EFFICACY OF A SERIES OF ALKYLAMMONIUM COMPOUNDS AGAINST WOOD DECAY FUNGI AND TERMITES

Alan F. Preston
Assistant Director
Institute of Wood Research, Michigan Technological University, Houghton, MI 49931

and

Darrel D. Nicholas[1]
Research Leader
Institute of Wood Research, Michigan Technological University, Houghton, MI 49931

(Received 1 October 1980)

ABSTRACT

The efficacy of four alkylammonium compounds was determined for eight common wood decay fungi and *Reticulitermes* sp. termites in laboratory tests. All of the compounds tested were found to be effective against both fungi and termites, but only dialkyldimethylammonium chloride was fully effective against all of the brown- and white-rot fungi tested in this study. On the basis of this and other studies, it is concluded that some of the alkylammonium compounds are satisfactory wood preservatives for the treatment of softwoods used in out-of-ground contact applications. More extensive field studies will be required before their potential as ground contact wood preservatives can be determined.

Keywords: Alkylammonium compounds, CCA, termites, wood decay fungi, brown-rot, white-rot.

INTRODUCTION

Ever-increasing environmental and economic pressures on currently used chemicals have led to a situation where considerable effort is now being directed towards the development of new wood preservatives. One group of compounds that has shown promise comprises long chain quaternary ammonium compounds and tertiary amine salts—collectively known as alkylammonium compounds (AAC). Studies with the AAC were initiated by Oertel (1965), but the major developments in this area have come about through extensive studies at the Forest Research Institute, New Zealand (Butcher 1979; Butcher and Drysdale 1977, 1978; Butcher and Preston 1978; Butcher et al. 1977a; Butcher et al. 1977b; Cross 1979; Preston and Butcher 1978) and have led to their commercialization in that country. Two recent reviews (Nicholas and Preston 1980; Butcher 1980) have summarized the accumulated knowledge and the present state of commercialization.

Interest in the use of alkylammonium compounds has spread, and a number of research laboratories throughout the world are now involved in developing the use of AAC as preservatives. These compounds are of interest because they:

---

[1] Presently, Professor, Forest Products Utilization Laboratory, Mississippi State University, P.O. Drawer FP, Mississippi State, MS 39762.

Wood and Fiber, 14(1), 1982, pp. 37–42

- can be used as waterborne systems
- exhibit a broad spectrum of biocidal effectiveness
- are environmentally more acceptable than presently used materials
- are reasonably close to being cost-competitive with the presently used preservatives such as copper-chrome-arsenate.

Recent research (Butcher et al. 1980) suggests that the performance of the AAC in ground contact can be significantly improved by combining them with small amounts of other fungicides. Hence, such combinations may produce preservative systems that are competitive on a cost-effectiveness basis with the current commercial preservatives.

In this present study, the relative efficacies of four AAC are compared against eight wood decay fungi and also against subterranean termites. This research has been carried out at the Institute of Wood Research as one part of a multidisciplinary program to develop new wood preservative systems. Sponsorship of this program is provided by the Electric Power Research Institute, Palo Alto, CA.

METHODS AND MATERIALS

Decay tests

The laboratory decay tests were conducted in accordance with the ASTM Standard D 1413 (1979a), with the exception that 14-mm cubes were used, with three blocks being tested in each container. The containers were pint mason jars that contained 150 grams of soil. Southern yellow pine was used for all test specimens and feeder strips. The following fungi were used in these tests:

Fungus	Type of rot
Gloeophyllum trabeum	Brown
Coniophora puteana	Brown
Poria vaillantii	Brown
Fomes gilvus	White
Poria placenta	Brown
Poria incrassata	Brown
Polyporous versicolor	White
Polyporous tulipiferae	White

Termite tests

The efficacy of these AAC against termites was evaluated by two different methods. The first method utilized filter paper disks (70-mm diameter), which were impregnated by dip-treating with varying concentrations of chemicals and then allowed to dry for a minimum of 7 days. Following this, each piece of filter paper was placed in a 100- × 15-mm petri dish and was saturated with 0.6 ml of sterile water. Twenty apparently healthy termite workers (*Reticulitermes* sp.) were then placed in each dish, with five replicate dishes being used for each chemical concentration. Ten control replicates, using untreated sterile filter paper, were run with each set of tests. The surviving termites were counted after 4 hours and daily thereafter for 30 days, or until all the test animals died.

