THE POWER OF HUMUS

COMPOST KEY IN GRAVEL PIT RECLAMATION

solid wastes annually. Campus renovation and development projects generate another 50,000 tons of clean fill, mainly soil and concrete/asphalt rubble. Since 1993, Purdue has been working on a management program to find beneficial uses for these materials.

RECLAIMING THE QUARRY

Using these residuals was made relatively easy with the opportunity to reclaim and develop a sand and gravel quarry, which lies to the southwest of the campus. This quarry had been mined for most of the last century, until its reserves were finally depleted in 1998. More than a decade ago, Purdue made arrangements to acquire this land for future development. While many universities have limited land available for campus expansion, this land provides an opportunity for Purdue to nearly double the size of its campus. However, the land presents significant development challenges, with its numerous deep holes, large ridges of spoil material, lack of topsoil and poor drainage. With the help of academic researchers, grants from state agencies, and partnerships with local municipalities and industries, Purdue is demonstrating that waste management and land reclamation can be mutually beneficial.

Development of the Purdue gravel pit will require large volumes of suitable structural fill material, gravel and stone for road construction, and topsoil suitable for campus lawns and shrubbery beds. Gravel and stone are currently "manufactured" by recycling concrete rubble. Since 1996, Purdue has stockpiled its concrete from demolition and hired companies to crush it, making gravel and stone for road and parking lot construction. Each year, about 8,000 tons of gravel and 2,000 tons of stone have been made for less than the commercial cost of similar materials.

The availability of suitable backfill material has largely been dependent on construction projects on or near campus. In 1993, Purdue began evaluating the use of coal ash as structural fill. The Purdue Wade Power Plant generates 30,000 tons of fly ash, bottom ash and fluidized bed combustion (FBC) ash each year. Using a research grant from the Indiana Department of Commerce and matching funds from a local industry (A.E. Staley), Purdue constructed an embankment that is now

As part of the SoilerMaker operation, pharmaceutical biosolids, leaves, straw, tree limbs and coal ash are composted at a site near the Purdue University campus.

Purdue University is involved in its largest planning effort since the original campus master plan was developed in the 1920s. A large sand and gravel quarry adjacent to the main campus in West Lafayette, Indiana is envisioned as the home for a variety of future campus facilities. A unique feature of the reclamation and development of this area (as large as the current main campus) will be utilization of large amounts of non-hazardous waste materials in road construction, backfill and topsoil building.

With a population of 36,000 students on its main campus, Purdue operates a recycling program similar to many municipalities in the United States. The Physical Facilities Department collects paper, cardboard, aluminum, glass, plastic, and wood pallets from campus buildings and recycles these materials. Although the volume of recyclables (about 1,300 tons/year) represents a significant fraction (19 percent by volume) of institutional waste, it is small by comparison with the volume of yard trimmings, animal bedding, coal ash and clean fill also produced on campus. The groundskeepers, the veterinary hospital and the Purdue Wade Power Plant generate about 40,000 tons of nonhazardous

As part of the Purdue University land management program, feedstocks generated on campus are used to make compost for revegetation.

Jody K. Tishmack
part of a road leading from campus into the gravel pit from 150,000 tons of coal ash, half of which was FBC ash. Engineering tests and ground water monitoring were conducted to determine the stability of these materials and their impact on the environment. Based on the success of this project, Purdue now utilizes most of its coal ash as well as some from A.E. Staley for backfill, in addition to the "clean fill" or natural soil that results from campus and local excavation projects. Structural fill has been successfully built with fly ash and bottom ash, but use of FBC ash is problematic. The formation of hydrated minerals in the FBC ash causes swelling and expansion in the compacted fill.

### SoilMaker Operation

Topsoil resources are precious, and it was apparent that it would be very expensive to acquire what was needed to cover 500 acres with a one-foot layer (about 500,000 tons). Historically, natural topsoil was obtained for campus maintenance and construction projects by stripping nearby farmland. In 1995, the Purdue Physical Facilities Department received a second grant from the Indiana Department of Commerce to develop a commercial application for manufacturing topsoil from waste materials. The research project was done in collaboration with Eli Lilly and Co., a local pharmaceutical manufacturer. Working together with researchers from the Purdue agronomy and civil engineering departments, and soil scientists from the U.S. Department of Agriculture, an operation was developed to utilize coal ash, pharmaceutical biosolids, municipal yard trimmings and animal bedding to make a variety of products including compost, mulch, agricultural lime and topsoil. A pilot mixing program followed the laboratory and field-scale testing in 1997. In 1999, Purdue and Eli Lilly opened the full-scale operation at Purdue and affectionately called it "SoilerMaker" after the Purdue Boilermakers.

Personnel in the Physical Facilities Grounds Department currently run the SoilMaker operation, which utilizes several different types of materials as feedstock for composting. The volumes and sources of these materials are given in Table 1.

