Report

Assessment of Biofilters at Harvest Power

Richmond, BC

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CDM Smith

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Section 1

Background and Data Sources

1.1 Background

This report has been prepared for submittal to the Greater Vancouver Regional District to meet reporting requirements under the Air Quality Management Permit GVA 1054 issues to Fraser Richmond Soil & Fibre Ltd., dated May 11, 2013. The report also provides recommendations for future odor control improvements . The composting operation has undergone considerable changes in 2-13. In April 2013, the covered aerated static pile (CASP) height was reduced from 20-30 ft to 10-12 ft to better match pile volume to aeration capacity and minimize anoxic conditions. In July digestate from the Energy Garden percolating tunnels was introduced into the mix. In September the process was converted from CASP to turned windrows with forced aeration to improve process control and better mix in the digestate. Much of the emissions data was collected in July, and may not accurately reflect current operating conditions.

1.2 Data Sources

The following reports were reviewed in preparing this report. Documents are referenced by source number as they are used in the text. In addition, operations were observed on December 11 and 12, 2013. Operational and odour control procedures were reviewed, and data were discussed to ensure a full understanding of sampling and operational reporting procedures.

Table 1-1 Reference Documents Used in Report

RD 1	Weekly Regulatory Check	Pressure, air temperature, % O_2, H_2S, CO, air velocity for each windrow composting biofilter lateral
RD 2	Biofilter Weekly Reports and pH and solids data from Benchmark Labs	Weekly pH, % solids, air temperature, and pressure entering biofilter
RD 3	Volatile Organic Compounds Analysis Benchmark Labs July 2013	VOC species pre-dating conversion to windrow composting
RD 4	Envirochem reports December 2013	Biofilter was divided into grid points and scanned using flame ionization and photo ionization detectors. Multiple scans
RD5	Biofilter Emission and Test Report 3rd Quarter 2013 by Levelton Consultants, Ltd., October 17, 2013	Air flow rates and total VOCs for each biofilter
RD 6	*Odour Evaluation of Forty Air Samples Environmental Odour Consulting December 16, 2013*	*Odour concentrations and hedonic values for inlet and outlet of each biofilter and fugitive sources*
RD 7	Benchmark Laboratory Report December 20, 2013	Analysis of biofilter media from test pits
RD 8	Air flow data by Harvest Power received 12/11/2013	Velocity traverses in all biofilter ducts, per EPA Method 1.
RD -9	Air Quality Assessment for Harvest Power by Levelton Consultants, Ltd. October 22,2013	Atmospheric dispersion models of odour using emissions that pre-dated conversion to windrow composting. Used for background information only

On December 12, 2013 test pits were dug to the bottom of the media in the two composting biofilters and the Energy Garden biofilter. The condition of the media was observed, and samples were sent out for laboratory analysis for sulfur and nitrogen species.

Section 2

Odour Capture

2.1 Overview of Composting Process

As originally designed, the composting process took place on two aerated pads. The continuous piles were generally level and covered most of the pad area except for vacant slots for unloading and loading. The composting mix was covered with mid-size screen overs or other material to provide a surface layer to act as a biofilter for odour control and to provide thermal insulation to meet pathogen reduction requirements. This was designated the covered aerated static pile (CASP) process. The pads were under negative aeration to provide oxygen and capture odour, and the exhaust was treated with biofilters. Historically the piles were 20 to 30 ft. high. In April 2013, the pile height was reduced to 10 ft. to meet or exceed stoichiometric aeration supply for the feedstock and to minimize odour-generating conditions.

Food waste was added to the composting feedstocks beginning in late 2012. Once the construction of the anaerobic digestion facility (Energy Garden) was complete in early 2013, food waste was transferred from the compost stream. Digested food and yard waste from the Energy Garden was added to the composting feedstock in increasing amounts since early 2013. This material is more odourous than the woody and vegetative waste and contains more moisture and acidity. The volatile solids content of the digestate is reported to be 65 percent, which is still high enough to contribute energy to the composting process.

