ANY COMMUNITIES evaluating biosolids management options are concerned with the cost of composting biosolids, the technology used, and odors associated with the process. Two new biosolids composting facilities which utilize aerated static piles provide useful insights on cost calculations and materials handling methods. One facility is a large 28 dry-ton per day, totally enclosed project in Davenport, Iowa that processes yard trimmings and biosolids. The other is a smaller 5.5 dry-ton per day facility, owned and operated by the Harrisonburg-Rockingham Regional Sewer Authority in Mount Crawford, Virginia. This report describes the equipment and initial operating stages, and compares capital and O&M costs of the two facilities.

DAVENPORT, IOWA

The city of Davenport, Iowa operates a 26 million gallons per day (mgd) capacity secondary treatment plant which serves approximately 156,800 persons. Thickened sludge from the treatment plant is anaerobically digested prior to dewatering. The resultant biosolids are dewatered using three two-meter belt filter presses to between 13 percent and 20 percent total solids. The dewatered biosolids were previously landfilled at the Scott County landfill. Increasing landfilling costs and environmental concern over this practice prompted the city to consider alternative biosolids management techniques. The city visited numerous composting facilities and other biosolids stabilization facilities in 1992 and early 1993 to gather information about performance, costs, and operability. After this evaluation, the city chose aerated static pile composting as the preferred management method to process yard trimmings as well as biosolids.

In 1992, several potential sites were considered for the facility. A parcel of land adjacent to the existing WWTP was selected due to its proximity to biosolids production and the compatibility of surrounding land use with the cost of composting city chose aerated static pile composting as the preferred management method to process yard trimmings as well as biosolids. The city made a commitment to manage all collected yard trimmings from Davenport and Scott County at the composting facility since a 1991 statewide ban on landfilling yard trimmings had been enacted. This required storage and processing areas and equipment. Total enclosures of the mixing, composting, and drying areas with all offgases being treated through biofilters was provided in the design to contain and treat the majority of facility odors. Due to increased costs and regulatory pressures, the city committed to cease landfilling dewatered biosolids in mid-1995. Design, permitting, and construction had to occur on a fast-track schedule to meet this timeframe. The facility design was initiated by E&A Environmental Consultants, Inc. and Shive-Hattery.
tory Engineers and Architects in May, 1993 with conceptual design completed by August; Final design was completed in March, 1994. Six bids were received, three of which were within the allotted budget. After receipt of bids and selection of Estes Company of Davenport as the contractor, construction began in June, 1994. Substantial completion of the facility occurred in August, 1995.

**FACILITY DESCRIPTION AND PROCESS FLOW**

The Davenport facility is designed to process 28 dry tons per day of 20 percent total solids digested biosolids cake on a five day per week operating basis. It is also designed to manage up to 35,000 cubic yards per year of yard trimmings.

The facility is located on a 15 acre rectangular parcel of land immediately south of the WWTP, which abuts a railroad yard to the west and the Mississippi River to the east. City owned property on the southern border creates additional buffer area to the only residential areas within half a mile of the site. A 6-foot high, 3,500-foot long levee completely surrounds the site to prevent flooding during a 100 year flood event.

Clean trimmings are delivered by private and public vehicles to a paved outside storage area. Quantities are estimated volumetrically by vehicle size by operations personnel for material billing. Materials requiring size reduction are ground with an 800 horse power horizontal grinder prior to use as a bulking agent. A 60 percent to 70 percent reduction in volume is achieved through grinding and stockpiling for one month. Wood chips and shredded tires are delivered and stored under cover in the bulking agent storage area. Dewatered biosolids are hauled via seven and 10 cubic yard capacity dump trucks from the WWTP to one of the two biosolids receiving bins.

The primary bulking agents used at the Davenport composting facility are paper mill quality wood chips and shredded rubber tires. Wood chips are supplemented with shredded tires at a ratio of one volume shredded tires to two volumes of wood chips.

