Co-Composting of Steam-Pressed Scrim Lumber Process Water

Lauren Mangum H. Borazjani S. V. Diehl M. L. Prewitt
R. D. Seale R. C. Sloan

Abstract

Steam-pressed scrim lumber (SPSL) involves crushing small diameter trees into mats that are coated with adhesive and pressed into boards. Water from the crushing process contains a high biological oxygen demand (BOD), chemical oxygen demand (COD), and total suspended solids (TSS). This water must be remediated before it can be discharged into public water systems. A 6-month study was conducted to evaluate the effectiveness of co-composting of the process water with wood waste and chicken manure as a method of remediation. Wood waste from the SPSL pilot facility in Shuqualak, Mississippi, was ground into small particles. This material was composted using four treatments: with or without added manure plus deionized (DI) water or process water to adjust moisture content. The compost end products for all treatments were evaluated for relative toxicity, weight loss, maturity, and suitability as a container substrate to grow plants. Additional testing determined the toxicity of compost leachate and evaluated the effects on germination rates of sensitive plant species. Co-composting successfully reduced the bulk and toxicity for all treatments. Treatments containing manure and process water showed over 90 percent emergence rate of sensitive seeds by Day 90. The manure amendments were comparable to the commercial greenhouse substrate in growth. Thus, a bio-based value-added medium that is nontoxic and suitable for potting mix was produced from SPCL wastes, remediating the process waste.

Composting wood residues is recognized as a value-added process with growth potential in Mississippi (Borazjani et al. 2004). According to the 1997 US Census data, there were more than 890 wood product manufacturing facilities in Mississippi. These facilities produce several million tons of waste every year, and less than 75 percent of this waste is used for energy or other economical purposes (Borazjani et al. 2004). The demand for high-quality, construction-sized wooden beams has outpaced reforestation, and fast-grown timbers do not provide the quality beams necessary for construction purposes. A new method for manufacturing lumber from small diameter trees by crushing and reforming with adhesives and steam pressing is being developed to produce structural quality timbers. This process involves an initial crushing process, which yields long fibers of wood called scrim, some of which is unusable and must be disposed. The initial crushing and the steam press process also yield a water effluent that contains a high concentration of organic material, wood extractives, and fibers. This effluent water is the main concern for disposal because it has a high biological oxygen demand (BOD), making disposal as a hazardous waste very costly. BOD is a measurement of the rate at which the available oxygen in an aqueous environment is depleted by microorganisms. Current methods of treating wastewater with a high BOD are aerated ponds, bioreactors, and coagulation and flocculation followed by filtration (Ali and Sreekrishnan 2001, Huang et al. 2004, Pokhrel and Viraraghavan 2004). These processes are costly, and disposal of spent filtrate or filter cakes produced by flocculation and coagulation remains an issue. A new method of treatment that would allow for the timely discharge of treated water into the environment is necessary.

A viable alternative treatment of waste products is co-composting. Composting is the aerobic biodegradation of organic material into stable, humus material by microorganisms at elevated temperatures. Composting reduces the overall volume and toxicity of waste products, yielding a valuable, nutrient-rich product that can be used as a soil amendment (Borazjani et al. 2000). Co-composting of forest products wastes, such as wood waste from the furniture

---

The authors are, respectively, Graduate Research Assistant, Professor, Professor, Research Assistant Professor, and Professor, Forest Products Dept. (leh101@msstate.edu, hborazjani@cfr.msstate.edu, sdiehl@cfr.msstate.edu, lprewitt@cfr.msstate.edu, dseale@cfr.msstate.edu); and Research Horticulturist, North Mississippi Research and Extension Center (rcsloan@ext.msstate.edu), Mississippi State Univ., Mississippi State. This article is approved for publication as Journal Article FP-551 of Forest & Wildlife Research Center, Mississippi State University, Mississippi State. This paper was received for publication in December 2009. Article no. 10716.

Forest Prod. J. 60(7/8):632–639.

manufacturing industry, preservative treated wood waste, and the composting of wastewater sludge from the paper and pulp industry, has been previously conducted (Wiltcher et al. 2000, Marche et al. 2003, Borazjani et al. 2004). Additionally, the positive effects of co-composted paper and pulp industry sludge and different residuals on soil properties and cereal yields have been documented (Sippola et al. 2003). Co-composting of wastewater and wood waste generated on site, combined with poultry manure from nearby broiler houses, provides a simple and cost-effective solution to problems posed by these three waste materials. Poultry manure was chosen as a nitrogen source because it is in abundant supply in Mississippi as a waste product. In 2007, Mississippi produced 824 million broiler chickens (*Gallus gallus domesticus*; USDA 2008). According to estimates of 1.5 kg of manure per bird per year (Moore et al. 1998), this yields more than 1.26 million metric tons of broiler manure for the 2007 production year. Because these three wastes contain only natural materials and chemicals, biological decomposition through composting should lead to an end product that is stable and can be sold as a soil additive or container media.

