BENEFICIAL REUSE OF MUNICIPAL WASTE-TO-ENERGY ASH AS A LANDFILL CONSTRUCTION MATERIAL

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Abstract

The Solid Waste Disposal Authority of Palm Beach County owns a municipal waste-to-energy plant located in West Palm Beach, Florida. Currently, ash generated by the operation of the facility is disposed at the Authority’s adjacent Class I Landfill. In 1998, the Florida Legislature amended certain provisions of the Florida Statutes to encourage the beneficial reuse of municipal waste-to-energy ash in manners that are protective of human health and the environment. To that end, the Florida Department of Environmental Protection developed a document entitled “Guidance for Preparing Municipal Waste-to-Energy Ash Beneficial Use Demonstrations” to assist communities in developing reuse demonstrations. SWA and CDM undertook a project and developed a report in accordance with the Guidance document to demonstrate that reuse of the ash from the SWA’s waste-to-energy facility as a landfill construction material is consistent with the reuse goals set forth by the Legislature. Initial studies were performed to identify locations and quantities for use of ash within the confines of SWA property. Some of these locations included future Class I and Class III Landfill cells and perimeter roadways. It was determined that nearly 3 million cubic yards of landfill space could be saved through beneficial reuse of the ash. An initial analytical screening was performed to test the leaching potential of the eight RCRA metals and compare to applicable groundwater and surface water standards. Overall results were favorable, with some indication that lead could pose potential concern. Geotechnical index testing (grain size, moisture content, and organic content) was performed to determine if ash has similar physical properties to the sand that is currently used on-site. Results indicated that the ash has similar physical properties to the sandy material. This initial testing was performed in accordance with the July 1998 DRAFT version of the guidance document.

Regulation Background

In 1998, the Florida Legislature amended Section 403.7045(5) of the Florida Statutes, addressing the disposal of ash residue generated by solid waste management facilities combusting solid waste. The amended language clarified the authority of the Florida Department of Environmental Protection (“FDEP”) to work with solid waste management facilities to identify and develop methods for recycling or reusing ash generated by resource recovery operations. More importantly, the amended language of the statute granted clear authority to the FDEP to approve ash reuse projects that present no significant threat to human health and that will not violate FDEP standards and criteria.
To implement the provisions of the statutory language, the FDEP, on August 21, 2000, published the Guidance for Preparing Municipal Waste-to-Energy Ash Beneficial Use Demonstrations. This Report, as well as the methods and means of obtaining data used throughout, follows the provisions laid out in that guidance document.

**Description of Operation**

A key component of SWA’s regional system is the North County Regional Solid Waste Management Facility located in West Palm Beach, Florida. The NCRSWMF includes the North County Resource Recovery Facility (hereinafter the “WTE Facility”), a Class I Landfill, a Class III Landfill and several associated facilities such as composting operations, ferrous metal recycling operations, and miscellaneous administrative buildings.

The WTE Facility is designed to combust up to 2,000 tons per day of processed municipal solid waste (MSW) known as “refused derived fuel” (RDF). Incoming MSW from collection vehicles and transfer trailers is directed to the tipping floor, where it is off-loaded directly onto the floor. Loaders transfer the MSW to three processing lines, where it is screened and shredded into RDF. In addition, ferrous metal is magnetically removed prior to combustion.

RDF is fed to two Babcock & Wilcox waterwall steam boilers, each equipped with a Detroit Spreaded Stoker fuel feed and stoker system. The boilers are of the two-drum design and can each operate with a maximum heat input of 413 MMBtu/hr. The steam flow rating for each is 324,000 lbs/hr. This equates to approximately 900 tons per day of RDF when firing waste with a reference heating value of 5,500 Btu/lb. With both boilers operating at full load, the single turbine generator is capable of producing 62 MW of electricity. Auxiliary natural gas fuel is used as necessary to enhance combustion of the RDF. Ash remaining on the combustion grates is directed to a water quench pit and is removed as “bottom ash.”