Because the shredded tires are 100 percent recovered through screening, the quantity and cost of new wood chips are reduced by one-third. Shredded yard trimmings are also used to supplement this wood chip/tire mixture at a rate of one volume yard trimmings for every four volumes of wood chips/tires. These materials, as well as recycled bulking agent, are stored under cover and then loaded into the automated mixing system. A variable bulking agent to biosolids ratio was allowed for in the design with an average volumetric ratio of three to one (.3:.1). A pilot test was conducted to verify the correct ratio and to generate a product for market evaluation.

Mixing of the bulking agents with biosolids occurs in a totally enclosed, automated continuous feed system. Biosolids and bulking agents are loaded into live-bottom hoppers for metering to the automated mixing system. Two 50 cubic yard capacity biosolids hoppers and two 20 cubic yard capacity bulking agent hoppers are provided. **Variable speed screw drives discharge biosolids and bulking agents onto a feed conveyor at a rate which is automatically controlled by weight belt sensors connected to a programmable controller. The bulking agents and biosolids are thoroughly blended in one of two continuous feed pugmill mixers with the resultant blend discharged into a concrete bunker at the south end of the composting building. Odorous gases from the mixing building are vented to the compost hall where they are collected for treatment in the biofiltration system.**

Composting of the biosolids occurs in a 66,000 square foot building which is totally enclosed and insulated. A 40 foot wide central access aisle separates the east and west aeration zones. Precast polymerized concrete trenches are placed six feet on center to provide aeration to the compost piles. The facility design allows for a one-foot base of wood chips to be placed over the aeration trenches followed by eight feet of mix and a one foot insulative cover of recycled compost. Compost piles are 90 feet long. A custom designed hole pattern was used in heavy duty cast iron covers to provide uniform aeration down the length of each trench.

Four trenches are serviced by one of 24 aeration stations each capable of providing 1,400 cfm at eight inches of water column. Negative aeration is practiced for the first 10 days of the composting process with exhaust gases being collected and vented directly to biofilters for treatment. The blowers are then switched to positive aeration mode for the remainder of the 21 day composting cycle to enhance drying of the mass. Offgases from the compost piles and the building are collected via centralized ducting for treatment with the compost pile exhaust through biofilters.

Aeration rate is controlled with a temperature feedback control system that is operated through the facility computer. Up to four aeration rates are provided for each individual compost pile based on variations in

**Due to increased costs and regulatory pressures, Davenport had committed to stop landfilling dewatered biosolids in mid-1995. Iowa had enacted a statewide ban on landfilling yard trimmings in 1991.**
Because shredded tires are 100 percent recovered through screening, quantity and cost of new wood chips are reduced by one-third.

Table 1. Comparison of capital costs

<table>
<thead>
<tr>
<th></th>
<th>Davenport</th>
<th>HRRSAP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total capital costs</td>
<td>$8,610,000</td>
<td>$5,510,000</td>
</tr>
<tr>
<td>Cost per dry ton of biosolids per day of capacity</td>
<td>$397,400</td>
<td>$274,500</td>
</tr>
<tr>
<td>Cost per wet ton per day of capacity</td>
<td>$61,500</td>
<td>$68,600</td>
</tr>
<tr>
<td>Capital cost minus food levee and yard trimmings</td>
<td>$7,710,000</td>
<td>$1,510,000</td>
</tr>
<tr>
<td>Adjusted cost per dry ton of biosolids per day of capacity</td>
<td>$275,400</td>
<td>$274,500</td>
</tr>
<tr>
<td>Adjusted cost per wet ton per day of capacity</td>
<td>$55,100</td>
<td>$68,600</td>
</tr>
</tbody>
</table>

