Memorandum

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TO: Zack Hansen and Nikki Stewart
Ramsey/Washington Recycling & Energy Joint Leadership Team

FROM: Kate Bartelt, Jennefer Klennert, and Nathan Klett, Foth Infrastructure & Environment, LLC (Foth)

RE: Pre-Processing: End Market Analysis for Process Residue

Executive Summary

Process residue is a byproduct generated at the Recycling & Energy Center (R&E Center) from the production of Refuse Derived Fuel (RDF) and the extraction of metals from the trash for recycling. Due to its composition, process residue is not suitable for RDF and is currently landfilled. As process residue is the direct result of processing, the tonnage generated each year will vary. Factors that influence residue tonnage include the total tonnage of Municipal Solid Waste (MSW) processed, availability of combustion capacity for the RDF, moisture content of the incoming MSW, and character of the incoming MSW.

This memorandum explores opportunities for end market alternatives for process residue.

Definitions

Process Residue Byproduct generated from the production of Refuse Derived Fuel (RDF).

Pre-Processing Mechanical systems that separate recyclable commodities from MSW prior to the generation of RDF.

Supporting Documents

1. Foth Infrastructure & Environment, *Summary of 2016-2017 Seasonal Waste Characterizations*, December 18, 2017.
2. Foth Infrastructure & Environment, *Mixed Waste Processing – Update on Technology Status*, April 15, 2015.
3. Foth Infrastructure & Environment, *Greenhouse Gas Systems Analysis Report*, April 2015.

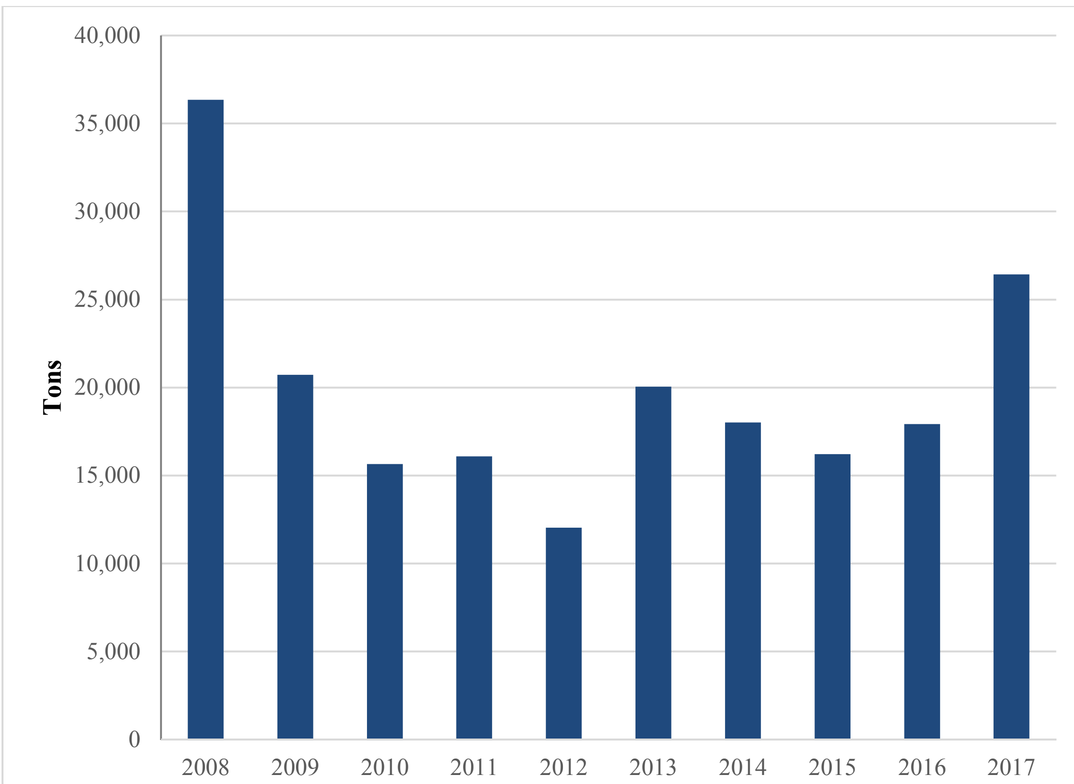
4. Foth Infrastructure & Environment, *Anaerobic Digestion (AD) – Update on Technology Status*, April 15, 2015.
5. Foth Infrastructure & Environment, *Summary of May 2017 Waste Characterization,* September 18, 2017.

Process Residue Recovery Analysis

Volume and Characterization of Process Residue

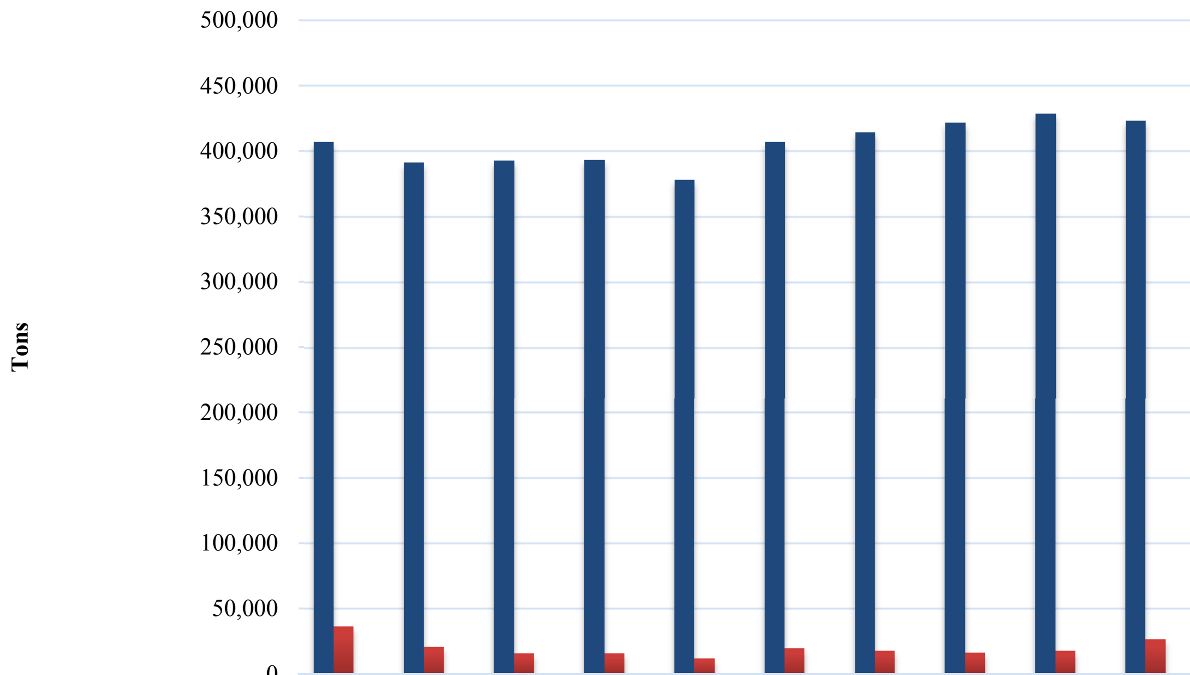
From 2008 to 2017, nearly 200,000 tons of process residue was generated as a result of RDF production at the R&E Center and was disposed of in MSW landfills. The R&E Center produces an average of approximately 20,000 tons per year (TPY) of process residue. The exact tonnage varies each year and ranged from a low of 12,000 TPY in 2012 to a high of 36,000 TPY in 2008, see Figure 1.