The composting process was changed in September 2013 from CASP to turned windrows, on a trial basis until the end of 2014, in order to increase surface area for natural aeration and increase homogeneity through turning. Aerated windrows are located within the confines of the original CASP pads, with the windrows running perpendicular to the aeration pipes. There are data from other composting facilities indicating that negative aeration can capture only a portion of the odour from an aerated static pile, because the high temperature generates convection currents that move odorous exhaust to the surface. The current approach to odour control is to utilize thermal convection in the windrows to provide most of the aeration, and to minimize odour by maintaining aerobic conditions. This approach is widespread throughout North America and usually provides sufficient process control when the feedstock includes only wood and vegetative material. Facility also has a detailed forecast and alert system which can assist in the timing of windrow turnings so that dispersion of odor is maximized.

Windrows are turned approximately 5-6 times over a processing period of 8 weeks. The facility trialed a Komptech Topturn Model x 67 turner, but, currently, windrows are mixed and turned using a large excavator because the turner got frequently stuck in the mud and compost between the windrows. A new turner with landfill tracks tracks is being investigated and a demo will likely occur in early 2014. Without careful attention to detail by the operator, mixing and turning with an excavator could result in non-uniform mixing and pockets of dense anoxic material, potentially contributing to odour emissions. This is indicated by the (RD 1) data, which shows the presence of hydrogen sulfide in some of the laterals during some of the weekly data collection. Hydrogen sulfide is generated only under anoxic conditions. Operators at the facility charged with this task have been doing this procedure for

>10years, as turning of large cured windrows was a common historical practice. Between September and December 2013, the trend in the presence of hydrogen sulfide has been downward.

Approximately 11 additional windrows are located off the aeration pad in a location designated as the curing area. The windrows that are not on the aeration pad do not include digested waste from the Energy Garden.

Oxygen in the aerated and non-aerated windrows is measured in the windrows using a 3-foot long probe. Oxygen concentrations are reported to be in the range of 12 to 18 percent. An oxygen content of 12 percent is near the lower end of the range to maintain anaerobic conditions throughout a windrow. (U.S. Composting Council 1994)The probes are not long enough to reach the core of the windrows, so it is not possible to obtain a complete oxygen profile.

Table 1-1 shows the mix ratios in the aerated and non-aerated windrows.

Table 2-1 Volumetric Mix Ratios in Windrows

	Percent solids	Volatile solids As % of solids	Windrows on aerated pads	Windrows off aerated pads
Ground yard waste	50 %	70 %	2	2
Mid-fraction from screening	65%	Est. 50 %	1	1
Digestate	30%	65 %	1	0

2.2 Aeration of Windrows

Each pad may contain up to six windrows which are 20 feet wide at the base, totaling 120 feet of coverage. The aeration laterals are 140 feet long, so they would be are mostly covered by the six windrows. At the time of the site visit, the space not occupied by windrows was covered with moist compacted compost. The resistance offered by this compacted material is preventing the air entering the laterals from bypassing the windrows.

Each of the two composting pad has 24 aeration pipes, 12 inches in diameter and 140 feet long, spaced 17.5 feet on center. Each lateral has a valve, so the air flows can be balanced, with the objective of drawing the same amount of air from all 24 pipes. Considerable attempt has been made to balance the flow among the 24 headers using the valves, but, since each adjustment affects the pressure profile in the main header, it is normally difficult to achieve balance without designing for high pressure loss. Each lateral was built with about (1,000) 5/8 inch holes. The lateral would be expected to have a pressure drop of about 0.1 inches w.g. , and each hole would have a pressure drop of 0.02 inches w.g. For uniform air distribution, the pressure drop through the holes should be about 10-20 times greater than the pressure drop in the laterals. In recognition of this, the laterals were modified by plugging most of the holes. The velocity, suction pressure, percent oxygen, and temperature are taken at each pipe once per week. Table 1-1 summarizes these values. . It is reported that the velocity measurements are not reliable and are not included in the table.

Table 2-2 Summary of Weekly Reports			
Southwest	**Ambient Temperature Deg C.**	**Temperature Range in Laterals Deg. C**	**Pressure Range in Laterals In. w.g.**
9/17/2013	16	50 to 72	-2.51 to -0.51
11/22/2013	0	28 to 60	-5.63 to -1.73
Northeast			
9/18/2013	17	67 to 82	-5.34 to -0.32
11/21/2013	0	28 to 65	-12.2 to -2.00
11/28/2013	8	32 to 60	-9.64 to -1.84
12/3/2013	-2	30 to 66	-10.83 to -2.22
Reference: RD 1			

The large difference between ambient temperature and the temperatures in the laterals indicates that most of the air entering the laterals is from the windrows rather than leakage of ambient air between the windrows. The wide range of pressures in the laterals indicates a correspondingly wide range of air flow. In general the higher negative pressures are closest to the blowers.

