PATTERNS OF FUNGAL ATTACK IN WOOD-PLASTIC COMPOSITES FOLLOWING EXPOSURE IN A SOIL BLOCK TEST[1]

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ABSTRACT

The ability of white and brown rot fungi to colonize wood-plastic composites was investigated by measuring weight loss and anatomical changes. Three composite materials were evaluated. The material containing a 70/30 wood-high density polyethylene (HDPE) mixture was most susceptible to fungal attack, while two different 50/50 wood-HDPE composites experienced little or no attack. Scanning electron microscopic (SEM) examination of samples not exposed to fungus revealed the presence of voids between the wood and HDPE in all three materials. Similar examination of decayed samples of the composite with a higher wood content revealed that the fungi had thoroughly colonized the particles, particularly near the point of initial fungal exposure. Fungal hyphae were also prevalent in the voids deeper in the composite. The two composites containing higher HDPE levels had little evidence of fungal attack, despite the presence of voids.

Keywords: Wood-plastic composite, high-density polyethylene (HDPE), white rot fungus, brown rot fungus, fungal hyphae, voids.

INTRODUCTION

The emergence of recycling programs to collect various plastics has created a substantial demand for the development of practical applications for these materials. One common application for recycled plastic has been the production of plastic lumber for use in decking and picnic tables. Plastic lumber has some excellent material properties, but its disadvantages include its weight and tendency to deform under load, particularly when heated. One method for enhancing its properties is to incorporate wood fiber in the mixture to lighten and reinforce the resulting board (Simonsen 1997). The addition of wood, however, can lead to performance problems with the boards because the added fiber can be susceptible to moisture absorption and degradation. The potential for degradation of components of wood-plastic composites has received little attention. Manufacturers apparently believe that the plastic encapsulates the wood fiber, limiting access to fungal attack; however, there is little literature to support this premise, and some evidence indicates that wood-plastic composites can absorb considerable moisture, albeit at slower rates than solid wood (Schmidt 1993; Naghipour 1996). A recent report noted extensive evidence of white and brown rot attack in a walkway in Florida exposed for 4 years (Morris and Cooper 1998), but there are few other reports on the performance of these wood-plastic mixtures. In this report, we describe a scanning electron microscopic (SEM)

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FIG. 1. Scanning electron micrographs of non-fungal exposed materials of all three composites showing the distribution of the wood in the plastic matrix and the potential for fungal movement through interconnecting pathways between individual wood particles. Figure (a) shows the 70/30 composite, while Figures (b) and (c) show the two 50/50 composites.

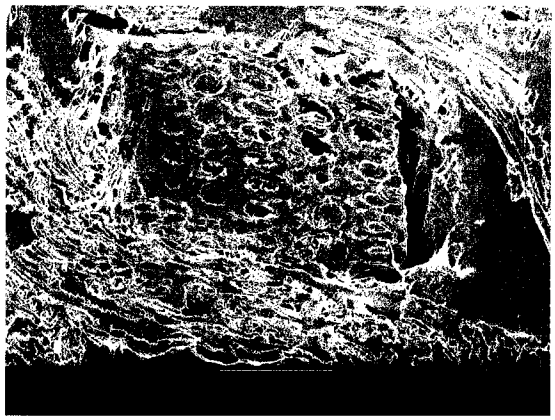

FIG. 2. Scanning electron micrograph of a block composed of composite Material A showing the intimate association between the wood and plastic, but also illustrating the presence of voids between these materials.

study of three wood-plastic composites following exposure to selected white and brown rot fungi in a soil block test.

MATERIALS AND METHODS

Blocks of three materials were cut approximately 10 mm × 10 mm × panel thickness. Material A was a 70/30 mixture of wood and high-density polyethylene (HPDE). The wood particles were approximately 0.25 mm in diameter. Materials B and C contained 50/50 wood-HPDE, with 1- to 2-mm-diameter wood particles. Because the materials provided were proprietary, the mixture of wood species in each was unknown. SEM examination suggested that the wood was primarily coniferous. An additional set of 36 ponderosa pine (*Pinus ponderosa* Laws.) sapwood blocks were included to serve as controls.

