *J. osteosperma* (*Adams 5047–5056*, 25 km E of Monticello, San Juan Co., UT); *J. pinchotii* (*Adams 4997–5001*, 28 km E of Ft.

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Stockton, Pecos Co., TX); (*Adams 5002–5006,* 10 km W of Sheffield, Pecos Co., TX); *J. scopulorum* (*Adams 5037–5046*, 5 km E of Clines Corner, Torrance Co., NM); and *J. virginiana* (*Adams 5017–5025*, 7 km W of Bastrop, Bastrop Co., TX). Voucher specimens are deposited at Baylor University.

The samples consisted of wood (20 cm long × 5–10 cm in diameter) and leaves (400 g). All samples were kept cool (February collections) in the field and then frozen in the lab until analysed.

The wood samples were separated into heartwood and bark/sapwood; each subsample was then kept separate. Portions of the heartwood, bark/sapwood and leaves were dried (48 h, 100 °C) to determine the percent moisture. Extracts were obtained from fresh heartwood, bark/sapwood and leaves by Soxhlet extraction of each set of materials for 6 h (Adams and McChesney, 1983). In each case the first solvent used was hexane and the second (sequential) solvent used was methanol. The material was dried (4 h at 70 °C) after the hexane extraction to remove the hexane before extraction with methanol (see Adams, Balandrin and Martineau, 1984, for detailed notes on the extraction protocol).

Qualitative antimicrobial screening was carried out using the agar-well diffusion assay (Clark *et al.*, 1981) against the following organisms: *Bacillus subtilis* 6633, *Staphylococcus aureus* 6538, *Escherichia coli* 10536, *Pseudomonas aeruginosa* 15442, *Mycobacterium smegmatis* 607, *Cryptococcus neoformans* 32264, *Saccharomyces cerevisiae* 9763, *Pycnoporus sanguineus* 14622, *Aspergillus flavus* 9170, *Aspergillus fumigatus* 26934, *Trichophyton mentagrophytes* 9972.

All test organisms were obtained from the American Type Culture Collection (Rockville, MD USA). Crude extracts and fractions were tested at a concentration of 20 mg/mL in ethanolic or aqueous ethanolic solution. Results of the qualitative screen were recorded as the average radius of the zone of inhibition surrounding the well containing the test solution (after 48 h incubation for bacteria and 72 h incubation for fungi) and are reported according to the following code: − = no activity; ± = questionable activity; + = 1–3 mm zone radius; ++ = 4–7 mm zone radius; +++ = 8–12 mm zone radius; ++++ = ≥13 mm zone radius. Streptomycin sulfate (1 mg/mL) and amphotericin B (1 mg/mL) were included as positive controls for antibacterial and antifungal activity, respectively.

RESULTS AND DISCUSSION

Antibacterial activity was assayed for the heartwood, bark/sapwood and leaf extracts. Essentially no activity was found against *E. coli* from the hexane extracts of the heartwood (Table 1). Nearly all species showed activity against *S. aureus*, particularly in the hexane extracts of the heartwood (Table 1). Little or no activity was observed against *P. aeruginosa* (Table 1). Almost all the species had antibacterial activity against *B. subtilis* and *M. smegmatis* (Table 1). The results of this screen indicate that follow-up research (bio-guided fractionation) will be needed.

Antibacterial activity of the bark/sapwood extracts was very similar to that of the heartwood extracts (cf. Tables 1 and 2). In general, more activity was found in the non-polar extracts than the polar extracts (Table 2) and activity was observed against the Gram-positive bacteria, *S. aureus* and *B. subtilis*, and the acid-fast bacterium *M. smegmatis*. Activities comparable to streptomycin were found in the hexane extract from *J. californica* and *J. monosperma* (Table 2).