Figure 1
R&E Center Process Residue
(Tons Per Year)



On average, 4.9 percent of the MSW received at the R&E Center becomes process residue. Figure 2 shows that between 2008 and 2017, the lowest percentage process residue observed was 3.18 percent of the total incoming MSW in 2012 and the highest percentage of process residue observed was 8.93 percent of the total incoming MSW in 2008.

Figure 2
R&E Center Percent Process Residue Produced
(Per Year)



	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
MSW Received (tons)	406,986	391,329	392,633	393,484	378,055	406,896	414,557	421,519	428,717	423,433
Process Residue (tons)	36,353	20,728	15,655	16,098	12,036	20,047	18,017	16,226	17,929	26,423
Process Residue (percent)	8.93%	5.30%	3.99%	4.09%	3.18%	4.93%	4.35%	3.85%	4.18%	6.24%

A Waste Characterization study was recently completed at the R&E Center, *Summary of 2016-2017 Seasonal Waste Characterizations* (Summary). Four (4) waste characterization events were conducted from October 2016 to August 2017 to evaluate the potential seasonal waste trends. The focus was on characterizing incoming MSW by size and was not intended to be a comprehensive waste composition study in accordance with ASTM D5231-92. Full details on the sampling methodology are located in the Summary.

During each of the four (4) waste characterization events, RDF, 2-inch minus material from the waste characterization, and process residue from the RDF production were sampled and sent to Dr. Morton Barlaz at North Carolina State University for analysis. Process residue from RDF production was sampled for moisture content, percent fines, percent inorganic fraction, and bio methane potential. The process residue analysis findings presented in the Summary are provided below.

Table 1: Waste Characterization Analysis Findings
Residue from RDF Production
Summary of Results

	October 2016	March 2017	May 2017	August 2017
Moisture Content (%)	26.61	33.88	38	37.1
Percent Fines (<6mm, %)	28.31	6.79	11.39	9.76
Carbon Content (%)	NT	NT	NT	NT
Hydrogen (%)	NT	NT	NT	NT
Nitrogen (%)	NT	NT	NT	NT
Inorganics (%)	NT	16.92	41.19	41.19
Calorific Value (BTU/lb. dry material)	NT	NT	NT	NT
Bio Methane Potential (mL CH4/g)	110.1	A	109.72	NA

NT = Not Tested

In summary:

- ♦ Process residue is a byproduct created from the production of RDF and material recovery; therefore, its volume, character, and quality are directly related to inbound material composition, material recovery and RDF production processes.
- ♦ Process residue composition varies annually and seasonally.

Pre-Processing Impact on Process Residue

The addition of Pre-processing equipment at the R&E Center could result in changes to the flow of material at the R&E Center as well as additional materials being recovered prior to entering the existing RDF lines. Pre-processing will have impacts on the character, quality, and quantity of process residue. The exact impacts cannot be determined until the final pre-processing designs are determined. General observations and trends, however, can be identified and are listed below.

Pre-processing equipment designed to remove ferrous, non-ferrous, cardboard and/or plastic containers through a series of mechanical processes may result in lowering the percentage of inorganic materials in the process residue. This is a direct result of those materials not being subject to the hammer mills during the production of RDF as currently occurs. The targeted materials would be extracted prior to RDF production as "whole" items.

The removal of organics through pre-processing is anticipated to have the largest impact on process residue quality. Organic materials, specifically food waste, has a high moisture content and extracting organic materials using pre-processing equipment will likely reduce the moisture content of the remaining process residue. The Summary found that the current moisture content of process residue ranged from 26.61 percent in October 2016 to 38.00 percent in May 2017. The percent moisture content after organics extraction is unknown and is dependent on the effectiveness of the pre-processing equipment at removing organic materials.

The 2015 Memorandum *Mixed Waste Processing – Update on Technology Status* (Processing Update) was based on several assumptions for tonnages and recovery rates.

The terminology, Mixed Waste Processing has been redefined by the R&E Joint Leadership Team to be pre-processing, as this would be a front-end addition to the two (2) RDF production lines. The Processing Update assumed approximately 340,000 tons of the 400,000 tons per year (TPY) of MSW delivered to the facility would first be processed with pre-processing equipment to remove ferrous, non-ferrous, cardboard, plastic containers, and organic material. It was anticipated that any MSW remaining after processing through the pre-processing system would be transferred (via conveyor) back to the beginning of the RDF lines. It is assumed some additional ferrous and non-ferrous recovery would occur in the RDF lines since there is equipment on these lines intended to remove these materials. It was assumed in the Processing Update that pre-processing would not process the entire 400,000 TPY of incoming MSW.

The Processing Update projected tonnage diversion rates assuming 340,000 tons per year are pre-processed. The projected incoming total MSW tonnage rate has grown by 10 percent from 400,000 to 440,000 tons per year since the Processing Update Memorandum was written. The diversion rates presented in the Processing Update were applied to the projected 220,000 tons per year of residential MSW (50 percent of the incoming 440,000 tons per year). Assuming the pre-processing equipment operated 364 days per year, 16 hours per day, the pre-processing system would need to operate at approximately 38 tons per hour.

Table 2 identifies the material flow and the impact on the volume of process residue with the updated assumptions. The estimates differ from the Processing Update as not all the incoming MSW to the R&E Center is anticipated to be pre-processed. The estimated material flow summary for the residential component of the MSW received at the R&E Center is provided below to show the projected reduction in TPY of process residue with the addition of pre-processing at the R&E Center. These numbers are estimates at this time based on calculations. The numbers will need to be further refined as the pre-processing system is designed.

Table 2
Material Flow Summary from the Addition of Pre-Processing

Material	Tons			
Total MSW	220,000			
Bulky Waste to Landfill		14,740		
MWP System		187,000		
Bypassed Material to RDF process		18,260		
Non-ferrous Recycled			1,383	
Ferrous Recycled			7,733	
Organics to Private AD Contractor			23,375	
HDPE Recycled			842	
PET Recycled			1,543	
Cardboard Recycled			3,292	
Process Residue to Landfill			7,701	
RDF to Combustion Plants			159,392	
Ash from Combustion to Landfill				45,666

In this pre-processing scenario, process residue tonnage is 23 percent less than the "currently produced" average generation rate of 19,951 TPY for all of the inbound MSW at the R&E Center.