Emissions are controlled by a spray dryer absorber (SDA) for acid gases and a four field electrostatic precipitator (ESP) for particulate matter for each boiler. Dry quicklime (CaO) is slaked to Ca(OH)₂ and sprayed into the scrubber vessel to control 70% of the inlet SO₂ concentration and 90% of other acid gases, primarily HCl. The reacted Ca(OH)₂ is converted primarily to CaCl₂ and CaSO₄, where it is removed as “flyash”. Particulate matter collected on the collection plates of the ESP’s is also removed from the process as flyash.

**Sampling Methodology**

Beginning on January 29, 2002, SWA began stockpiling at the Class I Landfill all of the ash generated by the WTE facility. Stockpiling continued for seven days, with each individual day’s ash being kept separate. The purpose of this procedure was to allow the ash to be sampled in accordance with the composite sampling strategy described in Chapter 9.1.4.1 of EPA publication SWA-846.

Sampling of the stockpiled ash was conducted over a two-day period beginning on February 6, 2002. Fourteen “composite” samples (two for each day’s worth of ash) and seven “grab” samples (one for each day’s worth of ash) were collected in accordance with the DEP’s Standard Operating Procedures (SOP) for Sampling WTE Ash as Part of a Beneficial Use Demonstration. The samples were shipped to Test America, Inc. (Florida Certification No. E83012/CQAP990129) in Orlando for analysis.

Each of the fourteen composite samples were analyzed as follows:
• Total analysis for 2,3,7,8 TCDD (dioxin) using EPA Method 8290

• Total analysis for arsenic, barium, cadmium, chromium, lead, mercury, selenium, and silver (the eight RCRA Metals) using the approved EPA Methods

• Total analysis for aluminum, copper, fluoride, iron, manganese, and zinc using the approved EPA Methods.

• SPLP extraction on all 14 composite samples

• Extracts from the SPLP extraction were analyzed for pH, chloride, sulfates, total dissolved solids, manganese, iron, aluminum, copper, fluoride, lead, and any other parameter that would be considered a “COC for leachability” on the basis of its total analysis.

Each of the seven grab samples were analyzed as follows:

• Total analysis for volatile organic compounds using EPA Method 8260B

• SPLP extraction on all 7 grab samples

• Extracts from the SPLP extraction were analyzed for the individual organic compounds using EPA Method 8260B that either have no SCTL for leachability or would be considered a “COC for leachability” based on the total analysis.

Results

Total metal concentrations for aluminum, zinc, iron, arsenic, copper, lead, barium, manganese, fluoride, cadmium, chromium, silver and mercury were detected in all of the baseline samples. The mean was calculated for these metals and the resultant data showed that the samples were not normally distributed. Lognormal transformation of the data set was performed in accordance with the calculation methodology described in Appendix C of the FDEP’s guidance document. Table 1-1 presents the lognormal mean and the transformed 95th % upper confidence level of the data.

Three metals were determined to be potential COC’s for direct human exposure: manganese, cadmium and mercury. Four metals were determined to be COC’s for direct human exposure: arsenic, copper, lead and barium. Selenium was the only metal that was below the detection limit for all 14 samples. The SPLP extract obtained on all of the fourteen composite samples was analyzed for the metals lead, copper, aluminum, arsenic, barium and manganese and for other inorganic parameters such as pH and TDS. The means for lead and copper were calculated and the resultant data showed that the samples were not normally distributed. Lognormal transformation of the data set was performed according to the calculation methodology required in Appendix C for the transformation of non-normally distributed data. Data for the SPLP leaching can be seen in Table 1-2. Lead, aluminum, pH, TDS, and chlorides are COC’s because their concentration exceeds the Groundwater Drinking Standards. Fluoride is considered to be a potential COC because its concentration exceeded 50% of the groundwater standard.