1. Davenport costs based on 24 DTPD, 5 days per week, 20 percent TS cake
2. HRRSAP costs based on 5.5 DTPD, 5 days per week, 25 percent TS cake
3. Includes all facilities, equipment, rate work, engineering, permitting, and construction management. Land costs are not included.
4. Adjusted cost after deletion of food levee and yard trimmings receiving/processing.
increased dramatically as the bulking agent ratio had to be increased to maintain the target mix solids content of 40 percent to 42 percent total solids. Less energy was available per volume of mix due to the decreased amount of dry biosolids. Therefore, increased amounts of yard trimmings were added to the bulking agent to provide the necessary energy for adequate drying during composting. Cake solids have since increased to the 17 percent total solids range and are anticipated to continue to improve over the next several months.

After the initial start-up and shakedown of the mixing system, the system has been able to operate and to process the quantity of biosolids generated in less than five hours per operating day. This allows operators enough process time to construct compost piles and move compost piles for screening.

The screening operation passed its performance test requirements in February. The trommel screen has a design capacity of 140 cubic yards per hour to achieve a 3/8-inch minus compost product. The performance test showed that the screen was able to process approximately 170 cubic yards per hour of material. The odor control system has worked very well over the seven months of operation to date. No increases in air handling system back pressures have been noted and no odor complaints have been received from the neighbors since start-up. The facility is operated by nine full-time personnel and a number of part-time personnel as follows: A superintendent, a clerk, six operators, one laborer, one part-time clerk (for weekend yard trimmings deliveries), and two part-time laborers in summer for various housekeeping and maintenance activities.

HARRISONBURG, VIRGINIA

The Harrisonburg-Rockingham Regional Sewer Authority (HRRSA) located in Mount Crawford, Virginia operates a 16 mgd capacity secondary treatment plant which serves approximately 40,000 persons and a significant amount of industrial wastes from four area poultry processors. The North River Wastewater Plant was recently expanded from 8 mgd to 16 mgd, and is currently treating 9.1 mgd of wastewater. Thickened sludge from the treatment plant is anaerobically digested prior to storage in a lagoon or dewatered with a new high solids belt filter press. The previous HRRSA management program included land application of approximately six million gallons annually of liquid biosolids at four percent solids on numerous farm sites. Rockingham County, in which the wastewater facility is located, is one of the largest poultry producing counties in the country. As a result, land application of poultry manure is common practice.

A karst soil geology combined with over application of these manures in some cases created isolated instances of groundwater nitrate contamination. HRRSA was, therefore, also concerned about the perception of their land application programs adding to the groundwater contamination problem. During recent years, siting of new land application sites, concerns over permitting issues, increased monitoring costs, and the potential for groundwater nitrate problems all contributed towards spurring HRRSA's interest in developing another management technique such as composting to supplement land application.

After selecting aerated static pile composting as the method of choice, HRRSA contracted with the engineering team of K&A Environmental Consultants, Inc., Patton Harris Russ & Associates, and Hazen & Sawyer for the design and construction of dewatering and composting facilities. The appropriate dewatering equipment was a key issue in the planning stage.

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Ground yard trimmings are blended with the wood chip/tire mixture at a rate of one to four on a volume basis; yard trimmings provide additional energy in the Davenport composting process which was particularly important when wetter biosolids cake was received.

Table 2. Comparison of O&M costs

<table>
<thead>
<tr>
<th>Category</th>
<th>$/Dry Ton of Biosolids</th>
<th>% of Total Budget</th>
<th>$/Dry Ton of Biosolids</th>
<th>% of Total Budget</th>
</tr>
</thead>
<tbody>
<tr>
<td>Labor</td>
<td>49.74</td>
<td>36.1</td>
<td>33.10</td>
<td>34.9</td>
</tr>
<tr>
<td>Utilities</td>
<td>38.47</td>
<td>28.0</td>
<td>9.46</td>
<td>10.0</td>
</tr>
<tr>
<td>Maintenance</td>
<td>25.65</td>
<td>18.6</td>
<td>11.64</td>
<td>12.2</td>
</tr>
<tr>
<td>Bulking Agent</td>
<td>16.67</td>
<td>12.1</td>
<td>28.99</td>
<td>31.2</td>
</tr>
<tr>
<td>Fuel</td>
<td>6.11</td>
<td>4.4</td>
<td>5.78</td>
<td>6.1</td>
</tr>
<tr>
<td>Miscellaneous</td>
<td>1.07</td>
<td>0.8</td>
<td>5.32</td>
<td>5.6</td>
</tr>
<tr>
<td>Total</td>
<td>137.71</td>
<td>100.0</td>
<td>95.07</td>
<td>100.0</td>
</tr>
</tbody>
</table>