The leaf extracts exhibited less antibacterial activity, in general, than the wood extracts (cf. Tables 1, 2 and 3). However, these extracts were from unground leaves and some of the active components may be sequestered in glands. Small antibacterial activities were found in both the non-polar and polar

Table 1. Antibacterial activity of juniper heartwood extracts after 48 hours

Species	*E. coli*		*S. aureus*		*P. aeruginosa*		*B. subtilis*		*M. smegmatis*	
	Hex	MeOH	Hex	MeOH	Hex	MeOH	Hex	MeOH	Hex	MeOH
J. ashei	±	−	++	+	−	−	++	NT	+++	+
J. californica 'A'	+	−	+	+	−	−	+	+	++	+
J. californica 'B'	−	−	+	+	−	−	+	NT	+	+
J. deppeana	−	−	++	+	−	−	++	+	+++	++
J. erythrocarpa	−	−	++	+	−	−	NT	NT	+++	−
J. monosperma	+	−	+	+	−	−	+	NT	++	+
J. occidentalis var. *australis*	−	−	++	+	−	−	++	+	++	+
J. occidentalis var. *occidentalis*	+	−	++	+	−	−	++	+	++	+
J. osteosperma	−	−	++	+	−	−	++	+	++	+
J. pinchotii	NT	−	NT	+	NT	−	NT	NT	NT	+
J. scopulorum	−	−	++	++	−	±	++	+	++	++
J. virginiana	−	−	++	+	−	−	++	+	+++	+
Streptomycin sulfate 1 mg/mL	++		+++		++		+++		++++	

HEX, hexane extract. MEOH, methanol extract.
Activities are reported as: + = 1–3 mm; ++ = 4–7 mm; +++ = 8–12 mm; ++++ = greater than 12 mm (average radius of the zone of inhibition). (−) = no inhibition.
Extracts were tested at 20 mg/mL, 100 μL applied. NT, not tested.

Table 2. Antibacterial activity of juniper bark/sapwood extracts after 48 hours

Species	*E. coli*		*S. aureus*		*P. aeruginosa*		*B. subtilis*		*M. smegmatis*	
	Hex	MeOH	Hex	MeOH	Hex	MeOH	Hex	MeOH	Hex	MeOH
J. ashei	−	−	++	+	−	−	++	+	−	±
J. californica 'A'	−	−	++	+	−	−	++	+	+	+
J. californica 'B'	−	−	++	+	−	−	+++	+	+	+
J. deppeana	−	−	++	+	−	−	+	+	+	+
J. erythrocarpa	−	−	++	+	−	−	++	+	+	+
J. monosperma	−	−	+++	+	−	−	++	+	+	−
J. occidentalis var. *australis*	−	−	++	+	−	±	++	+	++	+
J. occidentalis var. *occidentalis*	−	−	++	+	−	−	++	+	+	+
J. osteosperma	−	−	++	+	−	−	++	+	+	+
J. pinchotii	−	−	++	+	−	−	++	+	++	+
J. scopulorum	−	−	++	+	±	−	++	−	++	+
J. virginiana	−	−	+	+	−	−	++	+	++	−
Streptomycin sulfate 1 mg/mL	++		+++		++		+++		++++	

Abbreviations and symbols as Table 1.

Table 3. Antibacterial activity of juniper leaf extracts after 48 hours

Species	*E. coli*		*S. aureus*		*P. aeruginosa*		*B. subtilis*		*M. smegmatis*	
	Hex	MeOH	Hex	MeOH	Hex	MeOH	Hex	MeOH	Hex	MeOH
J. ashei	−	−	±	−	−	−	+	+	+	+
J. californica 'A'	±	−	−	+	−	−	±	+	−	+
J. californica 'B'	−	−	−	+	−	−	−	+	−	+
J. deppeana	−	+	−	−	±	+	+	++	±	+
J. erythrocarpa	−	−	−	+	−	+	+	+	−	+
J. monosperma	−	+	−	−	−	+	+	++	+	−
J. occidentalis var. *australis*	−	−	−	+	−	−	−	+	++	+
J. occidentalis var. *occidentalis*	−	−	+	+	±	−	NT	+	±	+
J. osteosperma	−	−	+	+	−	±	NT	+	+	++
J. pinchotii	+	+	+	−	−	+	+	++	±	+
J. scopulorum	−	+	−	+	−	−	−	+	±	+
J. virginiana	+	+	−	+	−	±	+	++	+	+
Streptomycin sulfate 1 mg/mL	++		+++		++		+++		++++	

Abbreviations and symbols as Table 1.

leaf extracts (Table 3). A more thorough examination of the leaf extracts from ground material is in progress.