A reduction in the volume of process residue produced would directly influence the Greenhouse Gas impact of waste processing. In the April 2015 *Greenhouse Gas Systems Analysis Report* (GHG Report), transportation and disposal of process residue were included in the calculation of greenhouse gas impacts from current operations, called the Processing Only Scenario. The scenario assumed 17,200 tons of process residue being transported 23 miles for landfill disposal.

- *Transportation of Process Residue:* The goal of the model was to quantify GHG emissions for material movements within the Ramsey and Washington Counties' system and account for diesel emissions as they pertain to GHG for the material movements. All transportation is modeled using on-road diesel fuel trucks.

- *Landfilling of Process Residue:* The emission factor used for process residue was based on previous laboratory testing of process residue. In 2009, Ramsey and Washington Counties conducted bio methane potential (BMP) testing on process residue collected from the R&E Center. Testing was conducted by the University of Florida under the direction of Dr. Tim Townsend. Test results indicated the BMP for the process residue was 0.045 liters of methane per gram of process residue. Since the process residue is placed in a landfill, the emission factor was adjusted for a landfill gas collection system collection efficiency and oxidation in the cover soils. The resulting emissions factor for process residue that is landfilled is 0.1565 $MtCO_{2e}$ per ton.

A reduction in the volume of process residue that needs to be transported for landfill disposal would reduce the GHG emissions both through transportation and ongoing generation rates from land disposal. Removal of organic material from the process residue would further reduce GHG emissions as it is the organic fraction of the process residue that generates the highest concentration of methane gases when land disposed. However, there is an increase in GHG emissions due to increased electrical usage at the R&E Center for the pre-processing system, which is yet to be determined. Additional GHG emission calculations will be necessary as the pre-processing system is designed.

In summary:

- ♦ Pre-processing could potentially reduce the volume of process residue for disposal. A reduction in the volume of residue transported for landfill disposal would likely reduce GHG generated.

- ♦ Pre-processing with organic recovery would reduce the moisture content of process residue. Additionally, removing all or a portion of the organic fraction in the process residue would reduce GHG generation rates of the remaining volume of material landfilled.

Marketability of Process Residue

Process residue is a by-product specific to RDF production. Table 3 contains a qualitative list of items that could impact the marketability of process residue.

Table 3
Qualitative Analysis of Process Residue

Factors	Analysis
Volume	Process residue is consistently generated by the R&E Center and available for market. Process residue generated at the R&E Center is currently transported to landfill by semi and trailer. The material destination could be adjusted with limited change to R&E Center operations.
The Character of Process Residue	Process residue character (i.e. moisture content, percent inorganic) varies and changes seasonally and on a year to year basis. How waste is processed can also affect the character and volume of process residue.
Adding Pre-Processing at the R&E Center	Removal of organic material may reduce the moisture content of the process residue and create a more consistent moisture content. Removal of organic material may reduce the moisture content of RDF. Pre-processing may reduce the rate of generation of process residue and, thus, reduce the volume of process residue that needs to be marketed.
Classification of Process Residue	Process residue may be re-classified as a manufacturing by-product or industrial waste. This could potentially open additional options for usage and disposal.
Market Availability	There is no current demand or market for process residue.

Opportunities for Improved Marketability

Potential opportunities to improve the quality of process residue through additional processing to improve marketability as a value added material include:

- *Change the character and volume* - The volume of process residue could be reduced and character could become more consistent through maximizing recycling and organics extraction. Maximizing recycling and organics extraction could occur through Source Separated Organics (SSO) programs and/or pre-processing of the inbound MSW and/or pre-or post-processing of residue. The "new" process residue would be very different from the "current" process residue. The new characterization and composition could lead to new opportunities such as disposal as industrial solid waste instead of as MSW (reduction in cost and increasing disposal options). Additional testing of residue should continue as recycling and organics extraction programs become more robust.

- *Develop a market* – Achieving a consistent character and volume of process residue may signal an opportunity to partner with bioenergy and/or university researchers to explore alternative uses for the material. Research may help to answer questions such as is process residue a good alternative for construction fill; could process residue be used as Alternative Daily Cover (ADC); and/or are there new technologies emerging to produce energy from process residue.

Process Residue Market Analysis

Residue for Composting

Assuming composting of "currently produced" process residue

The *Summary of 2016-2017 Seasonal Waste Characterization* found that the percentage of inorganic material in process residue ranged from 16.92 percent in March 2017 to 41.19 percent in May 2017. Assuming that the remaining material in process residue is organic in nature the percentage of organic material would range from 58.81 percent to 83.08 percent.

To calculate the potential tonnage of organic material in the "currently" produced process residue, findings from the *Summary of May 2017 Waste Characterization* were applied. Using this methodology, a potential of 11,733 TPY of organics from 19,951 TPY of process residue could potentially be composted. The calculations are summarized in Table 4.

Table 4
Calculating Tonnage of Organic Material in Process Residue

	May 2017
Inorganics (%) from Waste Characterization	41.19
Organic (%) from Waste Characterization	58.81
Average TPY Process Residue	19,951
Inorganic Fraction TPY	8,218
Organic Fraction TPY	11,733

The process residue can currently be composted. However, in order to market the compost that is created, a majority of the inorganic fraction would need to be removed either prior to or after composting. The inorganic fraction typically consists of rock, broken glass, small pieces of plastic, metals, etc. To mechanically remove the inorganic fraction, the process residue would need to pass through a series of trommels, disc screens, or densimetric tables. The screening could be done either before or after composting at the compost facility.

- ♦ *Technology Overview:* Trommels and disc screens separate materials according to their particle size. Densimetric tables separate material according to density. For a trommel screen, the material is fed into a large rotating drum which is perforated with holes of a certain size. Materials smaller than the diameter of the holes will be able to drop through, but larger particles will remain in the drum. For a disc screen, the material is loaded onto the disc screen where larger material travels over the top of the discs and smaller materials fall between the discs. For a densimetric table, the material is loaded onto a vibrating table. The material is separated based on particle density.

Conservatively, it is estimated that up to 50 percent of the organic fraction could be lost in these processes. This loss would represent both moisture loss and material loss. Using the calculated organic fraction tonnage and applying a 50 percent loss would result in 5,867 TPY being composted.

It is also important to determine if additional steps would be necessary to further process the organic fraction into a Class I or Class II compost. Minnesota Administrative Rule 7035.2836 indicates that Class I compost must not contain greater than three percent inert materials and Class II compost must not contain greater than four percent inert materials. Minnesota Administrative Rule 7035.2836 can be found in Appendix A.

In order to obtain a Class I compost classification, additional processing may be needed. This processing could consistent of using X-ray or optical sorters or a combination of technologies to further reduce the inorganic fraction from the end product. This additional processing could be done prior to composting or after curing of the compost.

- ♦ *Technology Overview:* X-ray sorting technology can be used to distinguish between different types of material based on their elemental atomic level. This technology allows the equipment to “see” the material at the elemental level, sensing material to ½" particle size, and detect different material types, i.e. glass from organics. The equipment then uses air or mechanical means to remove the material.