2.3 Energy Garden Biofilter

The Energy Garden design ventilation rate is 16.7 m^3 /sec (35,316 cfm) during the day and 50 percent of that value at night. The exhaust is treated in the Energy Garden Biofilter. The measured ventilation rate (RD 8) was 11.14 m^3 /sec (26,266 cfm). Most of the airflow is collected from the receiving hall, where odour is generated only by the stacked feedstock. However, freshly loaded percolator tunnels are vented continuously until they produce sufficient methane to be connected to the biogas line. Also, when a finished tunnel is offloaded it is first ventilated to the biofilter, such exhaust gases containing H2S, CO2, methane and VOCs. So the major odour sources for the Energy Garden biofilter are the stacked feedstock inside the hall and the tunnels being ventilated.

The building has 3 external doors: 2 with open areas of 25 m^2 and one with an open area of 38 m^2. When a door is open, air, in theory, moves into the building and the odour is confined. In practice, ambient wind movement creates a negative pressure that overcomes the negative pressure in the building. Effective capture requires an inflowing velocity of around 92 m/minute. With one of the smaller doors open, the inflow velocity will be only 26 m/minute, which is insufficient to prevent odour from escaping the building. It is the facility policy to keep doors closed when not in use, in accordance with the Air Permit.

2.4 Screenings Biofilter

The screening building is mostly open-sided. Some of the open area can be partially closed with curtains, but the large opening into which the material is dumped into the screen remains open. It is reported in (Source 5) that the air flow to the screenings biofilter is 286 m3/minute. The exhaust is collected at one point on the wall of a largely open building and does not collect odor close to the screen.   However, the biofilter inlet odor concentrations are in the range of 5,800 – 17,200 indicating that odorous air is being picked up.

Section 3

Assessment of Biofilters

3.1 Sizing and Air Loading

Biofilter depth was determined by digging test pits. The test pits for the Southeast and Northwest CASP were limited to 2.0 meters by the reach of the machine. Actual depths might have been greater. The test pit for the Energy Garden biofilter reached the perforated pipes. No test pit was dug at the screener biofilter, due to limited access for the excavator. Physical size and air flow data are summarized in Table 3-1.

Table 3-1 Summary of Air Loading and Residence Time

Location	Area m^2 (1)	Measured Air Flow m^3/min (2)	Face Velocity m/min	Depth m (3)	Volume M^3	Empty Bed Residence Time Minutes
Southwest	1,160	416	0.35	2.0 (3)	2,320	5.5
Northeast	1,090	510	0.47	2.0 (3)	2,180	4.3
Energy garden	240	668	2.78	1.2	288	0.43
Screener	260	286.4	1.10	No test pit		

Note (1) Measured in Field

Note (2) Reference: : RD 8

Note (3) Depth of test pit on December 11, 2013. Less than total depth of media, so actual media depth and volume may be greater

Typical face velocities for organic media biofilters are in the range of 1.0 to 1.5 M/minute. Typical empty bed residence times (EBRT) are in the range of 1.0 to 2.0 minutes. The Southwest and Northeast biofilters are under-loaded in comparison with those typical values. The Energy Garden biofilter is over-loaded in comparison with those same values.

3.2 Uniformity of Air Distribution on Biofilter Surfaces

The uniformity of air distribution can be measured by placing a hood at a large number of grid points on the biofilter surface and measuring the velocity of air through the hood at each point. This can be performed only under zero wind speed conditions and was not attempted during the December 2013 site visit. Another approach is smoke testing. This was not attempted due to the large amount of steam condensing into the cold humid air. The FID and PID surface sweeps (Source 4) were used as a surrogate for uniformity. Each biofilter was divided into 16 grid points at which surface sweeps were taken with a flame ionization detector (FID) and photoionization detector (PID). The FID includes concentration of methane. The PID excludes methane. Table 3-2 summarizes the data from each biofilter.