1 COC means “chemicals of concern” as that term is used in the FDEP’s guidance document. Chemicals are considered COCs if they could create a potential human health risk from direct exposure or if they have the potential to contaminate groundwater or surface water.
Table 1-1 Total Metals Results

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Arth. mean (mg/kg)</th>
<th>Transformed 95&lt;sup&gt;th&lt;/sup&gt; % Upper confidence</th>
<th>Statistical Result (mg/kg)</th>
<th>Industrial SCTL (mg/kg)</th>
<th>Residential SCTL (mg/kg)</th>
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<tr>
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<td>702</td>
<td>997</td>
<td>997</td>
<td>22000</td>
<td>1600</td>
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<td>Flouride</td>
<td>52</td>
<td>88</td>
<td>88</td>
<td>120000</td>
<td>500</td>
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<tr>
<td>Cadmium</td>
<td>31</td>
<td>46</td>
<td>46</td>
<td>1300</td>
<td>75</td>
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<tr>
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<td>56</td>
<td>61</td>
<td>61</td>
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<td>210</td>
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<tr>
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<td>6</td>
<td>6</td>
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<td>390</td>
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<tr>
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<td>2.46</td>
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<td>2.46</td>
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<td>3</td>
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<tr>
<td>Selenium</td>
<td>BDL</td>
<td>BDL</td>
<td>BDL</td>
<td>10000</td>
<td>390</td>
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<tr>
<td>Aluminum</td>
<td>27037</td>
<td>29436</td>
<td>29436</td>
<td>*</td>
<td>72000</td>
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<tr>
<td>Zinc</td>
<td>1747</td>
<td>2068</td>
<td>2068</td>
<td>560000</td>
<td>23000</td>
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<tr>
<td>Iron</td>
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<td>9446</td>
<td>9446</td>
<td>480000</td>
<td>23000</td>
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<tr>
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<td>61</td>
<td>61</td>
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<tr>
<td>Copper</td>
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<td>3696</td>
<td>3696</td>
<td>76000</td>
<td>110</td>
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<tr>
<td>Lead</td>
<td>1495</td>
<td>2260</td>
<td>2260</td>
<td>920</td>
<td>400</td>
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<tr>
<td>Barium</td>
<td>369</td>
<td>434</td>
<td>434</td>
<td>87000</td>
<td>110</td>
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</table>

* Contaminant is not a health concern for this default exposure scenario
To establish the physical characteristics of the ash, a series of geotechnical laboratory index and physical property tests were performed. The purpose of this testing was to demonstrate that the ash has similar physical properties to the soil used for the various applications.

Particle size analysis and Atterberg limits testing performed on the pure fly ash and pure bottom ash indicates that the ash is generally considered a non-plastic, coarse-grained sandy material with various amounts of silt and clay size particles as classified under the Unified Soil Classification System (USCS), with corresponding USCS symbols of SM and SP-SM, respectively.

Specific gravity testing on both the bottom ash and fly ash showed results of 2.43 and 2.67, respectively. The value for fly ash falls near the typical ranges of sandy soils but the bottom ash sample tested falls somewhat lower than that of sandy soils. It is anticipated that the specific gravity can vary somewhat depending upon the composition of the RDF at any given time. Results from the direct shear testing showed peak friction angles ranging from 56.0 to 68.6 degrees and residual friction angles ranging from 45.7 to 58.2 degrees.

According to our research, ash compacted and tested below optimum moisture yield permeabilities on the order of $10^{-2}$ to $10^{-3}$ cm/sec, which are within the range of values for naturally occurring sandy soils. When samples were compacted and tested above the optimum moisture content, however, permeabilities on the order of $10^{-5}$ to $10^{-6}$ cm/sec were reported. Further testing also showed permeability for the composite mixes to range from $1.3 \times 10^{-5}$ to $8.9 \times 10^{-5}$ cm/sec, the range was dependent on the ash mixing ratio of bottom ash to fly ash.