- *Technology Overview:* Optical sorters use refraction of light from a series of camera lenses pointed at a conveyor belt to see and record the light waves that bounce off the process residue. Each material generates a unique light "signature" that is read with a spectrometer. These spectral signatures (also called light fingerprints) are used to identify different types of materials. Optical sorting can be used to identify and separate a wide variety of materials including plastics, glass, wood, paper, cardboard and many other items. The equipment then uses air or mechanical means to remove the material.

With an assumed volume reduction of 3:1, the 5,867 tons of projected organic waste would produce 1,956 tons of finished compost. In two Minnesota Compost Council membership surveys (2012/2013 and 2015/2016) mean processing costs of $52 per ton of finished compost were reported, a mixture of Class 1 and Class II compost, with individual jurisdictions reporting as low as $5 per ton and as high as $104 per ton. Using this mean processing cost per ton, it would cost $101,689 to process the organic fraction of process residue produced annually at the R&E Center. Specific costs will vary based on the actual composition and technology used for process residue. There are additional costs for the technology applications listed above to prepare the material for composting.

In contrast, it would cost $1,197,060 to landfill the 19,951 TPY of process residue, assuming a landfill tipping rate of $60 per ton. There are additional costs for transportation of the process residue to a landfill.

Evaluate the Use of Residue for Anaerobic Digestion (AD)

Assuming anaerobically digesting "currently produced" process residue

The calculated organic fraction tonnage for composting will be used to evaluate AD potential for process residue.

The anticipated 19,951 tons of process residue would be delivered to a privately owned and operated AD facility. In *Anaerobic Digestion (AD) – Update on Technology Status*, AD processing of organic only materials was projected to result in approximately 38% material by weight remaining for composting. It is unknown how many tons would remain after AD processing of process residue.

- *Technology Overview:* The use of AD for processing organic materials in a controlled oxygen-deficient (anaerobic) environment is a proven technology that has been used for low solids waste stream such as manure, waste water solids, etc. The use of AD for processing high solids organic waste (e.g. organics from MSW) has been used to a lesser extent but is seeing increased adoption due to increased waste diversion goals in many communities and an increased emphasis on renewable energy and biofuels. There are two primary AD technologies in use today: Wet and Dry.

Wet (Low Solids) AD - In a wet AD system, the organic materials typically enter the AD process between 10% to 20% solids content. This solids content is typical of waste water sludge, manure, rendering waste, etc.

Dry (High Solids) AD - In a dry AD system, the organic materials typically enter the AD process at between 20% and 40% solids content. The higher solids content is generally more representative of the organics separated from MSW using pre-processing technology. Note: R&E Board Commissioners and staff saw a Dry AD system at the 2014 Renewable Energy from Waste Conference in San Jose, CA.

Figure 3
ZeroWaste Energy Development Company Facility,
San Jose, California
www.zwedc.com

The purpose of anaerobically digesting MSW is to produce biogas and to digest and reduce the amount of carbon in the organics present. Anaerobically digesting MSW results in a digestate that is comprised of an organic fraction and an inorganic/inert fraction.

The final use of the digestate is typically dependent on how the particular AD system is operated. This includes the amount of remaining carbon and the amount of contamination (i.e. inorganic materials such as glass, plastic, etc.) that remain:

- If carbon content is minimized or reduced substantially the digestate is often utilized as an alternative daily cover or inert landfill material for disposal.
- If adequate carbon content remains, the organic material can be composted to create a Class I or Class II compost to maximize diversion and minimize landfilled material.

In order to reach a Class I compost classification, additional processing would be needed. Glass remaining in finished compost is a known problem facing AD systems operating in the United States. *Anaerobic Digestion (ASD) – Update on Technology Status* noted that the Organix Solutions AD system known as Burr Cell is anticipated to result in a compost that meets Class I standards, but is believed to contain glass fragments that will inhibit retail sale.

It is unknown if the inorganic fraction would cause harm to AD equipment and, thus, a Trommel and/or disc screen system may need to be utilized prior to AD instead of after as may be an option with composting. This may add to the cost of delivering organics to an AD processor.

The same technology used for cleaning finished compost described in the compost evaluation would be needed for AD produced compost. R&E Board and Foth staff have had conversations with AD providers in the United States since 2015. During discussions in 2016, Zero Waste, an AD vendor, stated they would be willing to accept process residue for anaerobic digestion at a cost of $80 to $120 per ton. This cost is significantly higher than the current landfill disposal rates.

In May 2017, the R&E Board partnered with Anaergia, Inc. (Anaergia) to test its press technology. Results are reported in *Summary of May 2017 Waste Characterization*. Anaergia completed several press tests on six (6) different types of incoming material at the R&E Center including process residue, both the wet and dry fraction. Table 4 shows an excerpt of the findings.

The Anaergia analysis and organics characterization provided information on how much wet and dry fraction are in the various materials when pressure is applied. These findings will be useful when discussing the value of process residue as an AD feedstock with potential vendors.

Table 4
Waste Characterization and Anaergia Energy AD Analysis Findings Residue from RDF Production - Summary of Results

	Moisture Content (%)	Percent Fines (<6mm, %)	Carbon Content (%)	H (%)	N (%)	Inorganics (%)	Calorific value (BTU/lb. dry material)	BMP (mL CH4/g)
Sample 3 - <2" Residue	38.00	11.39	NT	NT	NT	41.19	NT	109.72
Pilot Press - Wet Fraction - R&E Center Residue	50.70	NT	NT	NT	NT	43.38	NT	171.18
Pilot Press - Dry Fraction - R&E Center Residue	36.20	28.75	31.71	10.71	0.52	41.39	5,594.00	NT

NT = Not Tested

Currently, there is no established AD facility in the vicinity of the R&E Center using process residue as feedstock.

Great River Energy Residue Testing

Great River Energy (GRE) also participated in the Anaergia test during May 2017. GRE transported samples of its 2-inch minus materials from its Elk River Resource Recovery Facility (ERRRF) in Elk River, MN to the R&E Center in Newport, MN. The ERRRF has the ability to divert and separately collect 2-inch minus materials. The R&E Center's current technology does not allow for this diversion; hence, this testing was a way to learn the differences between process residue and 2-inch minus.

In comparing the wet fraction test results, GRE's 2-inch minus had a considerably lower inorganics percentage and a higher BMP (mL CH4/g) than the R&E Center's process residue. The moisture content was higher in the GRE's 2-inch minus – dry fraction – as compared to the R&E Center's residue – dry fraction, see Table 5.

Table 5: Elk River Energy's Anaergia Energy AD Analysis Findings Residue from RDF Production - Summary of Results

	Moisture Content (%)	Percent Fines (<6mm, %)	Carbon Content (%)	H (%)	N (%)	Inorganics (%)	Calorific value (BTU/lb. dry material)	BMP (mL CH4/g)
Pilot Press – Wet Fraction – GRE 2-inch Minus	63.30	NT	NT	NT	NT	24.69	NT	259.41
Pilot Press – Dry Faction – GRE 2-inch Minus	41.10	16.77	29.75	9.47	0.55	40.30	5,497.00	NT

NT = Not Tested

Potential Next Steps

1. Conduct additional testing of the process residue to develop a baseline of organic and inorganic composition over time.