Table 3-2 Uniformity of Air Distribution by VOC Surface Sweeps				
	FID- ppm		PID- ppm	
Location	**Range (Mean)**	**Mean/Range**	**Range (Mean)**	**Mean/Range**
Southwest	50-800 (293)	0.4	2.2-28.9 (16.8)	0.6
Northeast	110-280 (189)	1.1	0.07-2.9 (1.5)	0.5
Energy garden	110-280 (178)	1.0	0.7-2.9 (1.5)	1.2
Screener	0		0	
Reference: RD 4				

Over the 16 grid points, the ratio of the mean value to the range of values provides a measure of uniformity, with the higher ratio indicating the more uniform distribution. On the southwest biofilter, low mean/range ratio suggests lack of uniformity of air distribution, or at least, lack of uniformity in pollutant removal efficiency. The northeast and energy garden biofilters show higher degrees of uniformity. There is no standard value of uniformity to which biofilters should conform, but non-uniformity indicates less effective pollutant removal. There appeared to be no correlation between surface VOC concentrations and location in relation to the inlet header, suggesting that non-homogeniety of the media is contributes more to the non-uniformity than structural problems with air distribution composting mix.

On the Energy Garden biofilter, the emissions picked up by the surface sweep are mostly methane. This is to be expected since much of the exhaust picked up near the ceiling of the tipping floor is methane from opening of the digester doors and exhaust from the tunnels themselves during batch start-up. The screener biofilter shows VOC emissions below detect for the FID and the PID. This is to be expected, since this biofilter draws mostly ambient air due to the open sides of the screener enclosure. For this reason, the uniformity could not be assessed by surface sweep.

3.3 Operating Conditions of Biofilter Media

Operating conditions are reported weekly in (Source 2). The data in Table 3-3 are mean values from June 7 through November 27, 2013. pH and percent solids are taken near the surface of the media and are affected by rainfall. Temperature is measured in the inlet air stream, not with probes in the media.

Table 3-3 Operating Conditions of Biofilter Media				
Location	**pH Mean Range**	**% Solids Mean Range**	**Inlet Temperature deg. C Mean Range**	**Inlet Pressure Inches w.c. Mean Range**
Southwest	6.1 4.5-7.5	30.4% 27 – 34 %	54 deg. 28-66 deg.	0.82 0.02-2.82
Northeast	5.9 4.7-7.1	30.5 25 – 38 %	55.2 deg. 38 – 70	0.9 0.01-2.4
Energy garden	6.5 5.3 – 7.1	61.3% 31 - 94	21.4 deg. 10 – 34	1.5 0.25 – 4.1
Screener	6.1 5.3 – 7.1	33.4 28 – 42 %	20.3 deg. 11 – 30	0.8 0 - 1.5
Reference: RD 7				

Optimal PH values for removal of a broad spectrum of VOCs are in the range of 6.0-8.0. (Devinny et.al) The Air Permit allows a pH range of 5.0 – 8.0. The low-end pH values for the windrow composting biofilters are below optimal for removal of a broad range of VOCs. The optimum range for percent solids for biofilter media is in the range of 30-40 percent. The Air Permit allows a range of 30-60 percent solids. The Energy Garden biofilter solids values indicate that the media near the surface is too dry much of the time. The maximum temperature for optimal biofilter performance is 40 deg. C. Although microbes can adapt to higher temperatures, absorption of pollutants onto the moisture film in the media decreases at high temperature. The Air Permit allows a temperature range of 25 – 45 deg. C. Since the temperatures are measured in the inlet air rather than with probes in the media, it is not possible to assess the temperature of the media accurately from the data that was provided. Based on inlet air temperatures alone, the windrow composting biofilters are operating at excess average temperatures. When test pits were dug into the media on December 12, the condition of the media was noted, and samples were sent out to a laboratory for analysis of sulfate and nitrogen species. Sulfate indicates loading with the products of oxidation of sulfur compounds such as hydrogen sulfide. Nitrogen species indicate the same for oxidation of ammonia and amines. Percent solids and pH were also analyzed, to assess these values near the base of the beds rather than near the surface.

Table 3-4 summarizes the observations and data from the test pits (Source 7).Two samples were taken, on opposite sides of each test pit. Both values are shown in the table. Chemical analyses were not requested for the Energy Garden biofilter, because it is did not appear to have much microbial activity and because loading of sulfur and nitrogen compounds would be expected to be light. No test pit was dug in the screener biofilter.