1. Based on first six months of operation and actual costs to process 2,039 dry tons of biosolids and yard trimmings.
2. Based on projected first year quantities of 40 dry tons of biosolids.
3. Based on first 10 months of yard trimmings revenues adjusted for six months.
4. Adjusted O&M cost based on estimated compost production at both facilities and $5 per cubic yard sales revenue.

The composting facility is designed to produce 5.5 dry tons per day of 25 percent total solids digested biosolids cake on a five day per week operating basis. The facility is on a 1.0 acre parcel of land immediately adjacent to existing digesters and the dewatering building at the North River Plant. All biosolids receiving, mixing, composting, drying, screening, and curing and compost storage activities occur under a 40,000 square foot pre-engineered metal building.

Dewatered biosolids are conveyed from the belt filter press to concrete storage bunkers in the composting facility. Wood chips are delivered in dump or live-bottom trailers for use as the primary bulking agent. A portion of the wood chips (up to three operating days’ supply) can be stored under cover with the balance stored outside on an asphalt pad. Paper mill quality wood chips are used as the primary bulking agent and supplemented with a limited amount of yard trimmings available from the Rockingham County Landfill. An asphalt pad is provided for storage of new bulking agent as well as recycled bulking agent.

Mixing of the bulking agents with biosolids occurs in an electrically driven, 18 cubic yard capacity batch mixer, which is equipped with weigh scales to determine exact quantities of each of the bulking agents as well as the biosolids used in any given mix. A front-end loader is used to load the batch mixer with the biosolids and the bulking agent. After thoroughly mixing these materials, the initial mix is discharged into a 60 cubic yard capacity three-sided concrete storage bunker, which is also under cover in the composting building.

Composting of the biosolids occurs under cover in a 15,000 square foot area. A front-end loader picks up the mixture from the initial mix discharge bunker and places it in the static piles in the composting area. The facility is designed to allow a one-foot base of wood chips to be placed over aeration piping, followed by eight feet of mix, and a one-foot insulative cover of recycled compost. Com-
post piles are approximately 90 feet long. High density polyethylene pipe is used to supply aeration to the compost piles. Sixteen aeration stations, each capable of providing 630 cfm at eight inches of water column, service two high-density polyethylene headers spaced approximately four feet apart. A custom design hole pattern was used in the design of the aeration laterals to provide uniform aeration down the length of the compost piles. Negative aeration is practiced routinely for the first 10 days of the composting process with exhaust gases being collected and vented directly to an open biofilter for treatment. Blowers are then switched to positive mode for the remainder of the 21 day composting cycle to enhance drying. The aeration rate delivered to the static piles is controlled based on operator adjustments through a central programmable logic controller system. Allowance for up to five days of aerated drying is also provided in the composting building for periodic times when additional drying is necessary. After composting, the material is screened through a deck-type screen that has a three-foot by five-foot rectangular deck with punch plate holes to a 3/8 inch sized product. The screening system has a capacity of 40 cubic yards per hour and produces a 3/8 inch minus compost product for curing and use.