2. Complete additional calculations on material outputs and GHG emissions as the pre-processing system design is further refined.

3. Continue to monitor and collect information on AD technology that can be utilized for the processing of process residue.

Appendix A: Class I and II Compost

7035.2836 COMPOST FACILITIES.

Subpart 1. **Scope.** The owner or operator of a yard waste compost facility must comply with subparts 2 and 3 only. The requirements of subparts 4 to 7 apply to the owner and operator of a facility used to compost solid waste. The owner or operator of a source-separated organic material compost facility must comply with subparts 6 to 11.

Subp. 2. **Notification.** The owner or operator of a yard waste compost facility shall submit a notification form to the commissioner on a form prescribed by the commissioner before beginning facility operations. The notification must include: the facility location; the name, telephone number, and address of the contact person; the facility design capacity; the type of yard waste to be received; and the intended distribution of the finished product.

Subp. 3. **Operation requirements for yard waste compost facility.**

A. Odors emitted from the facility shall comply with the applicable provisions of any agency odor rules.

B. Composted yard waste offered for use must be produced by a process that includes turning of the yard waste on a periodic basis to aerate the yard waste, maintain temperatures, and reduce pathogens.

C. Compost will not contain greater than three percent inert materials (dry weight) that are greater than or equal to four millimeters as determined by the testing procedure under subpart 5, item J, subitem (3).

D. By-products, including residuals and recyclables, must be stored in a manner that prevents vector problems and aesthetic degradation. Materials that are not composted must be stored and removed at least weekly.

E. Surface water drainage runoff must be controlled to prevent leachate leaving the facility. Surface water drainage run-on must be diverted from the compost and storage areas.

F. The facility shall be constructed and operated to prevent discharge of yard waste, leachate, residuals, and the final product into waters of the state.

G. The facility operator shall submit an annual report to the commissioner by March 1 of each year for the preceding calendar year that includes the type and quantity, by weight or volume, of yard waste received at the compost facility; the quantity, by weight or volume, of compost produced; an average of the inert test results; the quantity, by weight or volume, of compost removed from the facility; and a market description.

Subp. 4. **Design requirements for solid waste compost facility.** The owner or operator of a compost facility shall submit an engineering design report to the commissioner for approval with the facility permit application. The engineering report must comply with the design requirements in items A to G.

A. Site preparations must include clearing and grubbing for the compost operating and storage areas, building locations, topsoil stripping, excavations, berm construction, drainage control structures, leachate collection system, access roads, screening, fencing, and other special design features.

B. Access to the facility must be controlled by a perimeter fence and gate or enclosed structures.

C. Surface water drainage must be diverted around and away from the site operating area. A drainage control system, including changes in the site topography, ditches, berms, sedimentation ponds, culverts, energy breaks, and erosion control measures, must comply with part 7035.2855, subpart 3, items C to E.

D. The composting, curing, and storage areas for immature compost must be located on a liner capable of minimizing migration of waste or leachate into the subsurface soil, groundwater, and surface water. The liner must have a permeability no greater than 1×10^{-7} centimeters per second and, if constructed of natural soils, be at least two feet thick. The liner must comply with part 7035.2855, subparts 3, item A; 4; and 5.

E. Liquid in contact with waste, immature compost, and residuals must be diverted to a leachate collection and treatment system. The leachate collection and treatment system must comply with part 7035.2855, subpart 3, item B, and the applicable portions of part 7035.2815, subpart 9, items B to K.

F. The facility must be designed for collection of residuals and must provide for the final transportation and proper disposal of residuals.

G. The facility must be designed and operated to control odors in compliance with the applicable provisions of any agency odor rules.

Subp. 5. **Operation requirements for solid waste compost facility.** The owner or operator of a compost facility shall submit an operation and maintenance manual to the commissioner for approval with the facility permit application. The manual must include a personnel training program plan, a leachate management plan, and a compost sampling plan and must comply with the operation requirements in items A to L.

A. All access points must be secured when the facility is not open for business or when no authorized personnel are on site.

B. The personnel training program plan must address the requirements of part 7035.2545, subparts 3 and 4, and the specific training needed to operate a compost facility in compliance with this subpart and subparts 6 and 7.

C. All wastes delivered to the facility must be confined to a designated delivery area and processed or removed at least once a week to prevent nuisances such as odors, vector intrusion, and aesthetic degradation.

D. All salvageable and recyclable materials must be containerized or stored and removed from the facility in a manner that prevents nuisances such as odors, vector intrusion, and aesthetic degradation.

E. All compost residuals must be stored to prevent nuisances such as odors, vector intrusion, and aesthetic degradation. The residuals must be removed and properly disposed of at least once a week.

F. The leachate management plan must describe how the facility will store, reuse, or dispose of collected leachate. If leachate is to be recirculated into the compost, it must be added prior to initiating the PFRP process described in item I.

G. Odors emitted by the facility must comply with any applicable agency odor rules.

H. The owner or operator must cover or otherwise manage the waste to control wind dispersion of any particulate matter.

I. Compost must be produced by a process to further reduce pathogens (PFRP). The temperature and retention time for the material being composted must be monitored and recorded each working day. Three acceptable methods of a PFRP are described in subitems (1) to (3):

(1) The windrow method for reducing pathogens consists of an unconfined composting process involving periodic aeration and mixing. Aerobic conditions must be maintained during the compost process. A temperature of 55 degrees Celsius must be maintained in the windrow for at least three weeks. The windrow must be turned at least once every three to five days.

(2) The static aerated pile method for reducing pathogens consists of an unconfined composting process involving mechanical aeration of insulated compost piles. Aerobic conditions must be maintained during the compost process. The temperature of the compost pile must be maintained at 55 degrees Celsius for at least seven days.

(3) The enclosed vessel method for reducing pathogens consists of a confined compost process involving mechanical mixing of compost under controlled environmental conditions. The retention time in the vessel must be at least 24 hours with the temperature maintained at 55 degrees Celsius. A stabilization period of at least seven days must follow the enclosed vessel retention period. Temperature in the compost pile must be maintained at least at 55 degrees Celsius for three days during the stabilization period.

J. The owner or operator must comply with the compost sampling and testing plan approved by the commissioner. Proposed changes to sampling equipment or procedures must be submitted to the commissioner for review and approval. Testing must be conducted when each batch of compost matures. The plan must include the sampling and testing requirements in subitems (1) to (6).

