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Evaluation and Process Development of *Salt Cedar* and *Juniper* Bio-composites as Tools to Utilize Exotic and Invasive Species and Restore Native Eco-systems

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Abstract: This research program is developing and evaluating potential value-added uses for a variety of exotic-invasive woody species, such as salt cedar (*Tamarisk spp.*), one-seed juniper (Juniperus monosperma)), and eastern red-cedar (*Juniperus virginiana*). Because each of these species is encroaching into America's natural indigenous eco-systems, land managers need tools to off-set the costs to control or eliminate them. In most cases, exotic-invasive species are removed from rangeland by using bulldozers and chains, piled and then burned. Such harvesting and burning in itself has significant costs in watershed damage, erosion and air pollution. Attempts to utilize most of these problem species have been extremely limited. One potential method to help promote control and elimination of exotic-invasive species, such as salt cedar and juniper fiber and thereby promote natural rangeland restoration, is to develop new value-added uses for them. Such attempts at value-added utilization will defray the cost of removing them from these arid eco-systems, which may in turn enable subsequent restoration of less water-demanding native flora. This report will describe our recent work to address these problems.

Key words: *composites, wood-plastic composites, utilization, exotic-invasive species, eco-system restoration*

1. BACKGROUND

Salt cedar (*Tamarisk spp.*) is an exotic species introduced into North America from Europe that has now invaded the arid natural eco-systems of the Southwestern United States. It grows as a small bushy plant in creek beds and diverts excessive amounts of water from the ground or from freely flowing streams. The U.S. Department of Agriculture - Forest Service, the U.S. Department of Interior - Bureau of Land Management, several State Foresters and the International Boundary and Water Commission (a US-Mexico intergovernmental agency) are each interested in removing salt cedar from these eco-systems. Another significant consideration is a need for the U.S. to somehow increase water flows entering Mexico. In the summer, salt cedar is usually the only green plant species in these arid Southwestern U.S. or Northern Mexican regions. Elimination of salt cedar from these rangelands could have dramatic positive effects on available ground and flowing water in these regions, especially in the dry summer months.

Other invasive species in this arid Southwestern United States are One-seed Juniper (*Juniperus monosperma*)) and Eastern Red-cedar (*Juniperus virginiana*). Vast grassy rangelands covered the Western United States prior to European settlement. As a native species, juniper had long been part of these ecosystems. However, juniper shrubs and trees were widely scattered throughout the rangelands or were normally situated in areas where shallow soils would not support grasses. Range grass flourished in many areas because the periodic natural range tires favored fast-growing grasses over shrubs. Conditions have changed over the last 75-1 50 years. The elimination of natural range tire from these eco-systems has been favorable for the spread of juniper. As the western United States became more settled, grazing by cattle and sheep and improved fire suppression methods provided ideal conditions for the encroachment of juniper into former grasslands throughout the area. Juniper now covers millions of acres in the southwestern United States. The spread of juniper also corresponds with an increase in ecological problems such as increased topsoil erosion, reduced groundwater, loss of native grasses and shrubs, and reduced stream flows. The heavy juniper stands have also significantly reduced biological diversity in native flora and wildlife populations. Native flora is critical for the grazing of cattle, sheep, and other domesticated livestock in many of these areas. Several estimates indicate that close to 10 million hectares may now need to have this juniper eradicated if we wish to restore native grasslands.

The fiber from shrubby exotic-invasive species removed for rangeland restoration currently has few commercial value-added uses. The problems associated with using these shrubby trees include high costs for harvesting and processing, low yield due to the size and crooked nature of the woody resource, and limited markets for such products. Accordingly, most shrubby exotic-invasive species currently have virtually no value for logging or pulp production. Further, they have only limited value as firewood or fence posts unless the resource is located close to an urban center capable of creating the demand for individual household use or for commercial energy production.