Methods

Characterization of process water

An initial sample of process water was collected from the steam-pressed scrim lumber (SPSL) pilot facility in Lauderdale County, Mississippi. This initial sample was diluted to an approximately 1-to-4 ratio using distilled water. Two identical samples of this initial dilution were collected and sent to an off-campus environmental testing facility to determine the BOD (US Environmental Protection Agency [EPA] method 405.1), chemical oxygen demand (COD; EPA method 8000), total suspended solids (TSS; EPA method 160.2), and total nitrogen (N) content (EPA method 351.4). Metal content was determined at this time. In order to further characterize the process water, additional testing was conducted to determine the glucose content of undiluted water. High-pressure liquid chromatography analysis for glucose content was conducted at the Mississippi State University (MSU) Chemistry Laboratory.

Compost setup

Chicken manure was used as a nitrogen source in the composting process. The manure was collected from the Poultry Science Department at MSU. The manure was obtained from caged chickens and contained little sawdust or bedding material. The manure was spread in a dry, covered area to allow for some moisture evaporation over 48 hours. After the drying period, samples were taken from the manure to determine the overall moisture content, which was 50 percent by weight.

Wood waste was collected from the pilot plant. This material was ground into approximately 5-mm particles. The moisture content of the wood waste was determined to be approximately 10 percent by weight. These measurements were needed to ensure accurate calculation of weight loss on a dry weight basis. Before the experiment began, additional process water was collected from the pilot plant. When the process water was added to the composting replicates it was diluted 1:1 with deionized (DI) water to lower the COD level.

Compost experiment design was a modified version of that used by Hatten et al. (2009). Twelve 30-liter cans were used for the experiment. Five 3-cm holes were drilled into the bottom of each can, and a layer of gardener's fabric was placed on the bottom of each can to prevent compost from falling through the holes. On Day 0 of the composting experiment, each can was weighed and the weight was recorded. Five kilograms of test material was weighed and added to each can, and 0.45 kg of chicken manure was added to six of the containers. The compost was thoroughly mixed, and 3 liters of water, either distilled or a 1:1 dilution of distilled water and process water, was added to each can. The cans were weighed again and set in a permanent location.

The treatments were as follows:

Treatment 1. Test material plus DI water.

Treatment 2. Test material plus only process water.

Treatment 3. Test material plus DI water plus 10 percent poultry litter (dry weight basis).

Treatment 4. Test material using process water plus 10 percent poultry litter (dry weight basis).

A completely randomized design with three replications for each treatment was used in this study. The compost treatments were placed outside and were aerated by hand once per week to ensure an aerobic environment. Moisture content was assessed weekly and was adjusted to keep the moisture levels between 50 and 65 percent using either distilled water or a 1:1 dilution of process water and distilled water. Samples were taken at 45-day intervals. At each sampling interval, samples were tested for pH, toxicity, compost maturity, and moisture content.

Aeration

Aeration of all treatments and replications was performed weekly by physically turning the samples by hand to ensure thorough mixing. Aeration of the compost ensured that the moisture content remained around 50 to 65 percent within each container to prevent anaerobic conditions. Moisture content was adjusted through rain fall or by adding either distilled water or a 1:1 mixture of distilled water and process water. Compost cans were aerated once or twice per week depending on precipitation conditions or how much water was added.

To ensure that treatments were composting properly, temperatures were monitored on and between sampling days. Pile temperatures above that of the ambient air temperature served as an indicator of the composting process. After the thermophilic stage of composting, approximately 160°F, the pile should be significantly warmer than the surrounding air.

Sampling

At each sampling period, each container was thoroughly mixed before sampling was conducted to ensure a homogenous sample was obtained. Before collecting samples, each compost container was weighed to determine the overall weight loss of the compost. Samples weighing 150 g were collected from each container. Small subsamples were taken for moisture content and toxicity. Percent moisture content was determined for each sample and then extrapolated to determine the overall moisture content of the pile.

