Relative Toxicity of N'N-napthaloylhydroxamine (NHA) Toxicity Against Eastern Subterranean and Formosan Subterranean Termites in Southern Yellow Pine

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Abstract

Economic losses to homeowners by termites are second only to fungal wood decay, especially in the south where infestations of the Formosan subterranean termite (*Coptotermesformosanus* Shiraki) account for ~$200 million of damage to wood structures and living trees annually. The calcium precipitating agent N'N-hapthaloylhydroxamine (NHA) has been shown to protect southern yellow pine (SYP) from wood decay and termite damage by eastern subterranean termites (*Reticulotermes flavipes* Kollar) comparable to chromated copper arsenate (CCA) in field tests in Gulfport, Mississippi. SYP blocks vacuum treated with three concentrations of N'N-napthaloylhydroxamine (NHA), leached and unleached, were exposed in a no-choice test to eastern subterranean termites at Forest Products Laboratory, USA and Formosan subterranean termites at the Wood Research Institute, Japan for 3 to 4 weeks. Mean weight losses of wood blocks after termite exposure ranged from 0 to 18 percent for *R. flavipes* and 6 to 20 percent for *C. formosanus.* Threshold levels of NHA (0.5% and 1%) offered complete protection against *R. flavipes,* but for similarly treated blocks challenged by *C. formosanus* had weight losses of 6.0 percent and 6.2 percent, respectively. *C. formosanus* caused approximately 2.5 times more weight loss than *R. flavipes* in leached NHA blocks at 0.5 percent and 1.0 percent. One-half percent NHA is an effective termiticide for *R. flavipes,* but only *C. formosanus* soldiers are preferentially killed at this concentration. The threshold level of NHA for *C. formanosus* was not achieved in this study.

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Introduction

Environmental and safety restrictions are resulting in gradual removal of arsenical-based preservatives from worldwide markets. Recently the Netherlands announced a ban on chromated copper arsenate (CCA) treated lumber effective January 2001, following the lead of other European and Asian countries.

Simultaneously, a specter is haunting the U.S. forest products industry-the specter of the Formosan subterranean termite (FST). Hitching a ride on boats returning from the Orient after World War II, the insect has spread across the south, especially since 1988 when potent organo-chlorine poisons were banned. The infestation

centers on New Orleans where the annual damage to trees and wood structures is estimated at $200 million. In addition, FST damage is $1 billion in the United States and $2 billion worldwide. In 1999, the Louisiana legislature declared the FST a public nuisance and authorized its agriculture commissioner to adopt regulations for its control. A likely outcome will be the banning of untreated wood from structural members in construction, initially within the five parish New Orleans area, later statewide. Of more than passing interest to the wood products industry is the possibility that such a move could spur similar steps in other states (17).

> "This is a super bug. This Formosan termite is a soldier in a well-organized army of billions. When they join together, Formosans form a perfect eating machine, wrecking buildings and felling trees. In 10 years, they have destroyed more of metro New Orleans than hurricanes, tornadoes and floods combined. Many years ago, vigilance might have stopped them. Now, they are dug in. They are strong and they are hungry." (15).

In terms of biodeterioration, the most hazardous region in the temperate zone is Hawaii. Hawaii's proscription set a precedent for the Louisiana measure. Over the last three decades, codes there have banned the use of untreated wood in new construction and since 1970 CCA has been the preservative treatment of choice in new construction, although recently borate treatment exceeded that of CCA. However, Hawaii is a Douglas-fir consuming market and that species is hard to treat. CCA has shown excellent protection of unincised Douglas-fir interior structural lumber in field tests in Hilo, Hawaii (16). A local area standard was created, but Douglas-fir wood received bad press from the failure of improperly treated CCA lumber on some projects. That, combined with the higher cost of treating, has led some builders, primarily large volume developers, to switch to metal studs'. The exact shift in market share has not been determined but estimates of around 30 percent have been reported based on tonnage of steel shipped to residential projects (17). In Japan, *C. formosonus* is an equally economically important pest for wood structures (19).

In response to this growing threat, new wood treating options need to be explored not only to save wood and structures, but to protect the wood industry. The leachability of disodium octaborate tetrahydrate (DOT) in ground applications and disposal problems with CCA will be further exacerbated with the potential of mandated pressure treatment of all home framing members, as proposed in Louisiana, so it is prudent to explore some new approaches to termite control. Because of environmental concerns (4) and the risk for construction workers and residents, safer and more environmentally acceptable measures are needed. Making better use of ecological and physiological characteristics of target termite species should direct the future directions of termite research (19). We have shown previously that N'N-napthaloylhydroxylamine (NHA) is a relatively benign molecule with an LD_{50} approximately 130-fold less than copper for *C. dubia* (5).