2. INTRODUCTION

This research program has been conducted in several phases. Our early work involved value-added uses for invasive woody species such as juniper. In our trials we developed technology for making juniper-plastic composites which have since found commercial use as highly durable and dimensionally stable outdoor signs.

In another phase, we studied Salt-cedar and made a limited series of 400- x 400-mm by 6.5-mm thick particleboards using salt-cedar wood and a mixture of wood and bark, both using a phenol formaldehyde resin at a 5% application rate. At the same time, we also made another series of wood-plastic composites using salt-cedar wood chips and a mixture of salt-cedar wood- and bark-chips mixed with recycled polyethylene at a 50/50% mixture which was then compression molded into 400- x 400-mm by 6.5-mm thick sheets.

We have also investigated using invasive woody species in wood-plastic composites made with conventional plastics processes such as injection molding and extrusion. Salt-cedar, Eastern red cedar, and juniper were compared to commercially used pine wood flour in injection-molded polypropylene (PP) composites.

Additionally, we have evaluated both salt-cedar and juniper fiber in combination with recycled polyethylene at a 50/50% mixture that was then extruded as 10 x 125-mm wood-plastic composite material. The intended use will be as exterior cladding (i.e., siding) over OSB sheathing used in traditional North American light-frame residential construction. Laboratory and field evaluation of the performance of these 10 x 125-mm wood-plastic composite siding materials is currently on-going.

3. PROGRAM OBJECTIVES

The objective of this research program is to evaluate and develop possible value-added uses for a variety of exotic-invasive woody species, such as salt cedar (*Tamarisk spp.*), One-seed juniper (*Juniperus spp.)* and Eastern red-cedar (*Juniperus virginiana*), each of which are encroaching into America's natural indigenous eco-systems and must be eliminated.

4. PROJECT DESCRIPTIONS AND DISCUSSION

4.1 Development of compression molded juniper/PP composite panels to make wood-plastic composite signs

In an effort to address value-added uses for invasive juniper, FPL worked to develop technology to produce highly durable and dimensionally stable Juniper/PP composite panels using melt-blending and compression-molding technology. These composite panels were made from 50% whole-tree juniper and 50% recycled PP.

The One-seed juniper had been cut from the rangelands in central New Mexico where it is causing problems with the ecosystem, through depletion of the ground water and reduction of grazing lands for cattle. The entire juniper tree was chipped by passing the trunk, branches, bark and needles through a tree chipper. Because the resulting chips were still too large to use to make the desired juniper-PP composites panels, the chips were further reduced in size in a hammer mill that reduced the particle size down to the size of fine sand.

The PP was a post-industrial material that was a byproduct from a company manufacturing small plastic balls. This waste PP was a granulated like material, again very similar to fine sand, resulting from a machining operation on the plastic balls during their production process. This recycled waste PP was then used in producing our juniper/PP composite panels.

The juniper/PP composite panels were made by mixing the juniper and PP particles together and forming that mixture into a mat. Forming was done by pouring mixed juniper and PP particles into a forming box that was placed on a metal plate. The forming box was then removed and another metal plate was placed on top of the mat. The metal plates, with the mat between them, were then placed in a hot press at 188°C and hot-pressed for 15 min. The pressure was about 2 MPa. The heat caused the plastic to melt and the pressure densified the mat into a board. The boards were then cooled by running 15°C water through ports within the press-platens for 15 min, which allowed the plastic to harden before the press was opened.

This work has now been commercially marketed by P&M Plastics (http://www.altree.com), a small business in New Mexico. They now use this concept and technology to make wood-plastic composite signs for use on National Forests and for other outdoor uses (Fig. 1).

4.2 Preliminary evaluation of compression molded salt cedar (*Tamarisk spp.*) biocomposites using both thermoset and thermoplastic binders

Salt cedar is a non-native, invasive species in the arid Southwest. It grows as a small bushy plant in creek beds and sucks up large amounts of ground and flowing water. FPL was recently contacted by the International Boundary and Water Commission (IBWC) which is a cooperative Mexican-US agency considering issues related to a need for the US to somehow increase water flows into to Mexico. The IBWC was interested in developing new value-added uses for salt cedar fiber in an attempt to help defray the cost of removing this exotic-invasive species.