Only minor antifungal activities of the heartwood extracts were observed against any of the fungi (Table 4). However, hexane was removed with heat, so no volatiles were present in the hexane extracts. It should be noted that Oda *et al.* (1977) found high insecticidal activity in the volatile oils of *Juniperus recurva*. A study of the antimicrobial activity of the volatile heartwood oils is in progress. Essentially no antifungal activity was found in the bark/sapwood (Table 5), which is a little surprising because the antibacterial activity of the bark/sapwood extracts roughly paralleled the antibacterial activity of the corresponding heartwood extracts (Tables 1 and 2).

The antifungal activity of the extracts from unground leaves (Table 6) was strong against *C. neoformans* and *T. mentagrophytes* from a number of taxa. *Juniperus osteosperma* and both varieties of *J. occidentalis* were particularly active against *C. neoformans* (hexane extract, Table 6). The hexane extracts of these taxa, which are active against *C. neoformans*, are noticeably ineffective against *T. mentagrophytes*. The methanol (polar) extracts of *J. californica* and *J. osteosperma* showed activity against *T. mentagrophytes* (Table 6). This would seem to imply that a different component(s) is active against these two fungi. Almost no activity was found against the other fungi.

Overall, many positive antifungal activities were found in the heartwood and leaf extracts which will warrant a further examination by bio-guided fractionation.

Acknowledgements

This research was supported in part by funds from the National Science Foundation (DMB-8460062 to RPA).

Table 4. Antifungal activity of juniper heartwood extracts

Species	*C. neoformans* 32264		*S. cerevisiae* 9763		*P. sanquineus* 14622		*A. flavus* 9170		*A. fumigatus* 26934		*T. mentagrophytes* 9972	
	Hex	MeOH	Hex	MeOH	Hex	MeOH	Hex	MeOH	Hex	MeOH	Hex	MeOH
J. ashei	+	−	+	−	+	−	±	−	±	−	++	±
J. californica 'A'	±	±	−	−	−	−	−	−	−	−	±	+
J. californica 'B'	−	−	−	−	−	−	−	−	−	−	±	+
J. deppeana	+	−	+	−	++	−	−	−	±	−	++	−
J. erythrocarpa	++	+	+	++	+	−	+	−	±	−	++	+
J. monosperma	+	−	+	−	+	−	±	−	±	−	+	−
J. occidentalis var. *australis*	+	±	+	±	+	−	±	−	±	−	+	+
J. occidentalis var. *occidentalis*	±	+	±	+	+	−	−	−	±	−	+	±
J. osteosperma	+	±	+	−	−	−	−	−	±	−	+	±
J. pinchotii	NT	++	NT	++	NT	±	NT	−	NT	−	NT	+
J. scopulorum	±	±	+	±	+	±	−	−	−	−	+	+
J. virginiana	+	±	+	−	+	−	−	−	±	−	++	+
Amphotericin B 1 mg/mL	+++		++		NT		++		++		++	

Abbreviations and symbols as Table 1.

Table 5. Antifungal activity of juniper bark/sapwood extracts

Species	*C. neoformans* 32264		*S. cerevisiae* 9763		*P. sanquineus* 14622		*A. fumigatus* 26934		*T. mentagrophytes* 9972	
	Hex	MeOH	Hex	MeoH	Hex	MeOH	Hex	MeOH	Hex	MeOH
J. ashei	±	−	−	−	−	−	−	−	−	−
J. californica 'A'	−	−	−	−	−	−	−	−	−	−
J. californica 'B'	−	−	−	−	−	−	−	−	−	−
J. deppeana	−	−	−	−	−	−	−	−	−	−
J. erythrocarpa	−	−	−	−	−	−	−	−	−	−
J. monosperma	+	−	−	−	−	−	−	−	−	−
J. occidentalis var. *australis*	−	−	−	−	−	−	−	−	−	−
J. occidentalis var. *occidentalis*	−	−	−	−	−	−	−	−	−	−
J. osteosperma	+	−	±	−	−	−	−	−	−	−
J. pinchotii	−	−	−	−	−	−	−	−	−	−
J. scopulorum	−	−	−	−	−	−	−	−	−	−
J. virginiana	−	−	−	−	−	−	−	−	−	−
Amphotericin B 1 mg/mL	+++		++		NT		++		++	

Abbreviations and symbols as Table 1.