The blocks were oven-dried at 54°C and weighed to the nearest 0.001 g. All of the blocks were soaked in water for 30 min, then placed in plastic bags and sterilized by exposure to 2.5 mrad of ionizing radiation from a cobalt 60 source. Irradiation was used because heat sterilization can increase the decay susceptibility of wood specimens and might have altered the wood-HPDE matrix. The materials absorbed water differently, with Materials A,

B, and C showing weight gains of 16%, 2.4%, and 1.9%, respectively.

Decay chambers were prepared in 454-ml glass jars with either red alder (*Alnus rubra* Bong) or western hemlock (*Tsuga heterophylla* [Raf.] Sarg). Alder was used for the white rot fungi, while hemlock was used for brown rot fungi. The culture of white rot fungus inoculated on the red alder was one of the following: *Phlebia subserialis* (Gourd. & Galzin) Donk (Isolate RLG10693), *Trametes versicolor* (L.: Fr.) Pilat (Isolate R105), or *Xylobolus frustulatus* (Pers.:Fr.) Karst (Isolate FP106073-R). The culture of brown rot fungus inoculated on the western hemlock was either *Gloeophyllum trabeum* (Pers. ex. Fr.) Murr. (Isolate Madison 617), *Postia placenta* (Fr.) M. Larsen & Lomb. (Madison 698), or *Wolfiporia cocos* (Wolf) Ryvarden. & Gilbertson (Isolate FP104264-SP).

The jars were then capped and incubated at 28°C until the alder or hemlock was thoroughly covered by test fungus.

Once the fungus had covered the alder or hemlock water, the test blocks of Materials A, B, or C were placed on the feeder strip surface, and the chambers were incubated for 12 weeks at 28°C. Each fungus was tested on six blocks of each material (either Material A, B, C, or the ponderosa control). At the conclusion of the test, the blocks were removed, scraped clean of adhering fungal mycelium or soil, and oven-dried (54°C) prior to being weighed. The block's weight loss over the exposure period served as the measure of decay (i.e., the more decay, the more weight loss).

Blocks having a range of weight losses were selected for further microscopic study. In addition, unexposed controls from each of the materials were selected for comparison. The blocks were oven-dried, then split in half to expose an internal face. These blocks were sputter-coated with gold palladium and examined by using an AMR 1000A Scanning Electron Microscope (SEM, accelerating voltage 20 kV, tilt angle 30 degrees, working distance 12 mm). The distribution of wood in the plastic was examined on the blocks not exposed to fungus. Then the blocks exposed to fungus were examined for fungal-hyphae distribution and evidence of wood or plastic degradation.

RESULTS AND DISCUSSION

Weight loss in the blocks varied widely among the three materials as well as with the white or brown rot fungus to which the materials were exposed (Table 1). Weight loss approached 30% in a few blocks of composite Material A. Both the wood and plastic immediately adjacent to the fungal mycelium were completely degraded in many cases.

The weight losses associated with blocks of composite Materials B and C were generally negligible, in the range associated with the procedures of wetting, oven-drying, and other handling, rather than with fungal damage. These low weight losses may reflect slow water uptake by samples with lower wood contents. We soaked additional specimens in water for 5 days and only achieved moisture contents (MCs) of 24%, 6.5%, and 6.2%, respectively, for Materials A, B, and C. If we assume that all of the moisture was absorbed by the wood, this translates to wood MCs of 48%, 21.6%, and 20.7%, respectively. Clearly, the higher plastic composition substantially reduced moisture uptake, creating conditions that were less suitable for decay.

Scanning electron microscopic examination of the untreated control samples revealed that the wood particles were randomly distributed throughout the plastic matrix of all three materials (Fig. 1). Some wood particles appeared to be encapsulated in plastic, but there was an extensive series of voids around most wood particles, suggesting that channels existed for movement of the decay fungus into the matrix (Fig. 2). Most of the blocks that experienced low weight losses were essentially free from fungal attack or visible wood cell wall damage. Blocks of Material A that experienced larger weight losses tended to have more extensive hyphal growth, although most of the growth appeared to be concentrated near the