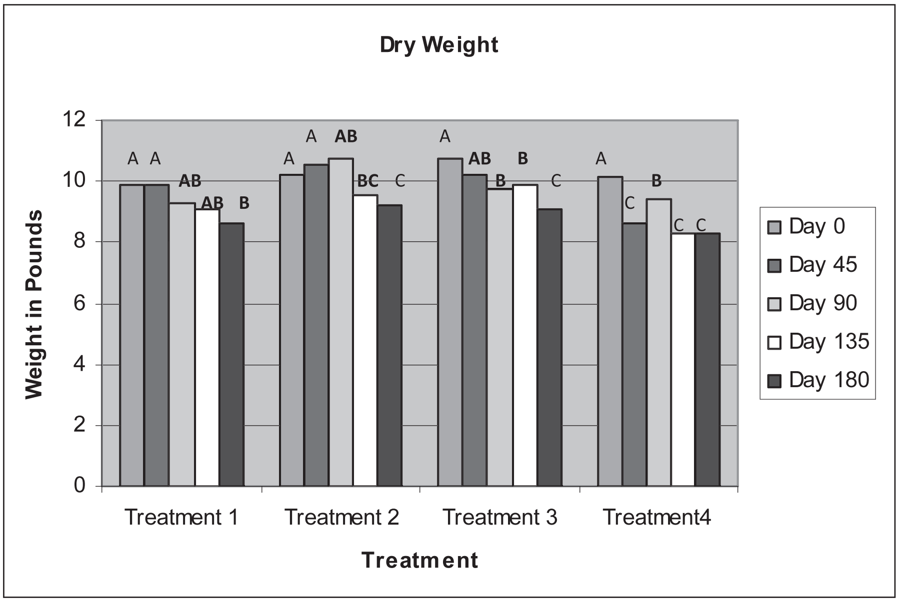

Figure 1.—Reduction in dry weight at each sampling period for all treatments. Columns with different letters indicate a significant difference between weight loss at the $\alpha = 0.05$ level of significance.

Toxicity

Toxicity was determined using the Microtox technique, which has been shown to be effective at measuring toxicity of compost leachates (Kapanen and Itavaara 2001). Eighteen milliliter aliquots of distilled water were added to 12 clean, 50-ml culture tubes. To each tube, 2 g of compost sample was added. These samples were vortexed, followed by sonication in a water bath for 10 minutes. The samples were then placed in the refrigerator overnight. After refrigeration, each sample was centrifuged at 50,000 rpm for 20 minutes with the acceleration of 167,700 × g. The pH of each sample was measured following the Microtox protocol and accordingly adjusted to a range of 6.0 to 8.0. Cuvettes were prepared with 0.05 g NaCl. Two and one-half milliliters of each sample was mixed and properly distributed among prepared cuvettes. Toxicity readings were taken for each sample, and toxicity was determined as more than a 5 percent difference between the control and leachate readings.

Nitrogen and carbon analysis of compost

On Day 0 and Day 180 sampling periods, samples of approximately 40 g were collected for total nitrogen and carbon analysis and sent to an environmental testing facility. EPA method 351.4 was used for total Kjeldahl nitrogen. Percent carbon was determined through measurement of volatile and suspended solids (EPA method 160.4).

Emergence and greenhouse test

These tests were conducted to determine whether the composted material is matured and does not have any adverse effects on seed emergence and growth of a transplanted ornamental (pansy, *Viola tricolor* subsp. *hortensis*). The compost maturity was determined using a modified radish seed emergence test, based on the maturity tests described by Florida's Online Composting Center (Florida Composting 2009). The radish test shows how the compost performs as a soil additive and whether it is harmful to the plants. Radishes (*Raphanus sativus*) are very sensitive and need specific growth parameters, so if the compost affects those parameters in a negative way the test allows for the visualization of these negative effects.