Table 6. Antifungal activity of juniper leaf extracts

Species	*C. neoformans* 32264		*S. cerevisiae* 9763		*P. sanquineus* 14622		*A. flavus* 9170		*A. fumigatus* 26934		*T. mentagrophytes* 9972	
	Hex	MeOH	Hex	MeOH	Hex	MeOH	Hex	MeOH	Hex	MeOH	Hex	MeOH
J. ashei	−	+	−	±	±	±	−	−	−	−	±	±
J. californica 'A'	+	+	−	+	−	±	−	−	−	−	−	+++
J. californica 'B'	−	+	−	±	−	−	−	−	−	−	−	+++
J. deppeana	±	+	−	+	−	±	−	−	−	−	−	+
J. erythrocarpa	−	+	−	+	±	−	−	−	−	−	−	±
J. monosperma	−	+	+	+	−	±	−	−	−	−	±	+++
J. occidentalis var. australis	+++	+	+	+	−	−	−	−	−	−	−	+
J. occidentalis var. *occidentalis*	++	−	±	−	−	−	−	−	−	−	−	+
J. osteosperma	++	+	+	±	+	±	±	−	−	−	±	++
J. pinchotii	−	+	−	+	±	−	−	−	−	−	−	−
J. scopulorum	±	+	±	±	±	−	−	+	−	−	−	++
J. virginiana	+	+	±	+	−	±	−	−	−	−	−	++
Amphotericin B 1 mg/mL	+++		++		NT		++		++		++	

Abbreviations and symbols as Table 1.

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Section 6.3.2(b)

TASKpro

Research Consulting Special Projects
Specialist in Wood Preservation, Deterioration, & Discolorations
2256 Smith Road Sturgis, MS 39769
Phone: 662-465-9939 FAX: 662-465-7438
www:taskpro.biz

MEMORANDUM

To: Dave Glassel, President
CedarCode Industries, Inc
2119 Old Ox Road
Spring, Texas 77386

From: Terry L. Amburgey, Ph. D.
TASKpro
2256 Smith Road
Sturgis, MS 36769

Date: July 24, 2006

Re: Corrosivity of wood treated with CedarCide Wood Protection Products

As of this date, I have seen no data that indicate that wood treated with CedarCide products is corrosive to fasteners (coated or uncoated steel, copper, galvanized) used with it. A series of corrosivity tests is planned on both the treating solutions and various species of wood treated with them to verify preliminary tests using a variety of fasteners in southern pine treated with CedarCide formulations where no corrosion was evident when placed in a warm, moist environment.

6. EVIDENCE SUBMITTED (Continued)

6.4 Appendix

(A) Formulation Mixture and Recommended Treatment Applications
(Schedule A)

(B) CedarTreat™ Wood Stabilizer ™ Product Dye-tracking
(Description and Photos)

CedarCide Industries, Inc.

CedarTreat™ Wood Stabilizer™

Formulation Mixture, Coverage and Recommended Treatment Application

Dilution Ratio	Actives Pct.	Formulation Mixture & Coverage: Mixture (in gals)	Carrier (in gals)	Actives (in gals)	Coverage[A] (in board feet)	Recommended Treatment Application
9:1	10.0%	10	9	1	1,250	GROUND CONTACT Deck & Floor Supports Fence Posts Piers
9:1	10.0%	100	90	10	12,500	
9:1	10.0%	1,000	900	100	125,000	
9:1	10.0%	5,000	4,500	500	625,000	
9:1	10.0%	10,000	9,000	1,000	1,250,000	
10:1	9.1%	11	10	1	1,375	
10:1	9.1%	110	100	10	13,750	
10:1	9.1%	1,100	1,000	100	137,500	
10:1	9.1%	5,500	5,000	500	687,500	
10:1	9.1%	11,000	10,000	1,000	1,375,000	
11:1	8.3%	12	11	1	1,500	ABOVE GROUND Framing, Flooring, Rails Trim & Fascia Sill Plates Decking Fencing Gazebos
11:1	8.3%	120	110	10	15,000	
11:1	8.3%	1,200	1,100	100	150,000	
11:1	8.3%	6,000	5,500	500	750,000	
11:1	8.3%	12,000	11,000	1,000	1,500,000	
12:1	7.7%	13	12	1	1,625	
12:1	7.7%	130	120	10	16,250	
12:1	7.7%	1,300	1,200	100	162,500	
12:1	7.7%	6,500	6,000	500	812,500	
12:1	7.7%	13,000	12,000	1,000	1,625,000	
13:1	7.1%	14	13	1	1,750	EXPOSED Structural and Millwork
13:1	7.1%	140	130	10	17,500	
13:1	7.1%	1,400	1,300	100	175,000	
13:1	7.1%	7,000	6,500	500	875,000	
13:1	7.1%	14,000	13,000	1,000	1,750,000	
14:1	6.7%	15	14	1	1,875	
14:1	6.7%	150	140	10	18,750	
14:1	6.7%	1,500	1,400	100	187,500	
14:1	6.7%	7,500	7,000	500	937,500	
14:1	6.7%	15,000	14,000	1,000	1,875,000	
15:1	6.3%	16	15	1	2,000	WOOD DRYING & 180 DAY CONSTRUCTION WINDOW
15:1	6.3%	160	150	10	20,000	
15:1	6.3%	1,600	1,500	100	200,000	
15:1	6.3%	8,000	7,500	500	1,000,000	
15:1	6.3%	16,000	15,000	1,000	2,000,000	