We believe this salt cedar fiber may have potential in several composite products. Several examples of composite materials that could be explored are particleboard, medium-density fiberboard, wood-plastic composites, ADA-accessible playground fiber or even erosion mats. It is hoped that industrial collaboration and cooperative development may follow if a few innovative new value-added products could be shown in the laboratory to show potential.

The salt cedar material was received at FPL as mostly 25-to-64-mm diameter twigs, with bark and foliage still attached. We separated the bark-on material into two groups and removed the bark by hand on one group. We then hammer-milled both groups of material into particles capable of passing through a 5- x 5-mm screen. We then divided both groups of screened chips into two more groups. Two groups were only salt cedar wood and two groups were salt cedar wood and bark. In each of these one group was made of 95% salt cedar and 5% phenolic resin and the other group was 50% salt cedar and 50% high-density polyethylene (HDPE).

We made a series of three 405- x 405-mm by 6.4-mm thick particleboard panels using salt-cedar woody chips alone and using a mixture of woody- and bark-chips (six panels total). Both types of particleboard panels used a phenol formaldehyde resin applied in a rotary blender at a 5% by weight application rate and were pressed at 180°C for 250 s. We also made another series of three compression-molded biofiber-plastic composites using both salt-cedar wood chips and a mixture of salt-cedar wood- and bark-chips mixed with recycled and shredded high-density polyethylene at a 50/50% mixture (six total). These biofiber-plastic composite panels (Fig. 2) were then compression-molded at 188°C (370°F) and hot-pressed for 15 minutes. The pressure on the panel was about 2 MPa (300 psi). The heat caused the plastic to melt and the pressure densified the mat into a board. The hot boards were then cooled by running 15°C (60°F) water thru ports within the press-platens for 15 minutes, cooling the composite and causing the plastic to harden yielding 405- x 405-mm by 6.4-mm thick sheets.

Four groups of six specimens (two flexural test specimens per panel) for a total of 24 specimens were tested. The salt cedar-HDPE and salt cedar-particleboard composites were tested in flexure using the methods described in Method A-Center-point Flexure Test (ASTM D3043, 2003) except for flexural specimen size. The tested specimen sizes were nominally 25mm x 6mm x 90 mm and were tested in three-point “Center-point'' flexure on a span of 70 mm using a crosshead speed of 0.68 mm/min. The span-to-depth ratio was 11:1. Modulus of Elasticity and Rupture are shown in Table 1.

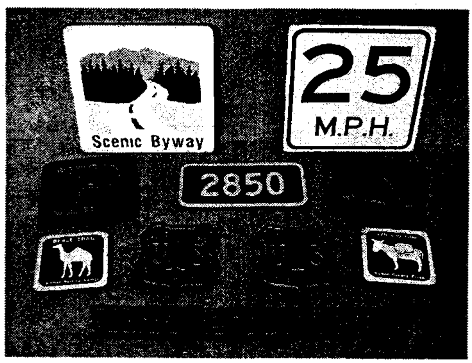

Figure 1. Examples of durable and stable outdoor sign made from compression-molded juniper-plastic composites using a 50/50% mixture ofjuniper fiber and recycled polypropylene.

Table 1. Summary of mechanical properties of compression-molded salt cedar particleboard and plastic composites.