N'N-napthaloylhydroxyamine is a water soluble calcium precipitating agent which has been shown to protect southern yellow pine (SYP) from fungal decay and eastern subterranean termite damage at a concentration of 1 percent in ASTM soil-block tests. Field tests have also shown that pressure treatment with 1 percent NHA can protect SYP to the same degree as CCA in a high degradation environment like Gulfport, Mississippi, for over 30 months (5,10). The primary objective of this study was to compare and contrast the ability of NHA to inhibit weight loss of SYP from *R. flavipes* and *C. formosanus* in a no-choice lab test using vacuum treated test blocks.

Materials and Methods

Treating Procedure

Test blocks were cut from southern pine sapwood. Small feeder blocks, 10 by 10 by 20 mm (12), and medium feeder blocks, 25 by 25 by 6 mm (1), vacuum treated with aqueous NHA (0.1%, 0.5%, and 1.0%) were prepared along with those treated with chromated copper arsenate (CCA) at 6.4 kg/m^3. The standard method of determining leachability, AWPA Standard E 11-97, was followed (2).

No-Choice Test with *C. formosanus*

Test samples measuring 10 by 10 by 20 mm (~1.2 gm) were placed on the center of the plaster bottom of an acrylic cylinder test container (90 mm in diameter and 60 mm in height) with 150 workers and 15 soldiers of *C. formosanus*. The containers were placed on damp cotton pads to supply sufficient water for termites and were maintained in the dark at 28°C and over 85 percent relative humidity (RH) for 3 weeks. At the end of the test, the samples were ovendried (60°C) and reweighed to determine percent weight loss. Mortality of the termites was also recorded. Five replications of each sample were used.

No-Choice Test with *R. flavipes*

Test samples measuring 25 by 25 by 6 mm (~2.2 gm) were placed in plastic containers containing 9 cm filter paper with one gram of *R. flavipes*. Dishes were maintained at 25°C and 80 percent RH for 4 weeks following

Table 1.—*Wood weight loss (%) of no-choice laboratory termite tests on pine sapwood vacuum treated with NHA or CCA (N=5)*

Treatment	*R. flavipes* (U.S.)	*C. formosanus* (Japan)
Untreated	19.0±13.7	20.1±3.3
0.1% NHA	0.4±0.9	7.5±0.5
0.1% NHA (leached)	7.7±7.1	20.6±4.7
0.5% NHA	0.0±0.0	6.0 1.2
0.5% NHA (leached)	4.3±4.0	10.9±2.6
1.0% NHA	0.0±0.0	6.3±1.1
1.0% NHA (leached)	1.4±0.4	7.2±1.5
CCA	1.3±0.0	Not done

the methods of AWPA E 1-97. At the end of the test, samples were ovendried and reweighed to determine weight loss. Mortality was recorded (N=5).

Field Stake Testing

Field trials (graveyard tests), in which the durability of experimentally treated wood is determined by periodically monitoring the resistance of the stakes to resist attack of naturally occurring fungi and insects, are the standard method for evaluating wood preservatives. Field trials were established at the Harrison Experimental Forest in Gulfport, Mississippi in January 1997. This plot was set up in a randomized block design consistent with the AWPA E7-93 (3). Grading for decay and termites was combined (i.e., 10 = sound; 0 = failure).

Results and Discussion

During the 4 week test, *R. flavipes* survived well and consumed 19 percent of the SYP control blocks (Table 1). At 1.0 percent NHA (not leached) more than 20 percent of individuals survived at the end of the test, but at 0.5 percent NHA (not-leached) we observed 100 percent mortality (Table 2). This might be due to repellency at the higher level of NHA. Treated blocks showed less than 2 percent weight loss, but leached feeder blocks showed increased weight losses approximately 20-fold at 0.1 percent NHA. Combined mortality of *R. flavipes* on NHA exceeded that of CCA (22%).