[A] Coverage based on application rate of 8 gallons of formulation per 1,000 board foot of wood media.

CedarTreat™ Wood Stabilizer™

Limited Warranty

NOTE: This document is your warranty certificate. Please attach and secure your original invoice as proof of warranty.

ELIGIBILITY

CedarCide Industries, Inc. (the "Warrantor"), is pleased to extend a Warranty to you. This Warranty is valid for standard residential applications and may not be assigned or transferred by you. The applicable Warranty Period is indicated on the original invoice, or on the product end tag. If there is no other indication, then a One Year Limited Warranty shall apply.

WARRANTY PERIOD

One Year Limited Warranty
Warrantor will replace any genuine treated product used in a residential application which becomes structurally unfit due solely to damage caused by wood warping, twisting, or termites within one year from the date of purchase.

Ten Year Limited Warranty
Warrantor will replace any genuine treated product used in residential application which becomes structurally unfit due solely to damage caused by wood warping, twisting, or termites within ten years from the date of purchase.

Fifteen Year Limited Warranty
Warrantor will replace any genuine treated product used in residential application which becomes structurally unfit due solely to damage caused by wood warping, twisting, or termites within fifteen years from the date of purchase.

Lifetime Limited Warranty
Warrantor will replace any genuine treated product used in residential application which becomes structurally unfit due solely to damage caused by wood warping, twisting, or termites.

WARRANTY DETAILS

This Warranty does not cover costs of installation, removal, or reinstallation, or for the natural characteristic of some wood to split, or crack, other chemical or biological factors, or damage caused by physical abuse, acts of God, and acts of war. Warrantor's sole obligation is limited to replacement of the treated product, and Warrantor shall have no further liability or obligation except as expressly stated herein. The Warranty does not apply to any of the following uses: foundation piles, poles, supports in pole-frame structures, swimming pool sidewalls, tree, vine or plant supports, use in commercial or industrial projects or any application involving immersion of the product in water or soil.

Always follow the guidelines stated in the applicable Safe Handling Information document when working with or handling this product. Warrantor reserves the right to investigate any claim and to inspect the materials on which a claim is made.

Some states do not allow limitations on how long an implied warranty lasts and/or do not allow the exclusion of incidental or consequential damages, so the above limitation and exclusions may not apply to you. Furthermore, you may have rights beyond this Warranty that vary from state to state. You are advised to seek legal counsel knowledgeable about such matters.

CLAIM PROCEDURE

To make a claim under this Warranty to receive replacement wood, the original owner must, within 90 days of actual or constructive notice of damage caused by wood warping, twisting, or termites, complete the following:

(1) Prepare a letter which includes the following:
- A list of the number of the damaged pieces and the size of each piece for which the claim is made.
- Proof of Purchase of the product, as shown on the original invoice, sales ticket or receipt.
- Proof of Warranty, such as the original end tag from the product, photo of the mark on the product, or other satisfactory evidence.

(2) Mail the above information to:
CedarCide Industries, Inc., P.O. Box 549, Spring, TX 77386

WARRANTOR DOES NOT MAKE ANY OTHER WARRANTY, EXPRESS OR IMPLIED, EXCEPT AS STATED HEREIN.

For more information about CedarTreat™ Wood Stabilizer™ products visit our website at:
www.cedarcide.com