In addition to the radish test, mature compost was evaluated as a suitable container substrate in combination with industry standard bedding plant media. In a 4-week study, pansy plugs were planted in the finished compost products along with a control containing standard potting media. Five treatments of the greenhouse test contained six replicates. Treatments were arranged in a completely randomized order inside a greenhouse. The plants were fertilized with commercially available fertilizer tailored to

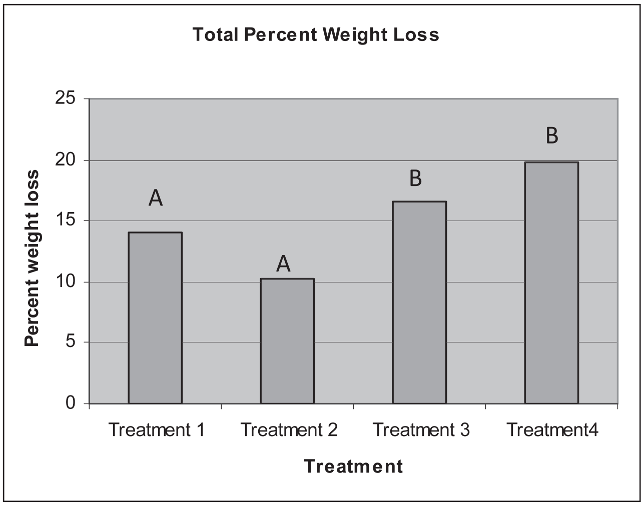

Figure 2.—Percent weight loss on Day 180. Columns with different letters indicate a significant difference between weight loss at the $\alpha = 0.05$ level of significance.

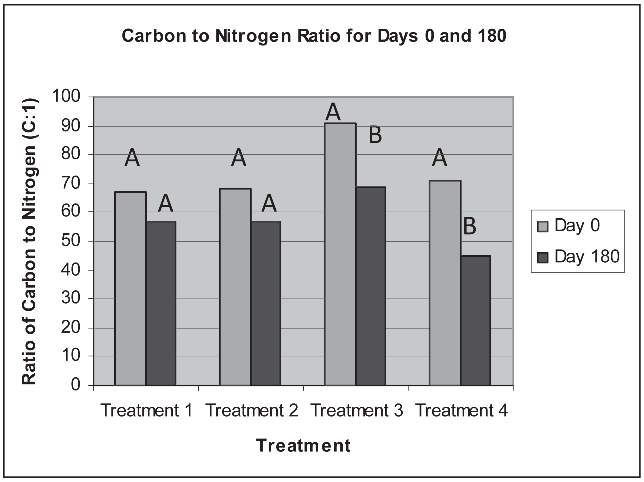

Figure 3.—Change in carbon-to-nitrogen ratio. Carbon to nitrogen is represented at C:1. Columns with different letters indicate a significant difference in C:N at the $\alpha = 0.05$ level of significance.

the nutrient requirements of pansies. The timing of the composting study resulted in a need to grow pansies during cold weather. Pansy pots were placed on heated mats to encourage root growth. At the end of the 4-week period, plant measurements of height and width, weight, and vigor were taken to determine which treatments produced the largest plants.

Analysis of composting data

Weight loss, nutrient content, and toxicity results from the co-composting and greenhouse studies were statistically analyzed to determine significant differences among treatments. Mean comparisons were made using a least significant difference at the $\alpha = 0.05$ probability level by the Statistical Analysis System (SAS) using Duncan's multiple range analysis.

Results

Weight loss results

Weight loss is a good indicator of any composting process. Dry weight for each sampling period as well as percent weight loss results are summarized in Figures 1 and 2, respectively. There was significant weight loss for all treatments on Day 180 (Fig. 1). However for percent weight loss, there was no statistical difference when DI water was added versus process water. The addition of manure did significantly increase the amount of weight loss for Treatments 3 and 4 (Fig. 2).

Nitrogen and carbon analysis results

Most treatment replicates showed a drop in nitrogen concentrations from Day 0 to Day 180. Percent carbon decreased from Day 0 to Day 180 for all treatments. The C:N ratio is highly important in horticultural and agricultural practices. Ratios below 45 are considered very suitable for normal plant growth. Overall, the C:N ratio for all treatments was reduced from Day 0 to Day 180. Only the two treatments with manure addition showed a significant decrease in C:N ratio (Fig. 3). Treatment 4 amended with manure and process water showed the greatest decrease in C:N over the 6-month study. C:N ratios for all replicates are detailed in Table 1.

pH results

All treatments were slightly acidic at the start of the tests and gradually increased over the period of composting (Table 2).

Toxicity screening

Composting resulted in a decrease in the overall toxicity of all treatments. In all treatments, the compost was significantly less toxic by Day 45, showing at least a 50 percent drop in toxicity levels (Fig. 4). Statistical analysis of treatments showed that there was a significant difference in toxicity between Day 0 and all other

Table 1.—Percent carbon, percent nitrogen, and carbon-to-nitrogen ratios for Days 0 and 180.