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Table 1-2 Leaching Results

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Arth. Mean (mg/L)</th>
<th>Transformed 95th % Upper Confidence</th>
<th>Statistical Result (mg/L)</th>
<th>Groundwater Drinking Standard (mg/L)</th>
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<tbody>
<tr>
<td>Lead</td>
<td>2.00</td>
<td>1.9979</td>
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<td>0.444</td>
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<tr>
<td>Arsenic</td>
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<td></td>
<td>BDL</td>
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</tr>
<tr>
<td>Barium</td>
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<td></td>
<td>1.053</td>
<td>2</td>
</tr>
<tr>
<td>Manganese</td>
<td>0.01</td>
<td></td>
<td>BDL</td>
<td>0.05</td>
</tr>
<tr>
<td>Iron</td>
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<td></td>
<td>0.005</td>
<td>0.3</td>
</tr>
<tr>
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<td></td>
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</tr>
<tr>
<td>Fluoride, (mg/l)</td>
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<td></td>
<td>1.46</td>
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</tr>
<tr>
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<td>42.12</td>
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<td>250</td>
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<tr>
<td>TDS (mg/l)</td>
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<td>Chloride (mg/l)</td>
<td>1038</td>
<td>1490</td>
<td>1490</td>
<td>250</td>
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</tbody>
</table>
**Beneficial Uses**

Initial studies were performed to identify locations and quantities for use of ash within the confines of SWA property. Some of these locations included future Class I and Class III Landfill cells and perimeter roadways. It was determined that nearly 3 million cubic yards of landfill space could be saved through beneficial reuse of the ash. SWA desires to beneficially reuse the ash as construction material in the following landfill applications:

- Intermediate Cover in the Class I Landfill
- Final Cover in the Class I Landfill
- Initial Cover in the Class III Landfill
- Intermediate Cover in the Class III Landfill
- Final Cover in the Class III Landfill
- Fill Material under the Class I and Class Landfills

**Intermediate Cover**

"Intermediate Cover" is defined in the Florida Administrative Code as "a layer of compacted earth at least one foot in depth applied to a solid waste disposal unit. The term also includes other material or thickness, approved by the Department, that minimizes disease vectors, odors, and fire, and is consistent with the leachate control design of the landfill." Rule 62-701 allows for intermediate cover to remain in place for up to 180 days without further "reactivation" of the area.

Ash provides superior qualities to compacted earth for its use as an intermediate cover material at the Class I Landfill. Ash has a lower permeability than compacted soil, and thus is more effective at covering the waste and preventing vectors, odors, and fires. Further, the ash provides superior containment of landfill gases, thus maximizing the landfill's gas collection and recovery system.

Use of the ash as intermediate cover in the Class I Landfill will not present a significant threat to human health from direct exposure. At least two feet of clean fill will be used on top of the ash as specified in section 4.2 of the FDEP's ash reuse guidance document. The Class I Landfill is a secure area, with controlled access to the general public. Perimeter fencing and security is in place to preclude unauthorized access. Landfill operators are trained in proper ash handling techniques and are protected by the rules of the Occupational Safety and Health Act (OSHA). These in-place institutional controls are sufficient to ensure that the ash material will not be disturbed in the future.

Because use of the ash in this manner is limited to within the lined area of the landfill, groundwater contamination concerns are minimal. The Class I Landfill is equipped with a leachate collection and removal system designed to collect leachate and properly dispose of it.

**Final Cover in the Class I Landfill**

"Final cover" is defined in the Florida Administrative Code to mean: "the materials used to cover the top and sides of a landfill when fill operations cease." In accordance with Chapter 62-701.600(5)(g), F.A.C., all landfill final covers must be designed to minimize infiltration and erosion.

The physical characteristics of the ash indicate that the ash is suitable for use as a final cover material in the Class I Landfill. The lower permeability of the material will also enhance landfill gas collection efficiency.

As with the use of ash for intermediate cover described above, risks associated with direct exposure to the ash are minimal. The same institutional controls of limiting public access
coupled with worker protection provisions will ensure that direct exposure is minimized. Further the ash will be covered with a geomembrane and clean soil. It is not anticipated that excavation of closed cells will occur.

Ash that is beneficially used in this manner presents no increased threat of groundwater contamination. Ash is already authorized for disposal in the Class I Landfill. Any infiltration into a closed area of the landfill would create an ash-contact leachate (either through contact with the final cover or contact with the disposed ash) that is collected and handled in accordance with proper leachate handling techniques. However, infiltration is next expected to occur once the cell is closed with liner materials.

Ash used as final cover will be overlain with a geomembrane, geotextile and geonet material, then covered with at least 18 inches of vegetative soil. This will control erosion and prevent surface water contamination concerns.