Coptotermes formosanus had higher mortality on SYP controls but similar weight loss on smaller blocks with one half as many termites (500 mg) in only 3 weeks. Weight loss of blocks plateau at 6 to 7 percent for all groups of NHA-treated blocks (Fig. 1). Worker mortality plateaus at about 25 percent but soldier mortality increased to nearly 100 percent in unleached blocks (0.5% and 1.0% NHA) (Table 2). Soldier mortality

Table 2.—*Percent mortality of termites in no-choice test of NHA-treated SYP.*

	Mortality		
	R. flavipes[a]	*C. formosanus*[b]	
Treatment	Combined	Workers	Soldiers
Untreated	0.0±0.0	12.2±4.5	20.01±8.2
0.1% NHA	39.1±3.6	20.0±9.2	64.0±23.7
0.1% NHA (leached)	not done	12.0±6.8	14.7±5.6
0.5% NHA	100%	26.7±9.5	93.3±8.2
0.5% NHA (leached)	not done	26.0±9.8	36.0±9.0
1.0% NHA	78.6±17.8	27.3±10.0	98.7±2.7
1.0% NHA (leached)	not done	23.1±8.7	73.3±18.9
CCA	21.8±6.3	not done	

[a] 4 weeks.
[b] 3 weeks.

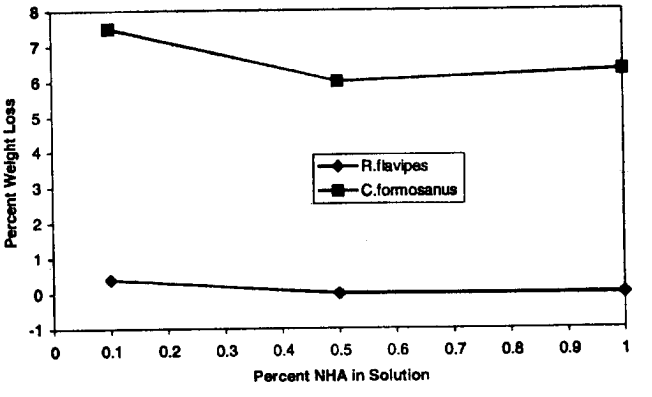

Figure 1.—*Weight-loss* of *wood blocks vs. percent NHA (unleached) in no-choice test.*

might result from reduced feeding by workers. Test block weight loss (%) and termite survival for *C. formosanus* vs. NHA was not as effective as that reported for 0.3 to 1.0 percent BAE disodium octa-borate tetrahydrate (DOT) (6,14).

In spite of encouraging results for *R. flavipes*, further correlated by 30 month NHA field stake tests in Gulfport, Mississippi (Fig. 2) (5) the results for *C. formosanus* did not meet the quality requirement of Japanese standard that requires less than 3 percent weight loss at the highest concentration of preservative tested (12). There was no special repellency of NHA-treated blocks against *C. formosanus* or *R. flavipes.* As such, the feasibility of developing NHA, or some other calcium precipitating agent, for use against *C. formosanus* is not warranted at the tested concentrations, although higher retentions above 1 percent should be tested and the mechanism of inhibition determined.

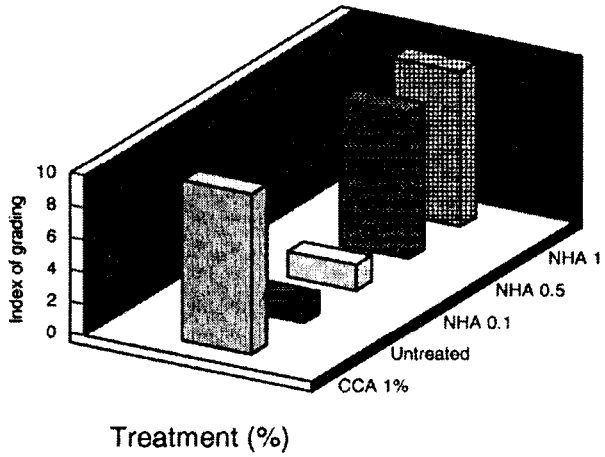

Figure 2.—*AWPA rating of field test stakes vs. preservative treatment (NHA or CCA).*

Numerous authors have tested wood treatments against Formosan subterranean termites but little comparative data is available for other termite species (7,17). Boric acid is reported to be 1.5 to 2.7 times more toxic to *R. flavipes* than to *C. formosanus* (10). Recently, a task force at AWPA 1999 (13) looked for comparative data in order to estimate thresholds concentrations of preservatives for Formosan subterranean termites (FST) based upon efficacy data for other termites i.e., *R. flavipes*. Many preservative systems had no FST data. EI-97 laboratory tests on efficacy against termites showed that CBA-A controls attack by both Formosan termites and *R. flavipes* at 0.204 pcf (3.3 kg/m^3) which is the recommended AWPA above-ground retention. Additional comparative studies should be designed and match tested in the future. Field testing of NHA (0.1% to 2.0%) against *C. formosanus* are currently underway in New Orleans, Louisiana.

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