Material	Max MOE (GPa)	Ave MOE (GPa)	Min MOE (GPa)	Max MOR (MPa)	Ave MOR (MPa)	Min MOR (MPa)
50% salt cedar Wood& Bark, 50% HDPE	2.105	1.903	1.461	23.532	19.930	14.544
50% salt cedar Wood, 50% HDPE	2.031	1.743	1.314	22.577	19.756	14.300
95% salt cedar Wood, 5% Phenolic Resin	1.770	1.574	1.434	14.020	12.758	11.285
95% salt cedar Wood & Bark, 5% Phenolic Resin	1.571	1.347	1.172	11.962	10.486	9.225

Because the processes were not optimized, the reported properties were low. However, these results clearly show that viable value-added composites can be made using salt cedar. We hope to expand this research program in the near future to further test and evaluate larger-size composite samples and more diverse combinations of salt-cedar materials and resins. Our results from this small-scale laboratory trial lead us to believe that wholesale or smaller scale substitution of salt-cedar for wood fiber is a viable possibility for traditional wood-based composites, such as particleboard. Other potential uses include composite sign materials (Fig. 1) and ADA-accessible playground surfaces (http://www.fpl.fs.fed.us/notices/highlights/playground_materials/playground_materials.html).

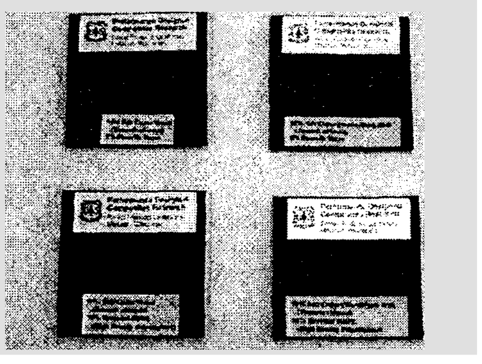

Figure 2. Two particleboards (top row) made using salt-cedar wood and a mixture of wood and bark, both using a phenol formaldehyde resin at 5% application rate. And two wood-plastic composites (bottom) using salt-cedar wood chips and a mixture of salt-cedar wood and bark chips mixed with recycled polyethylene at a 50/50% mixture and compression molded.

4.3 Invasive Species in Injection Molded and Extruded Composites

The rapid growth of wood-plastic composites (WPC's) in the U.S., especially in large-volume exterior products, provides an outlet for significant quantities of wood processing residues and has the potential to use invasive species as well. These composites are becoming increasingly popular with consumers because of their inherent durability without the need to paint or stain them. The greatest growth in WPC's has been in exterior building products such as decking and guardrails. We are investigating invasive species in both injection molded and extruded applications. Some preliminary results are described below.

Chips of salt cedar, One-seed juniper, and Eastern red-cedar were hammer-milled twice. The first pass used a 13 mm screen; the second a 0.8 mm screen. The largest particles were removed by sifting the wood flour using a screen with 0.4 mm openings. The wood flours were dried for at least four hours at 105°C. Each wood flour batch was blended with an injection-molding grade of PP in a 32 mm compounding extruder. For comparison purposes, commercial pine wood flour was also compounded with PP. Each blend contained 40% wood flour by weight. The compounded blends were then dried and test bars were molded using a reciprocating screw injection molder. Flexural (ASTM D790, 2003), tensile (ASTM D638, 2003), and impact tests (ASTM D256, 2003) were conducted and are summarized in Table 2.

Significant differences exist between the composites made from the different species. Particularly notable are the differences in modulus and unnotched impact energy and the trade-off between them. These preliminary tests demonstrate how different species can be used to influence the mechanical performance of composites. Further research on the use of fiber from exotic-invasive species in injection-molded composites seems promising and is ongoing.

Table 2. Summary of mechanical properties of injection-molded PP containing 40% of various wood flours. Values in parentheses are one standard deviation.