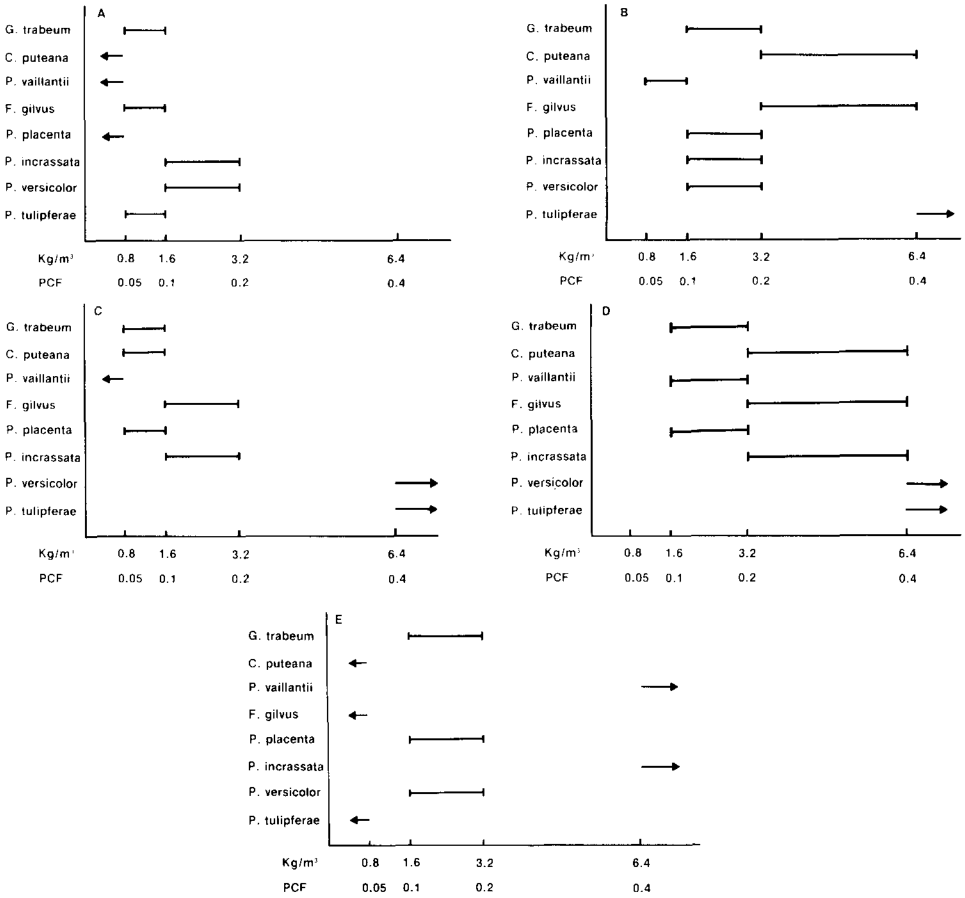

FIG. 1. Toxic threshold ranges for AAC and CCA treated wood exposed to eight fungi in the soil block test. A—Dialkyldimethylammonium chloride. B—Alkylbenzyldimethylammonium chloride. C—Alkyldimethylammonium acetate. D—Alkyldichlorobenzyldimethylammonium chloride. E—CCA.

The second method employed was ASTM Standard D 3345 (1979b), using southern yellow pine wood blocks and *Reticulitermes* sp. termites.

Chemicals

The alkylammonium compounds used in this study were commercial grade. Three of these were obtained from Lonza Inc. and are described as follows: 1) Bardac 22—dialkyl (C_{10}, C_{10}) dimethylammonium chloride, 2) Barquat OJ—alkyl (C_{12}, C_{14}) benzyldimethylammonium chloride, 3) Barlene 12—alkyl (C_{12}, C_{14}) dimethylamine. Stock solutions of the first two were used for the experiments, but Barlene 12 was reacted with analytical grade acetic acid to form the acetate salt. The fourth AAC was Maquat DLC 1214, which is an alkyl (C_{12}, C_{14}) dichlorobenzyldimethylammonium chloride compound that was obtained from Mason Chemical Co.