	% carbon		% nitrogen		C:N	
Treatment and replicate no.	Day 0	Day 180	Day 0	Day 180	Day 0	Day 180
Treatment 1						
Replicate 1	40.5	22.48	0.66	0.38	61:1	59:1
Replicate 2	41	24.22	0.52	0.46	78:1	52:1
Replicate 3	40	20.75	0.64	0.35	62:1	59:1
Treatment 2						
Replicate 1	43	19.95	0.78	0.42	55:1	45:1
Replicate 2	37	23.77	0.63	0.36	59:1	63:1
Replicate 3	42	24.57	0.46	0.38	90:1	64:1
Treatment 3						
Replicate 1	43	25.2	0.49	0.35	87:1	68:1
Replicate 2	44.5	25.41	0.48	0.37	92:1	66:1
Replicate 3	47	27.09	0.5	0.36	94:1	75:1
Treatment 4						
Replicate 1	43	26.18	0.61	0.6	71:1	43:1
Replicate 2	46	29.63	0.59	0.78	78:1	38:1
Replicate 3	40	22.73	0.63	0.42	64:1	54:1

Table 2.—pH measurements for all treatments and sampling days.

Treatment and replicate no.	pH values Day 0	Day 45	Day 90	Day 135	Day 180
Treatment 1					
Replicate 1	5.55	5.6	5.63	5.8	5.46
Replicate 2	5.65	5.43	5.78	5.9	5.88
Replicate 3	5.32	5.52	5.82	5.75	5.66
Treatment 2					
Replicate 1	4.8	5.48	6.04	6.04	6.24
Replicate 2	4.93	5.62	5.7	6.08	6.27
Replicate 3	4.96	5.6	6	6.06	6.28
Treatment 3					
Replicate 1	5.3	6.86	6.74	6.74	7.26
Replicate 2	5.79	6.89	6.98	6.77	7.36
Replicate 3	5.86	6.83	7.16	7.32	7.4
Treatment 4					
Replicate 1	5.62	7.18	7.34	7.59	7.5
Replicate 2	5.05	7.4	7.42	7.45	7.41
Replicate 3	5.85	7.4	7.34	7.42	7.47

sampling periods. There was not a significant difference in toxicity within treatments between Day 90 and Day 180. The largest reduction in toxicity was observed in Treatments 3 and 4.

Plant germination rates

The compost was fully matured, as evidenced by good radish seed germination tests. By Day 180, all amendments showed seed germination rates of 100 percent, indicating a mature product (Table 3). Visual ratings of seedling growth, on a scale of 1 to 5 (5 being the best), showed improvement from Day 0 to Day 180 for Treatments 2, 3, and 4 but not Treatment 1 (Fig. 5). Treatments 3 and 4 (with the added manure) showed good improvement, with the most improvement in Treatment 4, which was amended with process water and manure. Treatments not amended with chicken manure yielded plants with aboveground growth that was significantly stunted. Radishes from all treatments had root structure length and vigor that was comparable to that of the potting mix control. Toxicity results, along with germination rate results, indicated that this toxic process water can be remediated over time.

Compost maturity results

All composting treatments reached a temperature of at least 110°F by Day 45. Temperatures above ambient were maintained until Day 90 of the composting experiment. After the 90-day sampling period, temperature stratifications