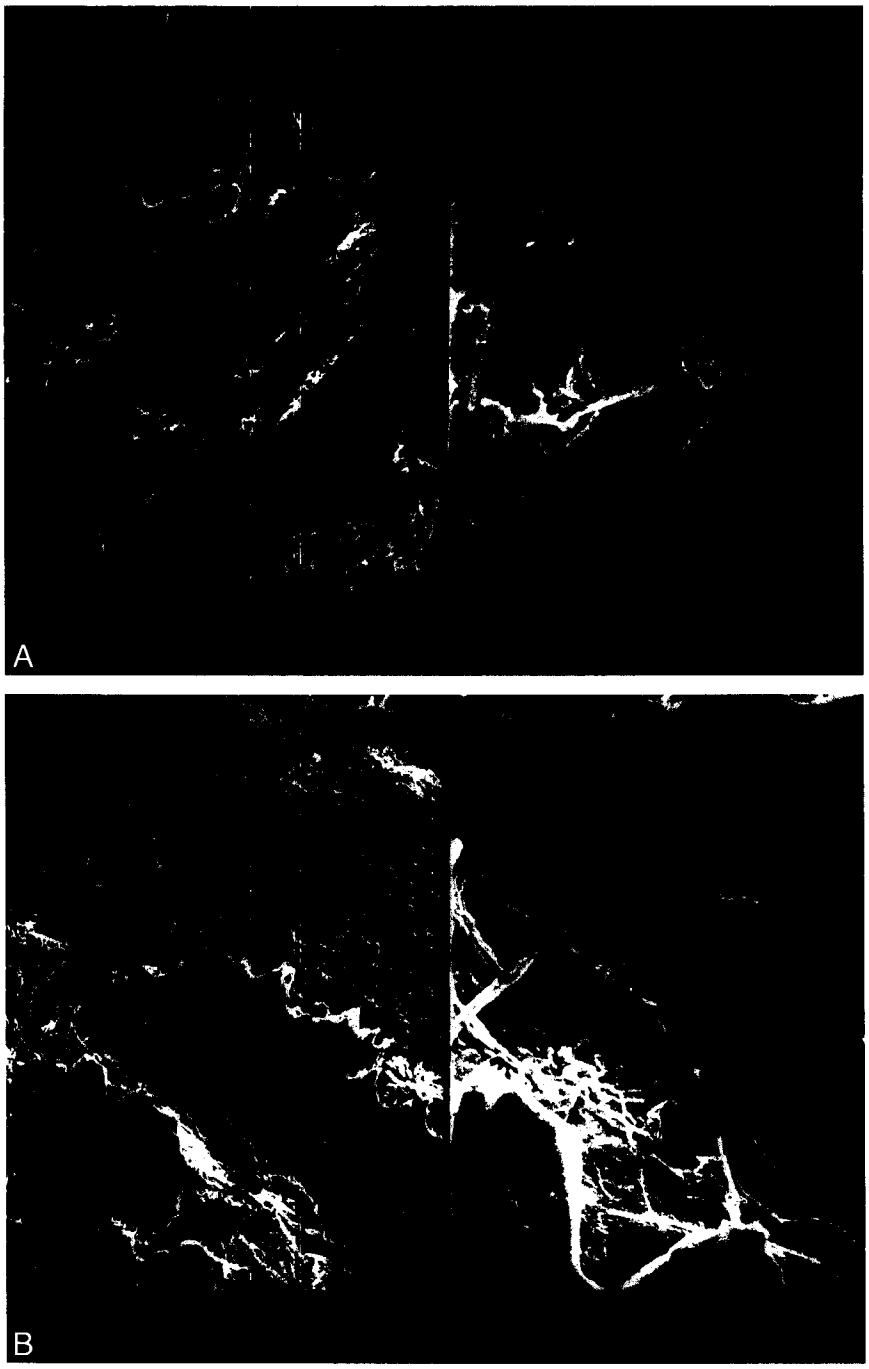

FIG. 3. Scanning electron micrographs of blocks composed of composite Material A and exposed to brown rot fungi (a) *Gloeophyllum trabeum* or (b) *Postia placenta,* showing voids containing extensive fungal mycelium. The enlargement of the boxed insert is to the right in each photo.