Aerated curing is provided under cover using portable stations and reusable perforated high density polyethylene pipe. This area is located adjacent to the composting area and is sized to handle screened compost production. Six portable aeration stations are provided in the curing area for positive aeration. Cycling timers control aeration rates as necessary in this stage of the process. Upon completion of the curing period, the compost is moved outside to the storage area for marketing. The paved storage area provides up to two months capacity for the finished compost product. Pricing for the compost has not been established, but is anticipated to be approximately $5 to $8 per cubic yard.

Odor control at this composting facility consists of treating process offgas from the most odoriferous composting process and treatment through a biofilter system. Initial modeling at the facility indicated that the nearest receptors, approximately 1,000 feet from the facility, would not be adversely affected with this type of odor control approach. A 3,150 cfm biofilter has been provided to allow a 60-second residence time of odorous gases in the open bed biofilter system for treatment. Moisture control is provided through in-line humidification and surface irrigation.

The HRRSA composting facility began processing biosolids intermittently in January, 1996. Because the North River Plant has a biosolids storage lagoon which is maintained for the land application program, the Authority could begin operations at the facility at a slow controlled pace, thus allowing operators to gain knowledge and confidence in the process prior to increasing loading to the facility. Seven individual compost piles have been constructed and 34 dry tons of biosolids have been composted as of mid-March. The composting process has met PFRP temperature requirements and screened compost is being produced for curing. Odors at the facility are minimal. Full-time utilization of the biofilter will begin in April as loading to the facility increases. Two part-time operators are utilized to operate the composting facility two to three days per week. These operators also perform other plant operations such as dewatering, land application of liquid biosolids, and other duties within the wastewater plant operation.

At the Harrisonburg facility, negative aeration is practiced routinely for the first ten days of the composting process.

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O&M costs are estimated to be $95 per dry ton of biosolids processed at HRRSA and $138 per dry ton of biosolids processed at Davenport. Actual O&M costs at Davenport will decrease as dewatered cake solids content continues to improve.

### COMPARISON OF COSTS

Comparing costs for both facilities is a very interesting exercise. Economies of scale play an important factor in the construction and operating costs of composting facilities. However, when comparing the costs of these two facilities, one should be cognizant of the basic differences in facility design which have the greatest impact on costs. The basic differences in the two facilities are summarized below by unit process for those which are impacted.

**Site Work** — The Davenport facility includes cost of approximately $400,000 for installation of a flood protection levee.

**Yard Trimmings** — The Davenport facility includes about $500,000 for yard trimmings receiving and grinding equipment.

**Mixing** — The Davenport facility includes two 50 cubic yard capacity biosolids bins and two 15 cubic yard capacity bulking agent bins with variable speed outfeed devices. Two pugmills are used to mix biosolids and bulking agent on a continuous basis. A weigh belt is used to weigh materials and to automatically adjust feed rates through a PC controller. HRRSA facility mixing system includes one 18 cubic yard capacity batch mixer with weigh scales to measure bulking agent to biosolids ratios.

**Aeration** — The Davenport facility includes in-trench aeration, whereas HRRSA utilizes above ground high density polyethylene pipe. Davenport has pile temperatur feedback to provide aeration rate adjustments. HRRSA has manual aeration rate adjustments through a central PLC system.

**Enclosures** — The mixing, composting and drying processes are totally enclosed in an insulated pre-engineered building at the Davenport facility. These processes are only covered at HRRSA.

**Odor Control** — The Davenport facility collects all offgases from mixing, composting, and drying processes and building air for treatment through biofiltration. HRRSA facility treats exhaust gases from composting piles when in negative aeration through biofiltration. In terms of cost comparison, the air collection system and the large size biofilter needed to treat that volume of air required much more capital investment at Davenport than the system at the HRRSA plant, which only handles the compost process exhaust gas.

**Biosolids Cake** — The Davenport facility design was based on 20 percent total solids, whereas the HRRSA facility design was based on 25 percent total solids. This single factor increases the facility capacity by approximately one-third more biosolids on dry weight basis because less volumes are managed per dry ton.