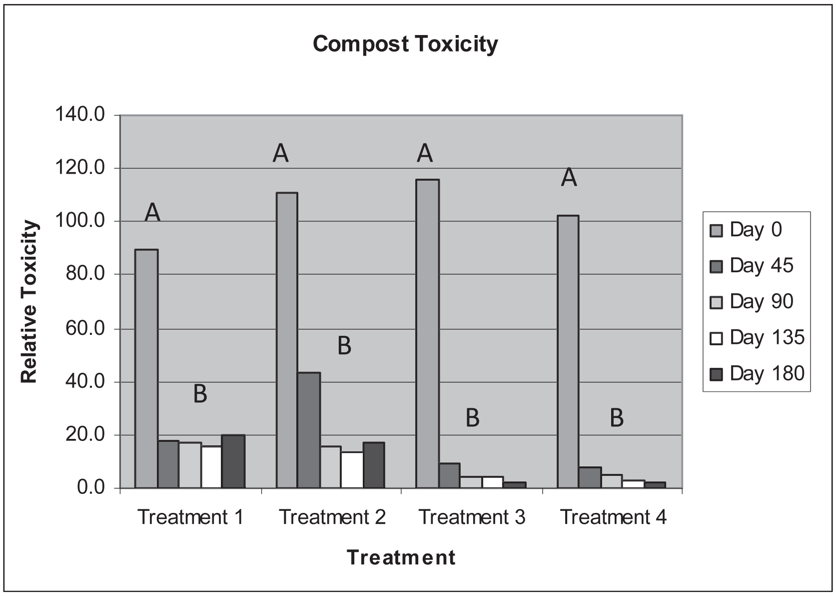

Figure 4.—Relative percent toxicity of compost leachate as compared with distilled water. Columns with different letters above them indicate a significant difference between toxicity measurements at the $\alpha = 0.05$ level of significance. "A" statistical grouping refers only to Day 0. All other sampling periods fall under the "B" statistical group, indicating no significant difference between all other sampling periods.

Table 3.—Percent seed germination rates during the 180-day study.

	Percent germination				
Treatment and replicate no.	Day 0	Day 45	Day 90	Day 135	Day 180
Treatment 1					
Replicate 1	96	92	100	100	100
Replicate 2	92	79	83	100	96
Replicate 3	79	79	92	83	100
Treatment 2					
Replicate 1	96	71	100	75	100
Replicate 2	71	88	96	92	100
Replicate 3	58	79	100	96	100
Treatment 3					
Replicate 1	83	79	100	100	100
Replicate 2	92	92	88	100	100
Replicate 3	67	96	100	96	100
Treatment 4					
Replicate 1	75	92	100	100	100
Replicate 2	83	75	88	100	100
Replicate 3	100	100	100	100	100
Control potting mix	100	100	100	100	100

within the treatments containing manure were evident. Even so, the composting treatments only partially composted because the treatments did not reach thermophilic temperatures. This partial composting did not affect maturity or cause increased toxicity levels, but it interfered with the formation of more humus material. It is possible that unusually high rainfall levels, a result of hurricane activity, retarded the later stages of composting and prevented complete composting.

Greenhouse results

Results of the subjective visual rating system for the growth of pansies in each treatment as well as a control of commercial plant media are detailed in Figure 5. The results of the greenhouse study indicated that composted material alone could support plant growth, as shown by weight of plant biomass in Figure 6. The averages of the visual ratings indicate that none of the compost treatments performed as well as the control potting mix.

It is possible that the greater average biomass of plants grown in composted material can be attributed, to some extent, to composted material clinging to the roots of some plants. The composted material was difficult to remove without also removing sections of root material, and some compost had to be left attached. This compost was then dried with the plants and weighed along with plant biomass. Therefore, no conclusion can be made on the treatment impact on the biomass weight. Despite higher average weight of plants grown in composted materials, visual ratings of the pansies on the basis of height, vigor, and root health clearly indicated that the compost treatments did not perform as well as standard potting media. Figures 7a

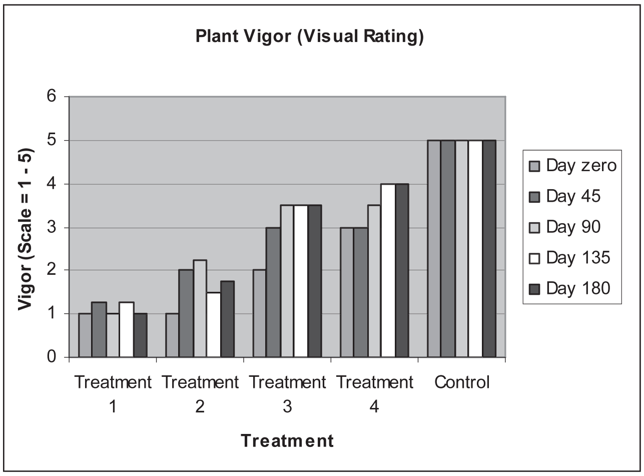

Figure 5.—Plant vigor ratings for each treatment and sampling period. Plants were rated on a scale of 1 to 5 (5 being the best).