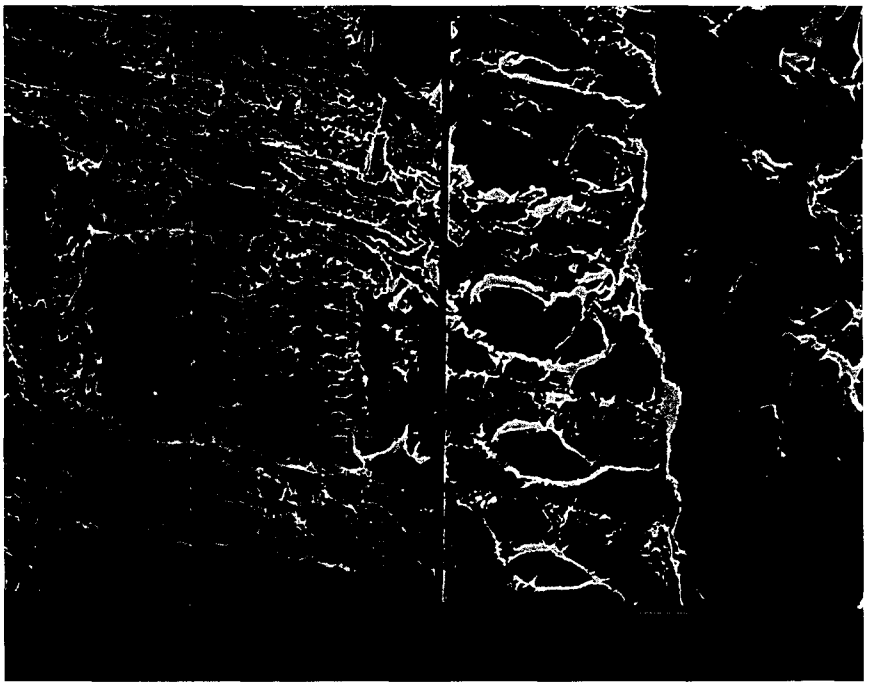

FIG. 4. Scanning electron micrograph of a block of composite Material A-including an enlargement of the insert on the right-exposed to brown rot fungus, *Postia placenta,* showing the absence of fungal mycelium or other evidence of fungal attack in a region near the middle of the block.

surface that was originally exposed directly to the test fungus. Most of the mycelium tended to be concentrated within the voids originally present between the wood and plastic (Fig. 3). These voids appeared to act as pathways through which the fungus grew between the wood particles in the plastic matrix. Voids around particles near the center of most blocks were essentially free of fungal colonization even in blocks with an elevated weight loss (Fig. 4). The absence of substantial fungal attack in these zones implies that the fungus was slowly growing through the block, producing near complete dissolution as it grew, but confining its attack to a relatively narrow area on the exterior of individual particles. This pattern of damage is somewhat abnormal for the brown rot fungi, which typically cause substantial degradation some distance away from actual fungal growth but leave a residual lignin skeleton (Zabel and Morrell 1992).

Clearly, all three materials contained numerous voids that could serve as conduits for fungal movement through the panel. The more decay-resistant composite Materials B and C contained higher percentages of HPDE, but

TABLE 1. *Weight losses in wood-plastic composite blocks exposed to decay fungi in a soil block test.*

Test fungus	Weight loss (%)[a]		
	Composite Material A	Composite Material B	Composite Material C
White rot fungi			
P. subserialis	10.2 (6.1)	0.6 (0.5)	0.4 (0.3)
T. versicolor	5.9 (7.6)	1.2 (0.5)	2.1 (0.7)
X. frustulatus	4.4 (3.2)	1.0 (0.4)	1.2 (1.2)
Brown rot fungi			
G. trabeum	20.4 (10.8)	2.7 (1.3)	3.1 (0.6)
P. placenta	15.8 (5.4)	0.3 (0.2)	1.3 (1.3)
W. cocos	9.9 (8.5)	1.8 (0.3)	2.3 (1.5)

[a] Values represent means of six replicates per fungus/composite treatment. Values in parentheses represent one standard deviation.

their individual wood particles were larger than those in Material A. Smaller particles might be expected to permit more uniform encapsulation by the plastic, but higher levels of HPDE (and lower percentage of wood) apparently had a greater effect on limiting water uptake (thus enhancing resistance to fungal attack) than did particle size or the presence of voids. Because the percentage of wood was much lower in Materials B and C, their voids were less likely to interconnect and thus less likely to provide a conduit for fungal movement.

The results suggest that the wood in wood-plastic composite lumber must be protected from fungal attack, or the percentage of wood must be limited, if the product is used in exterior exposures where wetting and fungal attack are possible.

ACKNOWLEDGMENT

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