Wood type	Modulus (GPa)		Strength (MPa)		Izod impact (J/m)	
	Tensile	Flexural	Tensile	Flexural	Notched	Unnotched
Salt cedar	4.66 (0.8)	4.28 (0.07)	26.3 (0.4)	50.8 (0.5)	15 (2)	48 (5)
Pine	4.53 (0.14)	3.75 (0.19)	29.0 (0.6)	54.4 (1.2)	22 (2)	68 (4)
Juniper	3.83 (0.07)	3.30 (0.08)	31.0 (0.6)	58.3 (0.9)	18 (2)	75 (9)
Red Cedar	3.52 (0.15)	3.08 (0.26)	31.0 (0.1)	58.0 (0.2)	16 (2)	78 (9)

Use of invasive species is also being investigated in extruded composites. This is the most common method of producing WPC's in the U.S. and has been the area of greatest growth. Composites containing 50% wood flour made from pine, juniper. or salt cedar were produced. HDPE was used as matrix material. A commercial lubricant was also necessary as a processing aid to improve surface quality when producing the extruded composites. Six (6%) was used for pine composites. A higher level of 8% was necessary for salt cedar and juniper composites. We believe this is probably due to the fibers smaller particle size and larger surface area. A control and various combinations of coupling agent (to improve wood-HDPE bonding) and UV package (for UV stability) were produced to study the effect of these additives on durability during field tests.

HDPE, wood flour and additives were first compounded in our twin-screw extruder. The compounded pellets were then dried and extruded into 10 x 125-mm boards using our pilot-scale profile extrusion line (Fig. 3). This material is being attached as a siding material to the north and south sides of a test building at a field test site near our laboratory. Laboratory and field evaluations are currently ongoing.

5. FUTURE RESEARCH

Historically, much of our past wood-plastic composite research program has focused on the use of commercially available pine wood flour as a filler. Our current program has demonstrated the feasibility of manufacturing composites using flour from exotic and invasive species. The next steps are to learn to use fiber instead of flour and to characterize the unique characteristics of invasive species to determine how they affect our ability to process them and the durability of wood-plastic composites. This fundamental understanding will allow us to use invasive species to improve the performance of wood-plastic composites and generate a market for invasive species.

Because of the problems invasive species cause throughout the U.S., several U.S. government agencies are involved with programs involving the eradication, utilization, and replacement of invasive species. We hope to work together with the U.S. Bureau of Reclamation, U.S. Bureau of Land Management, U.S. Forest Service, and any interested State agencies to provide a total package for the investigation into uses and replacements for salt cedar and other exotic-invasive species. Fundamental research will allow us to determine whether salt cedar and other similar exotic-invasive species can have commercial value as new products.

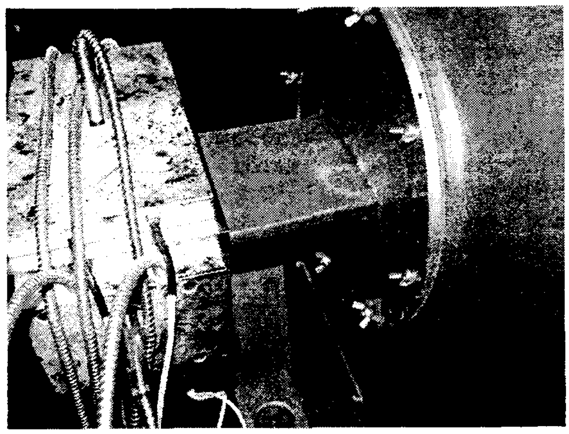

Figure 3. Profile extrusion of HDPE containing 50% salt cedar and additives. Composite melt exiting extruder die (left) and entering cooling tank (right).

6. SUMMARY

This report describes our recent work to develop innovative value-added biocomposites from bio-fiber from exotic-invasive species, such as salt cedar and juniper. The elimination or control of these problem species that are encroaching into natural indigenous eco-systems is a high-priority in the United States. The development of value-added uses will defray the high costs currently associated with removing these species from arid rangeland-type eco-systems. After restoration of less water-demanding native flora, other benefits will include enhanced surface- and ground-water availability across arid Western watersheds. We anticipate that further product development projects for adding value to bio-fiber obtained from these problem woody species will follow as additional innovative new value-added products are shown in the laboratory to show commercial potential.

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