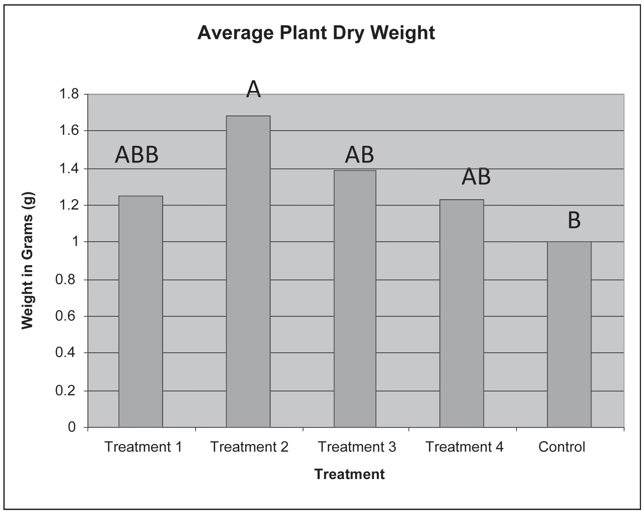

Figure 6.—Average plant dry weight. Columns with the different letter groupings indicate a significant difference between means at the $\alpha = 0.05$ level of significance.

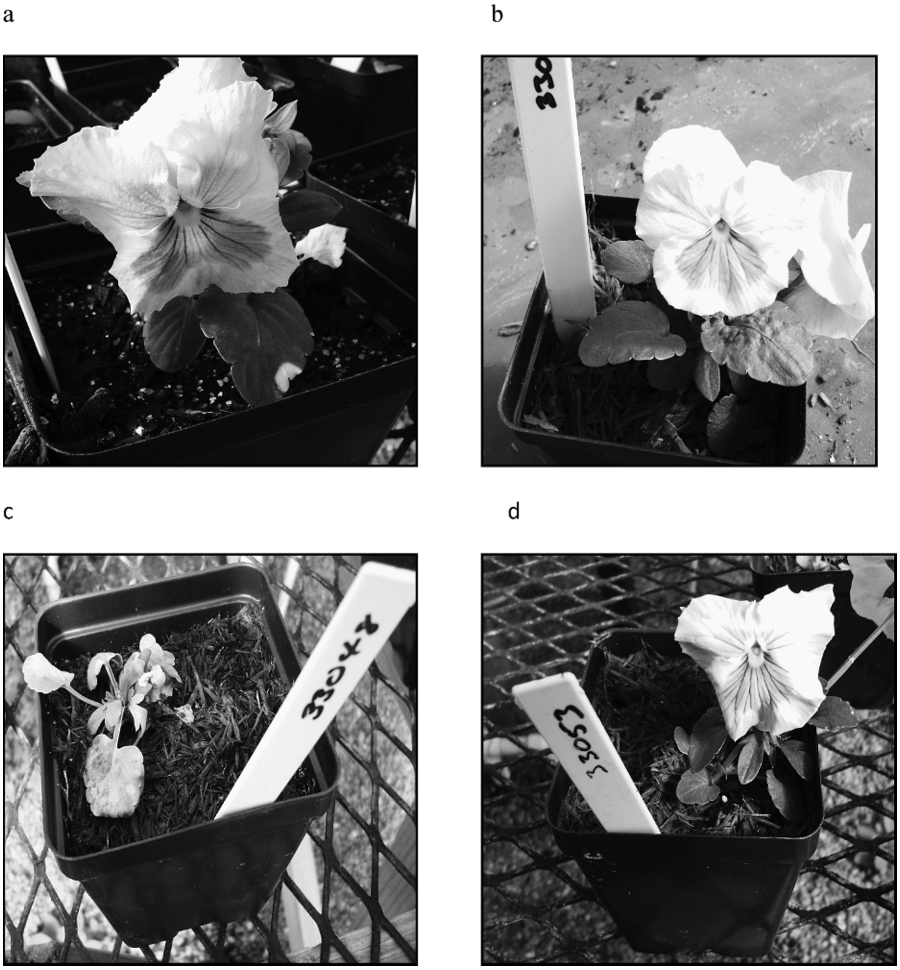

Figure 7.—(a) An example of a control grown in standard potting mix. (b) A replicate from Treatment 3 compost. (c) An example of a replicate from Treatment 2. (d) An example of a replicate grown in compost from Treatment 4.

through 7d illustrate the different appearances of plants grown in potting media and selected treatment replicates. In all treatments, at least a few replicates flowered and established extensive root systems. However, none of the plants grown in compost treatments had root systems, leaves, or flowers as pronounced as that of the control.