The CCA was obtained from Koppers Co. as a 50% (oxide basis) liquid concentrate (Wolmanac CCA-C Oxide).

TABLE 1. *Feeding and damage ratings on blocks exposed to* Reticulitermus flavipes *in an ASTM D 3345 test.*

Chemical	Retention (kg/m^3)	Rating	Mean mortality (%)
Untreated	—	0	16
Barlene 12 Acetate	0.8	2.7	33
	1.6	8.3	67
	3.2	9.8	100
Barquat OJ	0.8	7.8	100
	1.6	9.8	97
	3.2	10.0	97
Maquat DLC 1214	0.8	9.8	100
	1.6	10.0	100
	3.2	10.0	100
Bardac 22	0.4	8.8	100
	0.8	9.3	100
	1.6	10.0	98
	3.2	10.0	75

RESULTS AND DISCUSSION

The threshold values established in the decay tests against eight *Basidiomycetes* fungi using four alkylammonium compounds and chromated copper arsenate are shown in Fig. 1.

With the exception of *P. versicolor,* the unsubstituted (Fig. 1B) and dichlorobenzalkonium (Figure 1D) chloride salts exhibited very similar fungicidal spectra in this series of tests. Since the chlorinated analog is less effective against this particular white-rot fungus, such a modification would not appear to be beneficial. The tertiary amine acetate (C) included in these tests gave very good control of the brown-rot fungi, reaching a threshold for all except one at a retention of 1.6 kg/m^3, but against the two *Polyporous* white rot species control was not achieved at the highest retention (6.4 kg/m^3) tested. This lack of effectiveness against white-rot may not be important for the treatment of softwoods to be used in above ground situations, but it may explain the unexpectedly poor performance of tertiary amine salts in field and fungus cellar tests (Butcher et al. 1980).

The dialkyldimethylammonium compound was superior to all of the preservatives tested in this study. As can be seen from Figure 1A, complete control of all eight fungi was achieved at a retention of 3.2 kg/m^3. This is in contrast to CCA (Figure 1E) which failed to control two of the fungi.

All of the AAC tested against *Reticulitermes* sp. exhibited marked activity at the highest retentions tested (3.2 kg/m^3), though trends in effectiveness at levels below this were evident (see Table 1).

In terms of effectiveness against termites, the relative activities of the AAC tested were as follows: Maquat DLC 1214 > Bardac 22 > Barquat OJ > Barlene 12 acetate. This order of activity closely parallels the overall order of these compounds against fungi (see Figs. 1A–1D) with the exception of the dichloro benzalkonium chloride analog, which exhibited markedly enhanced anti-termite activity compared with its overall activity against decay fungi.

Table 2. *Percent termite survival at various times when exposed to the treated filter paper screening test.*

Chemical	Treating soln. strength (% a.i.)	Number of days										
		0.16	1	2	3	4	5	6	7	8	9	10
Barlene 12 Acetate	0.125	10	3	0								
	0.25	5	0									
	0.5	0										
	1.0	0										
	2.0	0										
Barquat OJ	0.125	99	99	96	94	92	86	79	69	60	52	43
	0.25	100	100	96	92	88	84	71	52	47	46	37
	0.5	97	96	91	83	72	64	52	36	32	21	12
	1.0	25	0									
	2.0	39	18	8	1	0						
Bardac 22	0.125	99	99	96	90	85	81	72	64	53	50	39
	0.25	83	83	72	61	51	44	35	24	17	15	9
	0.5	96	79	52	12	5	2	1	1	1	1	0
	1.0	0										
	2.0	0										
Dieldrin	0.1	98	83	3	0							
Controls		100	100	99	97	95	94	94	93	93	92	92

These results are substantially different from those obtained in preliminary studies using a filter paper–petri dish screening technique (see Table 2). In this test the tertiary amine salt had a much more rapid effect on termites than the benzalkonium chloride, with the activity of the didecyldimethylammonium chloride being intermediate between the other two.