### Table 1. Source and volume of feedstock materials used for composting at Purdue University

<table>
<thead>
<tr>
<th>Material</th>
<th>Sources</th>
<th>Volume/Year (tons)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coal ash</td>
<td>Purdue</td>
<td>600</td>
</tr>
<tr>
<td>Fermentation biosolids</td>
<td>Eli Lilly &amp; Co.</td>
<td>1,400</td>
</tr>
<tr>
<td>Leaves</td>
<td>Lafayette, West Lafayette, Purdue</td>
<td>8,000</td>
</tr>
<tr>
<td>Straw (animal bedding)</td>
<td>Purdue Veterinary Hospital</td>
<td>500</td>
</tr>
<tr>
<td>Tree limbs (brush)</td>
<td>Purdue, West Lafayette</td>
<td>3,500</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>15,000</td>
</tr>
</tbody>
</table>

Composting is a rapidly growing industry and a necessity in today's market. Ag-Bag Environmental, the recognized leader in composting solutions, offers a simple and affordable way to compost all types of waste, including wood, food, yard and mixed organics from industrial by-products. This complete system is 1/3 more space efficient, less expensive than other methods and reduces transport costs. The Ag-Bag composting system is an in-vessel system that is proven to control leachate and odors. Call today and turn waste into wealth!

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Windrow and static pile composting methods can be mixed directly with the other feedstocks. Experiments have shown that the calcium hydroxide (hydrated lime) in the FBC ash quickly forms calcium carbonate due to the conditions in the compost pile (elevated temperatures, high vapor pressure and high carbon dioxide concentrations). Although water extracts taken from the starting materials often have a pH as high as 12, within five to ten days the pH drops to 8. One would not expect composting to proceed rapidly in a material with a pH of 12. Therefore, it is not likely that these organic materials are all in direct contact with the ash. Surfaces of the wood chips, straw, and leaves provide microenvironments upon which bacteria and fungus thrive. Monitoring of the compost piles indicate that the mixture rapidly attains thermophilic temperatures (140°F to 165°F) within 24 to 48 hours.

**ADDRESSING ODOR CHALLENGES**

The composting operation suffered from odors generated in the decomposition of the biosolids. The biosolids are produced from an anaerobic fermentation process used to manufacture an antibiotic. The composition of the biosolids and other feedstocks are provided in Table 2. The organism that produces the antibiotic is grown on a food substrate containing several raw ingredients including corn gluten, fish meal, lard oil, peanut meal, soybean floor, soybean meal and soybean oil. During our field trial and pilot mixing operation, several dozen complaints were received about the odors coming from the composting site. Complaints of "dead body" odors suggested the presence of compounds such as cadaverine and putrescine.

In April 1999, six months after the first full-scale site was opened, operations had to be suspended and relocated to a new site about one and a half miles further away from campus. During the development and construction of this new site, work continued on recipe design and compost methods since an enclosed facility with air scrubbers was not economically feasible. It was found that windrow turning generally increased odor production because the volatile compounds were dispersed into the air along with the steam.

One alternative that worked reasonably well to decrease odors was to mix the biosolids with wood chips and compost them in a static pile. These piles were covered with leaves to act as a biofilter and were not disturbed until odors were diminished. The decomposition of the biosolids still produced odors but since the piles were not disturbed, the odors did not travel further than 30 to 50 feet. After six to eight weeks, the biosolids and wood chips were mixed with straw and leaves and finished as windrows.

Although there were fewer odor complaints from neighbors, visitors to the site still noticed the odors. There were also several drawbacks to this composting method. The process increased the amount of material handling required and lengthened the composting time by more than two months. The windrows took longer to reach thermophilic temperatures, the rows didn’t maintain this temperature for more than a few weeks and the compost took longer to finish out. In addition, the finished quality of the compost was not as good because there was a higher concentration of larger wood chips remaining in the compost.

In the spring of 2000, Purdue began experimenting with BAT 506, a liquid odor control product developed by Global Odor Control Technologies. It was tested in two

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**Table 2. Composition analysis of feedstock (as is basis)**

<table>
<thead>
<tr>
<th>Variable Measured</th>
<th>Coal Ash</th>
<th>Fermentation (Animal Limbs)</th>
<th>Biosolids</th>
<th>Leaves</th>
<th>Straw (Animal Bedding)</th>
<th>Tree Limbs</th>
<th>Brush</th>
</tr>
</thead>
<tbody>
<tr>
<td>Density (lbs/yd³)</td>
<td>1790</td>
<td>1585</td>
<td>489</td>
<td>169</td>
<td>623</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Solids (%)</td>
<td>89.5</td>
<td>23.9</td>
<td>38.0</td>
<td>47.4</td>
<td>52.6</td>
<td>47.4</td>
<td></td>
</tr>
<tr>
<td>Moisture (%)</td>
<td>10.5</td>
<td>76.1</td>
<td>62.0</td>
<td>52.6</td>
<td>47.4</td>
<td>52.6</td>
<td></td>
</tr>
<tr>
<td>Inert Matter (%)</td>
<td>0.6</td>
<td>0.6</td>
<td>0.6</td>
<td>0.6</td>
<td>0.6</td>
<td>0.6</td>
<td></td>
</tr>
<tr>
<td>pH (1:1 H₂O)</td>
<td>12.26</td>
<td>5.14</td>
<td>8.36</td>
<td>8.75</td>
<td>7.17</td>
<td>7.17</td>
<td></td>
</tr>
<tr>
<td>Organic Matter (%)</td>
<td>20.1</td>
<td>23.6</td>
<td>43.0</td>
<td>50.4</td>
<td>50.4</td>
<td>50.4</td>
<td></td>
</tr>
<tr>
<td>Conductivity (mmho/cm)</td>
<td>8.9</td>
<td>26.8</td>
<td>57.2</td>
<td>228.2</td>
<td>228.2</td>
<td>228.2</td>
<td></td>
</tr>
<tr>
<td>Carbon:Nitrogen (C:N) w:w</td>
<td>1.216</td>
<td>0.474</td>
<td>0.406</td>
<td>0.119</td>
<td>0.119</td>
<td>0.119</td>
<td></td>
</tr>
</tbody>
</table>