### CAPITAL COSTS

The capital costs reported are in 1995 dollars and include all moving stock, stationary equipment, buildings, site improvements, engineering, permitting, and construction management. The cost of land acquisition is not included.

The Davenport and HRRSA composting facility capital costs are summarized in Table 1. Capital costs for Davenport are shown as is and then with the deletion of the flood protection levee and the yard trimmings receiving processing for comparison with HRRSA. This comparison shows that the large capacity totally enclosed aeration static pile composting facility at Davenport...
has a similar unit cost of $275,000 per dry ton of biosolids capacity as the smaller HRRSA facility which is simply housed underground. It should be noted that because of the higher solids content in the dewatered biosolids at HRRSA, one-third more were amortized at five percent interest as biosolids capacity on a dry weight basis is available, reducing the resultant unit costs per dry or wet ton of biosolids capacity.

O&M COSTS

O&M costs for the two facilities are compared in Table 2. The O&M costs at Davenport are based on actual operating data for the first six months of operation. These costs include yard trimmings processing. The quantity of biosolids processed on average is only 21.3 dry tons per actual operating day. The 2,339 dry tons of biosolids processed over that period compares to a design quantity of 3,640 dry tons which translates to 64 percent of facility capacity. This lower throughput is due to start-up/shakedown of the system and loading/operational problems at the WWTP which resulted in much wetter biosolids cake during November through February (13 percent to 17 percent) as compared to the 19 percent to 20 percent total solids which was being achieved in September and October.

O&M costs for HRRSA are estimated based on projections since no historical data is yet available. HRRSA is designed to operate only three days per week in the initial design year (1996). However, because of start-up/shakedown, the facility has not been operated at that type of schedule as of yet.

Labor accounts for the largest percentage of O&M costs at both facilities at roughly one-third of the budget. Typically, bulking agent costs are the next largest portion which is also true at the HRRSA facility. However, Davenport’s bulking agent costs are greatly reduced by using shredded rubber tires and yard trimmings to supplement new wood chips as the bulking agents. Utilities at Davenport are a higher percentage of the O&M cost due to the large amount of airflow which is collected for treatment through the biofilter system. Maintenance costs at both facilities are projected based on hourly costs and operating costs and hourly run times for moving stock and stationary equipment. It is interesting to note that maintenance of the aeration trenches in Davenport is minimal in terms of cleaning between composting cycles. This saves labor and the cost of replacing above ground aeration pipes. Fuel is based on actual usage at Davenport to operate the front-end loaders and grinder. Miscellaneous includes product monitoring.

O&M costs are estimated to be $95 per dry ton of biosolids processed at HRRSA and $138 per dry ton of biosolids processed at Davenport. Figure 1 shows the relative cost impact of these cost categories. Actual O&M costs at Davenport will decrease as the dewatered cake solids content continues to improve. These cost compare very favorably with other operating biosolids composting facilities nationwide.

Total annualized costs for both facilities are compared in Table 3. The capital costs were amortized at five percent interest as follows: Moving stock at seven years; Stationary equipment at 10 years; Structures, sitework, and engineering at 20 years.

Yard trimmings tip revenues are accounted for at Davenport. Compost revenues of $5 per cubic yard are assumed at both facilities based on preliminary market investigations and reported revenues from other similar facilities.

In conclusion, both facilities utilize the aerated static pile method of composting as well as unique process control features that have a proven track record at other facilities. Many of these most recent features have been incorporated into these facilities based on owner preference and the budgetary constraints. Odor control at both facilities has been completely satisfactory. Cost comparisons provided here show that cost-effective composting can be achieved using aerated static pile with a high degree of odor removal efficiency and varying characteristics of the feedstock biosolids and bulking agents available.

For Harrisonburg, Virginia officials, concerns over permitting issues, increased monitoring costs of land application sites, and the potential for groundwater nitrate problems led to their interest in composting.