(1) The compost maturity must be determined using testing protocol described in the sampling plan. "Mature" means more than 60 percent decomposition has been achieved as determined by an ignition-loss analysis and one test method approved by the commissioner including, but not limited to, the following:

	Test Method	**Maturity Standard**
(a)	Carbon/nitrogen ratio - U.S. EPA Method 9060A: Total Organic Carbon and Dumas	In the range of 10:1 to 20:1
(b)	Dewar Self-Heating Method	Temperature rise above ambient in CÃ,Â°, range of 0Ã,Â° - 20Ã,Â° Celsius
(c)	Respiration Rate, CO_2 Analysis	<2-5 (mg. CO_2-C/g compost carbon-day)
(d)	U of M Z-test - Soil and Crop Research on Municipal Solid Waste Class I Compost Utilization in Minnesota, April 10, 1994	The weight of the worms in the cellulose treatment increases and that of the worms in the noncellulose treatment remains the same
(e)	Cress Seed Germination - Recommended Test Methods, The Composting Council	Germination index in the range of 1.0 - 0.8

(2) Each batch of compost that has been determined to be mature must be analyzed for the metal contaminants listed in subpart 6, item A, subitem (1), using the U.S. EPA test methods in EPA SW-846. PCBs in the compost must be extracted using either method 3540 or 3550 and analyzed with method 8080.

(3) The amount of inert material in each batch of compost that has been determined to be mature must be determined using testing protocol described in the sampling plan. Inert content greater than four millimeters shall be determined by passing four replicates of 250 cc oven-dried (70 degrees Celsius) samples of compost through a four millimeter sieve. Material remaining on the sieve shall be visually inspected and inerts, including glass, metal, and plastic, shall be separated and weighed. The weight of the separated inert material divided by the weight of the total sample, multiplied by 100, shall be the percent dry weight of the inert material content.

(4) The mature compost must be analyzed for the following parameters using the testing protocol described in the sampling plan:

(a) pH;

(b) moisture content;

(c) particle size;

(d) NPK ratio; and

(e) soluble salt content.

(5) The sampling plan must contain techniques for collecting and processing the samples required in subitems (1) to (4), including:

(a) the training and experience qualifications of persons who collect samples;

(b) equipment used to collect, process, and store samples;

(c) sampling equipment cleaning procedures and other actions taken to prevent sample contamination;

(d) the location or locations where samples are collected;

(e) procedures used to collect grab samples;

(f) procedures used to process grab samples to form composite samples;

(g) chain-of-custody and sample storage procedures; and

(h) compost sampling quality assurance and quality control measures.

(6) The sampling plan must describe how the test results from the samples required in subitems (1) to (4) will be utilized to define the compost at distribution, and must include:

(a) a description of the batch process, statistical average, or other method used to classify the compost, and assign it physical and chemical properties; and

(b) a description of the method used to calculate the cumulative and annual pollutant loading rates for Class II compost.

K. An annual report complying with part 7035.2585 must be submitted to the commissioner by March 1 of each year for the preceding calendar year. A record of the following information must be maintained at the facility and included in the annual report:

(1) the quantity of source-separated compostables or solid waste delivered to the facility;

(2) the quantity and general material breakdown of recyclables and rejects removed from the waste;

(3) the sources and quantities of other materials used in the compost process, such as nutrient or bulking agents;

(4) a summary of temperature and retention time for all compost produced verifying that the process, set out in item I, to further reduce pathogens is being met;

(5) the quantity and classification of all compost produced;

(6) a summary of all lab analyses conducted according to the sampling plan approved under item J;

(7) a record of each Class II compost distribution, including the following:

(a) a copy of the information sheet or label accompanying all Class II compost distributions according to subpart 7;

(b) the name of the compost user and a legal description of the application site location, including the quantity of compost and acreage over which it was distributed;

(c) copies of the letters of notification to the local governments; and

(d) a copy of the United States Geological Survey map of the application site and the surrounding areas showing contours and surface waters.

L. If, for any reason, the facility becomes inoperable, the owner or operator of the facility must notify the commissioner within 48 hours and implement the contingency action plan developed under part 7035.2615.

Subp. 6. **Compost classification.** Compost produced at a solid waste compost facility must be classified as Class I or Class II compost based on the criteria outlined in items A and B. Compost test results shall be used to classify the compost according to the approved sampling plan under subpart 5, item J, the maturity standard in subpart 5, item J, subitem (1), and the PFRP requirement in subpart 5, item I.

A. Class I compost must meet the following criteria:

(1) Class I compost cannot exceed the contaminant concentrations in milligram per kilogram on a dry weight basis as listed in the following table or Code of Federal Regulations, title 40, section 503.13(b)(3), as amended, with the exception of mercury, which cannot exceed contaminant concentrations of five milligrams per kilogram.

Contaminant	**Concentration (mg/kg)**
Arsenic (As)	41
Cadmium (Cd)	39
Copper (Cu)	1,500

Lead (Pb)	300
Mercury (Hg)	5
Molybdenum (Mo)	18
Nickel (Ni)	420
Selenium (Se)	100
PCB	6
Zinc (Zn)	2,800

(2) Class I compost must not contain greater than three percent inert materials (dry weight) greater than or equal to four millimeters as determined by tests according to the approved sampling plan under subpart 5, item J, subitems (1) to (5).

B. Class II compost consists of any compost that fails to meet the Class I standards and meets the criteria in subitems (1) and (2):

(1) Class II compost must meet the following pollutant loading rates and have a PCB concentration that does not exceed six milligrams per kilogram.

Pollutant	**Cumulative Pollutant Loading Rate**	
	(lbs/acre)	**(kg/hectare)**
Arsenic	37	41
Cadmium	34	39
Copper	1,338	1,500
Lead	267	300
Mercury	5	5
Molybdenum	16	18
Nickel	374	420
Selenium	89	100
Zinc	2,497	2,800

Pollutant	**Annual Pollutant Loading Rate (for a containerized compost)**	
	(lbs/acre)	**(kg/hectare)**
Arsenic	1.8	2
Cadmium	1.7	1.9

Copper	66.8	75
Lead	13.3	15
Mercury	0.25	0.25
Molybdenum	0.5	0.5
Nickel	18.7	21
Selenium	4.5	5
Zinc	124.6	140

(2) Class II compost must not contain greater than four percent inert materials (dry weight) greater than or equal to four millimeters as determined by tests according to the approved sampling plan under subpart 5, item J, subitems (3) and (5).

Subp. 7. **Compost distribution and end use.** The owner or operator of a solid waste compost facility shall submit a compost distribution plan to the commissioner for approval with the facility permit application. The plan must comply with the requirements in items A to C.

A. Compost distributed or marketed as a fertilizer, specialty fertilizer, soil amendment, or plant amendment, as defined in Minnesota Statutes, section 18C.005, must be registered with the Minnesota Department of Agriculture.