Compost is blended with natural soil to produce about 20,000 to 30,000 tons of manufactured topsoil that is used for campus construction projects (right). The blend forms a soil that resembles a natural prairie soil (above).
piles of about 100 cubic yards (cy) each. One pile was made with 30 percent each of wood chips, straw and leaves, and ten percent fresh biosolids. The other pile was made from 50 percent leaves, 30 percent straw, and 20 percent fresh biosolids. The objectives were to add fresh biosolids without causing odors and increase the volume of biosolids in the recipe. The experiments were successful in terms of odor control, and the facility started to use the product in full-scale operations.

OTHER PROCESS CHANGES

At the same time, changes were made to the overall composting method. The operators use a front-end loader and silage wagon to place wood chips, leaves and straw into windrows. The biosolids and fly ash are added and a tractor and an Aeromaster PT-120 compost turner with water tank are used to turn, water and mix the materials (usually six to eight turns versus four to six turns previously). Once the biosolids and ash have been added, the liquid odor control product is added to the water tank along with 1,000 gallons of water and sprayed directly into the row. Finally, the row is covered with six inches of leaf mulch as a biofilter.

Previously, the piles were turned daily during the first month of composting. Now, rows are left to compost as static piles for at least 28 days, after which they are turned and watered six to eight times during the next two months. After three months, the rows are stockpiled for curing. The addition of the biofilter initially makes the rows too large to turn, but after 28 days of composting the rows shrink down to a size that fits the turner. This results in more material being added to each windrow, increasing throughput of the site. In addition, rows no longer have to be combined prior to curing since larger piles are built at the outset. As a result of these changes, the new method of composting has reduced operating expenses. The previous method of 30 turns plus combining windrows cost $412/row. The new method (15 turns plus odor management) costs $276/row.

The new recipe still utilizes wood chips since this material comes from campus tree trimmings and is one of the residual streams we are designated to handle. Experimentation showed, however, that wood chips did not have to be used to successfully control odors. While mixes can be made with higher volumes of biosolids this resulted in more leachate from the rows and the finished compost had higher nitrogen concentrations. Higher ammonia concentrations also were detected, which limits the application rate of the finished compost as topsoil. The university’s permit limits the volume of compost that can be applied based on plant available nitrogen. Ammonia is very soluble and so higher concentrations increase plant available nitrogen. If a producer wanted a product that had higher fertilizer value this would be a positive factor. But since Purdue wants to use large appli-
Static piles sit for at least 28 days, after which they are turned and watered six to eight times during the next two months.

DOUBLING OR TRIPLING PLANT GROWTH

A greenhouse study using compost-amended soils was conducted in 1997 to evaluate plant growth and determine metal uptake in the plant tissue. In most cases, plant growth doubled or tripled when the compost was added to soil. Compost additions increased tissue concentrations of plant nutrients such as potassium, phosphorous, boron, molybdenum and calcium, but did not increase concentrations of other metals. Although boron concentrations were elevated in the compost due to the addition of coal ash, it did not appear to reduce plant growth in the study.

Currently, the SoilerMaker operation blends mature compost with suitable natural soil to produce about 20,000 to 30,000 tons of manufactured topsoil. Where suitable soil exists on site, compost is spread three to four inches deep and tilled into the soil to produce fertile topsoil. The finished compost is not screened, and the small amount of woody material that remains helps reduce soil erosion on steep hilllides and slopes. Leaving wood chips in the compost resulted in less settlement of the manufactured topsoil.

Purdue uses almost all of the topsoil that's made for campus construction projects, although smaller amounts have been used by local municipalities for parks and recreation areas. The manufactured soil is spread six to eight inches deep with minimal need for tilling and rock picking. It also does not clump when wet, and resists compaction. Our experience has shown that with compost application, grass establishes quickly with few weeds and there is less need for herbicides or fertilizers, reducing the overall cost of establishing campus lawns. Lawns also were established directly in compost without blending it with natural soil, but the soil was somewhat soft during the first growing season and under wetter conditions the lawn mowing equipment left indentations. By the second growing season, however, the soil was firm and resembled a natural prairie soil.

The ability to manufacture topsoil has eliminated the need to strip topsoil and has allowed Purdue to use residuals that would otherwise be disposed of in landfills or land applied. Processes like SoilerMaker represent a significant improvement in waste management and conservation of natural resources.

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