The primary objective of a landfill final cover system is to reduce the infiltration of stormwater into the waste mass. Final cover system designs vary but usually consist of a gas collection/venting layer, a low permeability barrier layer, a drainage layer, and an erosion protection/vegetative support layer. Ash used as final cover would be covered with clean fill soils and/or possibly a geosynthetic filter fabric to reduce the risk of direct human exposure. With this in mind, it is anticipated that the most probable beneficial use for ash in a final cover system would be as material for the construction of a low permeability barrier layer.

*Initial Cover in the Class III Landfill*

There are two primary geotechnical design concerns regarding the use of ash as the low permeability barrier layer component of a final cover system: strength and permeability. Barrier layer material must have sufficient internal strength to resist veneer failure (i.e., sliding down the constructed slope), must have adequate interface friction with any geosynthetic components that are in direct contact with the material, and must have sufficiently low permeability to meet regulatory requirements for infiltration of water into the waste mass and/or leachate impingement rates on the leachate collection system.

The Class III Landfill at the NCRSWMF is used to dispose of construction and demolition debris, carpet, furniture and other non-putresible materials that are not expected to produce leachate that poses a threat to human health or the environment. Rule 62-701.500(7)(e) requires that initial cover be applied over the waste at the end of each work week to minimize blowing litter, disease vectors, and fires. Rule 62-701.500(7)(f) requires that intermediate cover be applied as individual cells reach capacity. And, finally, Rule 62-701.500(7)(g) requires that final cover be applied once the landfill reaches its design elevation. SWA desires to beneficially use the ash as its cover material (initial, intermediate, and final) at the Class III Landfill. Because of its physical properties, the ash provides superior qualities to compacted earth with respect to its ability to control disease vectors, odors, blowing litter and fires.

As with the Class I Landfill, the Class III Landfill at the site has been designed with a leachate collection and removal system. The leachate system is similar to that of the Class I Landfill, employing perforated HDPE lateral pipes above a single 60-mil HDPE liner system.

Use of the ash as cover material in the Class III Landfill will not present a significant threat to human health from direct exposure. As
with the Class I Landfill, the Class III Landfill is a secure area, with access by the general public controlled. Perimeter fencing and security is in place to preclude unauthorized access.

Because the Class III Landfill employs a liner design, with associated leachate collection and removal systems, groundwater concerns associated with this use are minimal. Leachate collected from the Class III Landfill is collected and disposed in the same manner as leachate from the Class I Landfill.

**Fill Material Under Class I and Class III**

The current active cell being utilized at the Class I Landfill is projected to reach design capacity in approximately two years. Prior to the cell reaching capacity, SWA will begin to design a new cell to accommodate the MSW and ash disposal needs of the county. The ultimate design of the new cell will be similar to that of the existing cells, namely, use of a double composite liner with associated leachate collection and removal equipment.

SWA desires to beneficially utilize the WTE ash as a base material underneath the liner(s) of the new cell. The ash base will be overlain with a processed sand to prevent damage to the liner system.

The physical properties of the ash are capable of providing the necessary structural support to prevent overstressing of the liner. Prior to any such authorized use, SWA would develop final specifications and provide them to the Department for approval in accordance with the provisions of Chapter 62-701.400(f), F.A.C.

Use of the ash in this fashion will preclude any possibility of direct exposure concerns because the ash will be underneath the liner and all of the subsequent MSW and fill materials placed above the liner. Precautions to minimize worker exposure while the base material is being constructed will include watering for dust suppression. As required by 62-701.400(f), F.A.C., detailed specifications for the ash will be prepared and submitted for approval prior to use in this fashion. Such specifications will include particle size distribution, Atterberg limits, moisture criteria, hydraulic conductivity, etc.

Ash placed as a liner sub-base material will have minimal potential for exposure to water, hence, leaching concerns are minimal. New cell construction will take into account the seasonal high groundwater elevation, so that potential ash contact with the groundwater will not take place. Further, because the liner and leachate collection system is designed to prevent leachate from penetrating the bottom liner, exposure of the ash to rainfall will not occur. Essentially, the ash will be encapsulated below the liner and above the seasonal high groundwater elevation.