B. The allowable end uses for the compost must be listed and described in the plan.

C. Class I compost may be distributed for unrestricted use. Class II compost may be distributed on a restricted basis. The commissioner or a compost operator trained as required in subpart 5, item B, shall determine the appropriate distribution for a Class II compost used in land application. Compost proposed to be distributed for end uses other than land application may be distributed with the commissioner's approval or as part of the approved facility compost distribution plan under this subpart. All Class II compost distributed must be accompanied by an information sheet or label describing the compost product and its physical and chemical quality, including at least the following information:

(1) the name and address of the generator;

(2) a statement from the generator certifying that the compost meets the Class II classification standards under subpart 6, item B, and providing the standards;

(3) a list of best management practices to use when applying the compost;

(4) the annual or cumulative application rate calculated according to the testing and reporting methods approved under subpart 5, item J, subitem (6);

(5) the compost maturity tested and reported according to subpart 5, item J, subitem (1);

(6) the compost inert content tested and reported according to subpart 5, item J, subitem (3); and

(7) a statement of the compost parameter values tested and reported according to subpart 5.

Subp. 8. **Location requirements for a source-separated organic material compost facility.** An owner or operator must not establish or construct a source-separated organic material compost facility in the following areas:

A. within locations described in part 7035.2555;

B. on a site with karst features including sinkholes, disappearing streams, and caves;

C. within five vertical feet of the water table; and

D. unless a different distance is specified by a local unit of government by ordinance, within 500 feet horizontal separation distance as measured from the closest edge of all compost activities to the closest edge of a property boundary of the nearest residence, place of business, or public area, such as parks, wildlife areas, and public buildings, except:

(1) upon approval of the commissioner, operational modifications, geographic features, or other natural or man-made physical characteristics that reduce nuisance conditions, such as noise, litter, and odor, may be used to reduce the 500-foot horizontal separation distance; and

(2) adjacent commercial activities operated by the facility owner are excluded from the 500-foot horizontal separation requirement for the owner's residence or place of business.

Subp. 9. **Design requirements for a source-separated organic material compost facility.**

A. The owner or operator of a source-separated organic material compost facility must submit an engineering design report to the commissioner for approval with the facility permit application.

B. The engineering design report must comply with the design requirements in subitems (1) to (10).

(1) Site preparations must include clearing and grubbing for the compost operating and storage areas, building locations, topsoil stripping, excavations, berm construction, drainage control structures, storm water management systems, contact water collection systems, access roads, screening, fencing, and other special design features.

(2) Access to the facility must be controlled to prevent unauthorized entry. A perimeter fence and gate, enclosed structures, or other physical barriers must be used to prevent unauthorized entry to the facility.

(3) Storm water drainage must be diverted around and away from the compost storage and operating areas. The storm water drainage control system must be designed to manage a 24-hour, 10-year storm event. A storm water drainage control system, including changes in the site topography, ditches, berms, sedimentation ponds, culverts, energy breaks, and erosion control measures, must comply with part 7035.2855, subpart 3, items C to E. For purposes of this subpart, water that has come into contact with compost in the curing and finished storage areas is considered storm water. For purposes of this subpart, compost has reached the curing stage after PFRP as described in subpart 11, item B, subitem (10), has been achieved and the Solvita maturity index is greater than or equal to five with the ammonia greater than or equal to four. An owner or operator may use alternative test methods that are approved by the commissioner as equivalent to those listed in this subitem.

(4) Contact water must be diverted to a contact water collection and treatment system. The contact water collection and treatment system must comply with applicable portions of part 7035.2815, subpart 9. For purposes of this subpart, immature compost is defined as not having reached the curing stage described in subitem (3).

(5) The facility must be designed for collection of rejects and residuals and must provide for the final transportation and proper disposal of rejects and management of residuals.

(6) The tipping, mixing, active composting, curing, and storage areas for compost must be located on a hard-packed, all-weather surface capable of minimizing migration of materials or contact water into the subsurface soil, groundwater, and surface water.

(7) The working surface of a source-separated organic material compost facility must have a minimum of five feet of soil separation to the water table.

(8) Unless designed as allowed under subitem (9), the site must have at least five feet of any combination of the following soil types comprising the soil profile above the water table: sandy clay loam, sandy clay, clay loam, silty clay loam, silty clay, and clay. An owner or operator may use an alternate separation distance according to unit (a). Water tables classified as perched or epi-saturated by the United States Department of Agriculture, Natural Resources Conservation Service, are not considered to be the seasonal high water table. The soil profile must be characterized by the use of soil borings, piezometers, or test pits as certified by a Minnesota-licensed soil scientist, engineer, or geologist. The owner or operator may propose the use of alternative methods for soil profiles according to unit (b).

If the site cannot meet the soil criteria, an impervious pad or liner must be installed under all activity areas except curing and storage of finished compost.

(a) The owner or operator may use an alternative separation distance that is approved by the commissioner as equivalent to that listed in this subitem if, during the previous five years:

i. the site has experienced an abnormally wet period or an abnormally dry period; and

ii. the elevation of the water table at the site has changed.

The alternative separation distance must maintain a sufficient distance between the water table and compost activities to account for the movement of the water table through normal wet and dry years.

(b) An owner or operator may use alternative methods that are approved by the commissioner as equivalent if the owner or operator can demonstrate that the alternative methods provide soil profile characterization substantially equivalent to characterization by soil borings, piezometers, or test pits.

(9) Owners and operators whose sites are unable to meet the soil requirement listed under subitem (8) must install a pad system in all areas where source-separated organic materials will be managed and composted prior to curing. For the purposes of this subpart, compost has reached the curing stage after PFRP as described in subpart 11, item B, subitem (10), has been achieved and the Solvita maturity index is greater than or equal to five with an ammonia test result of greater than or equal to four. An owner or operator may use alternative test methods that are approved by the commissioner as equivalent to those listed in this subitem. Sites requiring a pad must comply with one of the options listed in units (a) to (c).

(a) If a geomembrane is used, the liner system must be designed and built according to the applicable criteria in part 7035.2815, subpart 7. The surface must comply with part 7035.2855, subpart 3, item A.

(b) If a concrete or asphalt pad is used, the surface must at a minimum meet requirements established in the Minnesota Department of Transportation, Road Design Manual, incorporated by reference under part 7035.0605. The owner or operator must inspect the pad routinely and immediately repair any cracks, crumbling, and failures. The owner or operator must include the results of all inspections and repairs in the annual report submitted to the commissioner.

(c) An alternative liner system design may be used when approved by the commissioner. The owner or operator must demonstrate that the proposed liner system will control contact water migration, meet performance standards, and protect human health and the environment.

(10) The owner or operator must design the site to minimize liquids; odors; vectors, such as flies and rodents; and nuisance conditions, such as litter, noise, ponding water, and erosion.

Subp. 10. **Construction requirements for a source-separated organic material compost facility.** The owner or operator must include the construction requirements in items A to G in the project specifications for all design features of a source-separated organic material compost facility.

A. The owner or operator must notify the commissioner in writing at least ten days before the day construction is expected to begin on any design features.

B. The construction firm's inspector must record all procedures completed during construction at a source-separated organic material compost facility. The record must document that design features were constructed according to parts 7035.2525 to 7035.2915. The record must include pictures, field notes, and all test results.

C. The owner or operator must install a permanent benchmark on site and show its location on the facility as-built plan.

D. The owner or operator must complete tests for compaction, grain size distribution, and field moisture density, at a minimum, for soil pads constructed at the facility.