In his investigations of the use of AAC as insecticidal wood preservatives, Cross (1979) found that benzalkonium chloride (64% C_{12}, 30% C_{14}, 6% C_{16}) was more effective than dialkyl (C8, C10) dimethylammonium chloride both in an oral injection test with *Prionoplus reticularis* and in artificial block tests with *Anobium punctatum* larvae. In recent studies, Cross (1980) has shown that tertiary amine acetates are equally as effective as the benzalkonium chloride used, both compounds giving 100% mortality in egg-laying tests with *Anobium punctatum* on *Pinus radiata* sapwood at retentions as low as 0.2 kg/m^3.

The reasons for differences in relative effectiveness among the AACs in the various insect tests mentioned above are unclear. One possible explanation relates to toxicant availability with respect to the substrate used. This could manifest itself in two ways. First of all more substantive AAC will absorb more strongly onto the substrate, and thus tests using substrates with a high surface area to volume ratio (e.g. filter paper, artificial block) will cause stripping of the treating solution and result in a greater than expected retention of the preservative. Secondly AAC will vary in the strength of the ionic bond absorbing them onto the substrate and substances that are the most strongly bound will be less easily utilized by, and hence, less toxic to, the insects. Indeed, in a broad sense this explanation may also account for the apparent lower effectiveness of certain AAC against *Lyctus* (Butcher et al. 1977), which unlike termites and the Anobids and Ceranbycids, do not utilize cellulose, preferring instead starch as their primary food source.

CONCLUSIONS

All of the AAC tested in this study were reasonably effective against both wood decay fungi and termites. However, at the treatment levels used in this study, only dialkyldimethylammonium chloride completely controlled both the brown- and white-rot fungi. The other compounds failed to control either one or both of the white-rot fungi.

On the basis of this and other studies, it can be concluded that these AAC compounds are satisfactory wood preservatives for the treatment of softwoods used in out-of-ground contact applications. More extensive field studies will be required before their potential as ground contact wood preservatives can be determined.

REFERENCES

American Society for Testing and Materials (ASTM). 1979a. Standard method of testing wood preservatives by laboratory soilblock cultures. ASTM Standard Method D 1413-76. ASTM, Philadelphia, PA.

———. 1979b. Standard method of laboratory evaluation of wood and other cellulosic materials for resistance of termites. ASTM Standard Method D 3345-74. ASTM, Philadelphia, PA.

Butcher, J. A. 1979. Testing new preservatives for protection of wood exposed in above ground situations. Mater. Org. 14(1):43–53.

———. 1980. Current status of AAC preservatives in New Zealand. International Research Group-Wood Preservation, IRG/WP/3141.

———, and J. Drysdale. 1977. Relative tolerance of seven wood-destroying basidiomycetes to quaternary ammonium compounds and copper-chrome-arsenate preservatives. Mater. Org. 12(4):271–277.

———, and ———. 1978. Efficacy of acidic and alkaline solutions of alkylammonium compounds as wood preservatives. N.Z. J. For. Sci. 8(3):403–409.

———, and A. F. Preston. 1978. Toxicity of tertiary amine acetates against basidiomycetes and soft-rot fungi. N.Z. J. For. Sci. 8(3):392–396.

———, M. E. Hedley, and J. Drysdale. 1977a. Comparisons of a quaternary ammonium compound and copper-chrome-arsenate as wood preservatives. For. Prod. J. 27(7):22–25.

———, A. F. Preston, and J. Drysdale. 1977b. Initial screening trials of some quaternary ammonium compounds and amine salts as wood preservatives. For. Prod. J. 27(7):19–25.

———, ———, and ———. 1980. Potential of unmodified and copper-modified alkyl ammonium compounds as groundline preservatives. N.Z. J. For. Sci., 10, in press.

Cross, D. J. 1979. Alkyl ammonium compounds as insecticidal wood preservatives. Mater. Org. 14(2):105–116.

———. 1980. Future insecticidal treatments for wood products. International Research Group-Wood Preservation, IRG/WP/3140.

Nicholas, D. D., and A. F. Preston. 1980. Evaluation of alkyl ammonium compounds as potential wood preservatives. Proceedings of American Wood Preservers' Association. In press.

Oertel, J. 1965. Novel wood preservatives of good leaching resistance, based on water soluble organic compounds, and their potential uses. Holztechnologie 6(4):243–247.

Preston, A. F., and J. A. Butcher. 1978. Fungicidal effectiveness of various salts of a tertiary amine. N.Z. J. For. Sci. 8(3):392–396.