Conclusions

This study found that SPSL process water has a high BOD, COD, and TSS (Table 4). Further characterization of the process water determined that metal content was not a major concern because most metals, aside from Zn, were present in low concentrations (Table 4). Co-composting offers a potential solution to the problems that may be presented by the SPSL manufacturing process. This study has shown that it is possible to co-compost two wastes from the same facility, wood residues and process water, with chicken manure to produce a mature product. These tests show that composting lowers toxicity and improves the germination rates and the addition of poultry manure increases the rate of improvement. Radish seed germination tests as well as greenhouse tests have indicated that the mature compost is a nontoxic potting media that offers nutrients to plants. The material did compost as it did reach

Table 4.—Background analytical results of steam-pressed scrim lumber process water.[a]

Chemicals	Results (mg/liter)
Arsenic	<0.002
Beryllium	<0.001
Cadmium	0.0044
Chromium	0.034
Copper	0.21
Lead	0.0092
Nickel	0.032
Selenium	<0.002
Silver	<0.002
Antimony	<0.006
Thallium	<0.01
Mercury	<0.0002
Glucose	ND
BOD	>5,190
COD	>6,135
TKN	>10
TSS	>235

[a] ND = not detected; BOD = biological oxygen demand; COD = chemical oxygen demand; TKN = total Kjeldahl nitrogen; TSS = total suspended solids.

sustained temperatures of approximately 120°F to 130°F. As such, the composted material might be useful as a soil additive that could be effectively mixed with topsoil to produce a suitable potting media. The composted material could potentially be popular with nurseries and sold to farmers as a bulking agent and nutrient source, adding revenue to the future facility.

More studies are needed to determine optimal ratios of process water, wood waste, and chicken manure to create a product that is better or comparable to commercial potting media.

Literature Cited

Ali, M. and T. R. Sreekrishnan. 2001. Aquatic toxicity of pulp and paper mill effluents: A Review. *Adv. Environ. Res*. 5:175–196.

Borazjani, H., S. V. Diehl, and K. Brasher. 2004. Composting research targets forest products and poultry industries. *BioCycle* 45(5):42–44.

Borazjani, H., S. Diehl, and H. A. Stewart. 2000. Composting of wood wastes: Plywood and sawmill residue. FWRC-FP-188. Forest and Wildlife Research Center, Mississippi State University, Mississippi State. *Research Advances*. Vol. 5. No. 1. 4 pp.

Florida's Online Composting Center. 2009. Compost maturity tests (modified). http://www.compostinfo.com/tutorial/MaturityTests.htm. Accessed March 9, 2011.

Hatten, N. R., H. Borazjani, S. Diehl, and L. Prewitt. 2009. Effects of composting on removal of nitrogen, phosphorus, and potassium from sawdust amended with chicken litter. *Compost Sci. Utilization* 17(3): 166–172.

Huang, W. H., C. Y. Poynton, L. V. Kochian, and M. P. Elless. 2004. Phytofiltration of arsenic from drinking water using arsenic-hyper-accumulating ferns. *Environ. Sci. Technol*. 38:3412–3417.

Kapanen, A. and M. Itavaara. 2001. Ecotoxicity test for compost application. *Ecotoxicol. Environ. Saf.* 49:1–16.

Marche, T., M. Schnitzer, H. Dinel, T. Pare, P. Champagne, H.-R. Schulten, and G. Facey. 2003. Chemical changes during composting of a paper mill sludge-hardwood sawdust mixture. *Geoderma* 116: 345–356.

Moore, P. A., T. C. Daniel, A. N. Sharpley, and C. W. Wood. 1998. Poultry manure management. *In:* Agricultural Uses of Municipal, Animal, and Industrial Byproducts. Agricultural Research Service Conservation Research Report No. 44. R. J. Wright, W. D. Kemper, P. D. Milner, J. F. Power, and R. F. Korcak (Eds.). US Department of Agriculture, Washington, D.C. Chap. 3, pp. 60–77.

Pokhrel, D. and T. Viraraghavan. 2004. Treatment of pulp and paper mill effluent—A review. *Sci. Total Environ*. 333:37–58.

Sippola, J., R. Makela-Kurtto, and P.-R. Rantala. 2003. Effects of composted pulp and paper industry wastewater treatment residuals on soil properties and cereal yield. *Compost Sci. Utilization* 11(3): 228–237.

US Department of Agriculture (USDA). 2008. Map of broiler chicken production by state. http://www.nass.usda.gov/Charts_and_Maps/Poultry/brlmap.asp. Accessed March 9, 2011.

Wiltcher, D., H. Borazjani, S. V. Diehl, and H. A. Stewart. 2000. Composting of phenolic-bonded softwood plywood waste. *Forest Prod. J*. 50(10):82–85.