E. Flexible membranes must be installed during dry conditions. The seams joining membrane panels must be inspected as construction proceeds. Seams must be air tested and field seams must be tested for tensile strength. All flexible membranes must be protected after placement. The natural layer above and below the barrier layer must be free of roots, sharp objects, rocks, or other items that might puncture the liner.

F. A quality control and quality assurance program must be established for all construction projects. The program must include the tests to be completed during construction. The program must also establish the frequency of inspection and testing, the accuracy and precision standards for the tests, procedures to be followed during inspections and sample collection, and the method of documentation for all field notes including testing, pictures, and observations.

G. If a geomembrane is used, the surface must comply with part 7035.2855, subpart 5.

Subp. 11. **Operation requirements for a source-separated organic material compost facility.**

A. The owner or operator of a source-separated organic material compost facility must submit an operation and maintenance manual to the commissioner for approval with the facility permit application. The manual must include a source-separated organic materials management plan, a personnel training program plan, a contact water management plan, a storm water management plan, an odor management plan, and a compost sampling plan.

B. The facility operations must at a minimum meet the requirements in subitems (1) to (16).

(1) All access points must be secured when the facility is not open for business or when no authorized personnel are on site.

(2) All source-separated organic materials delivered to the facility must be confined to a designated delivery area and processed or removed by the end of the day on which the materials were delivered to prevent nuisances such as odors, vector intrusion, and aesthetic degradation.

(3) All salvageable and recyclable materials must be containerized or stored and removed from the facility in a manner that prevents nuisances such as odors, vector intrusion, and aesthetic degradation.

(4) All rejects and residuals must be stored to prevent nuisances such as odors, vector intrusion, and aesthetic degradation. All rejects and residuals must be managed to prevent the generation of contact water. All contact water from rejects and residuals storage areas must be diverted to the contact water collection and treatment system. The commissioner shall grant an exception to contact water requirements for residuals if the owner or operator demonstrates during the permit application process or during a site inspection that residuals do not exceed three percent rejects by volume.

(5) Liquid that has come in contact with source-separated organic material, immature compost, and residuals must be diverted to a collection and treatment system.

(6) Contact water or storm water may be reused in the compost process. It must be added to the source-separated organic materials prior to initiating the PFRP process described in subitem (10). Any water to be discharged into waters of the state must meet all federal and state national pollutant discharge elimination system requirements.

(7) The owner or operator must operate and maintain a drainage system to divert storm water around and away from the site operating area.

(8) The owner or operator must cover or otherwise manage all the material on site to control wind dispersion of any particulate matter.

(9) The owner or operator must develop and maintain a source-separated organic material management plan. The plan must, at a minimum:

(a) include a waste analysis plan to characterize source-separated organic materials prior to acceptance at the facility;

(b) identify the area of the facility where source-separated organic materials will be delivered; and

(c) describe management methods to be employed when source-separated organic materials are delivered to the facility. The management methods must address reducing odor, vectors, such as flies and rodents, and nuisance conditions, such as litter, noise, ponding water, and erosion; minimizing liquids; and mixing source-separated organic materials to achieve the proper moisture content, carbon-to-nitrogen ratio (C:N ratio), porosity, and pH.

Acceptable source-separated organic materials are defined in part 7035.0300, subpart 105a, and acceptable bulking agents include untreated wood waste, nonrecyclable paper, ground tree and shrub materials, and other similar materials approved by the commissioner.

(10) Compost must be produced by a process to further reduce pathogens (PFRP). The owner or operator must monitor and record the temperature and retention time for the material being composted each working day until PFRP is achieved, and weekly thereafter. Each time a windrow is turned, the temperature must be measured no more than four hours before turning the windrow and no more than 24 hours after turning the windrow. Acceptable methods of PFRP are described in units (a) to (c).

(a) The windrow method for reducing pathogens consists of an unconfined composting process involving periodic aeration and mixing. Construction of each windrow must incorporate porous materials that promote aerobic conditions within the windrow. Windrow height must not exceed 12 feet. Aerobic conditions must be maintained during the compost process. A temperature of 55 degrees Celsius must be maintained in the windrow for at least 15 days, during which the windrow must be turned at least once every three to five days, unless otherwise approved by the commissioner in the operation and maintenance manual due to defined weather conditions.

(b) The static aerated windrow method for reducing pathogens consists of an unconfined composting process involving mechanical aeration of insulated compost piles. Windrow height must not exceed 12 feet. Aerobic conditions must be maintained during the compost process. The temperature of the compost pile must be maintained at 55 degrees Celsius for at least seven days.

(c) The enclosed vessel method for reducing pathogens consists of a confined compost process involving mechanical mixing of compost under controlled environmental conditions. The retention time in the vessel must be at least 24 hours, with the temperature maintained at 55 degrees Celsius. A stabilization period of at least seven days must follow the enclosed vessel retention period. Temperature in the compost pile must be maintained at least at 55 or more degrees Celsius for three days during the stabilization period.

(11) The owner or operator must comply with subpart 5, item J. For Class I compost as defined under subpart 6, the owner or operator may request removal of mercury (Hg) and polychlorinated biphenyls (PCB) sampling and testing requirements based on five years of sampling batch data. The data must demonstrate nondetect results for Hg and PCB.

(12) The owner or operator must develop and maintain an odor management plan detailing the best management practices (BMPs) to be used during normal operations to minimize odors. These BMPs must address how the oxygen levels and porosity will be managed to minimize odors. The plans must detail how the facility will handle odor complaints and the specific odor control measures and safeguards the owner or operator will employ to resolve the complaints. At a minimum, the odor management plan must address BMPs to minimize odor generation in the mixing and tipping areas, active compost processing areas, and contact water and storm water ponding areas.

(13) The owner or operator must develop a personnel training program. The personnel training program must address the requirements of part 7035.2545, subparts 3 and 4, and the specific training needed to operate a source-separated organic material compost facility in compliance with this subpart and subparts 6 to 10. Personnel training for a source-separated organic material compost facility must include a training schedule that:

(a) provides an initial training session of 24 contact hours within 12 months of employment; and

(b) provides five contact hours of training on an annual basis.

A contact hour means a pertinent instructional or training session of 50 minutes. The commissioner shall prepare and make available to the operators and inspectors a list of accredited training courses and approved educational activities. The commissioner shall grant approval if the content includes topics such as the compost process, composting methods, facility operations, odor control, source-separated organic materials management, or other topics related to the best management practices of operating a compost facility.

(14) The owner or operator must submit an annual report according to subpart 5, item K. The annual report must be submitted on a form prescribed by the commissioner. For source-separated organic material compost facilities, the annual report must include the county of origin and volume of source-separated organic materials received.

(15) If for any reason the facility becomes inoperable, the owner or operator must notify the commissioner within 48 hours and implement the contingency action plan developed under part 7035.2615.

(16) If a geomembrane is used, the owner or operator must comply with part 7035.2855, subpart 4.

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