Table 3-4 Biofilter Test Pit Data

Location	pH	Total Solids %	TKN Mg/kg dry	Soluble Nitrite Mg/kg dry	Soluble Nitrate Mg/kg dry	Soluble Sulphate Mg/kg dry
Southwest	5.6 5.9	26.2% 24.4	0.93 1.27	9.8 26.4	274 689	24.4 95.2
Northeast	5.8 5.8	26.8 29.2	0.63 0.83	9.3 13.5	6.3 16.5	73 141
Energy Garden	6.5 6.8	35.3 38.1	Not tested	Not tested	Not tested	Not tested

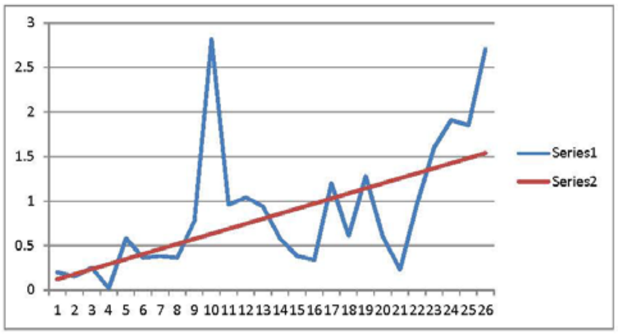
The table shows that the pH values are slightly on the acidic side, but probably not to a significant degree. The acidity is probably in the media itself rather than due to sulfur compounds. None of the sulphate concentrations are high. The media in the CASP biofilters is wet, but has enough structure to hold up under the high moisture conditions. The nitrogen is mainly in the form of nitrate, indicate good oxidizing conditions.

All the media samples had good structural integrity. The larger wood particles were not pulpy and there did not appear to be excessive fines caused by physical breakdown of the media. Microbial assays were not conducted, because there is no baseline data with which to compare the results. There is on-going research on the microbial population of the Harvest Power biofilters. However, some qualitative assessments were possible. The SW and NE biofilter samples had a strong odor of soil fungus and layers of visible hyphae, indicating healthy microbial populations. The media in the Energy Garden biofilter had a slight solvent odor but no odor that would be characteristic of robust microbial activity. There were some hyphae near the surface but not near the base of the bed, where most of the microbial activity should be taking place.

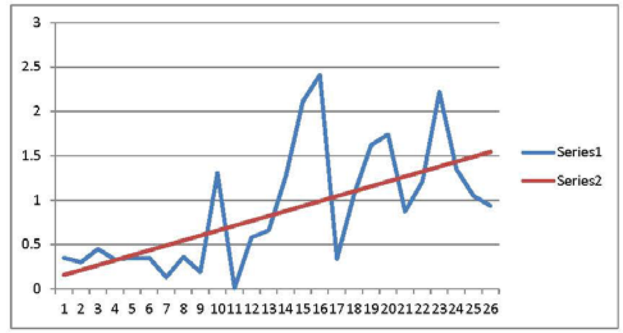
Figure 3-1 shows the inlet pressure trends for each biofilter from June 7 to December 13, 2013. The pressure is rising most rapidly in the southwest and northeast biofilters and to a lesser extent in the Energy Garden biofilter. This is not unexpected, as there is more moisture and there appears to be more microbial activity in the two composting biofilters, causing more rapid physical breakdown of the media. The data for the screener had some discontinuities, but existing data shows no significant pressure increase during the same time period. As inlet pressure increases, flow will decrease unless the fan speed is increased. The pressure trends cannot be used to predict media useful media life without knowing the full capacity of the fans at the maximum speed that can be supported by the motors. Organic biofilter media has a typical useful life of 3-5 years.

FIGURE 3-1 BIOFILTER INLET PRESSURE (INCHES) OVER PRECEDING 26 WEEKS

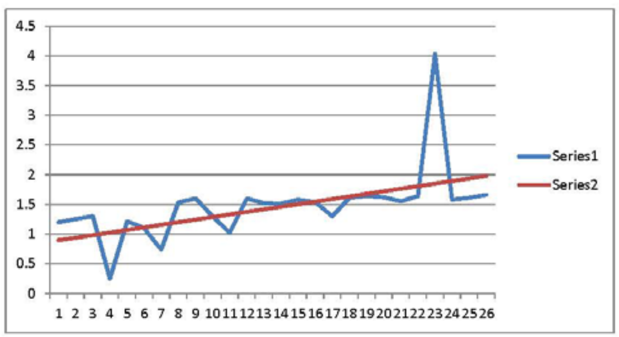
REFERENCE RD 2



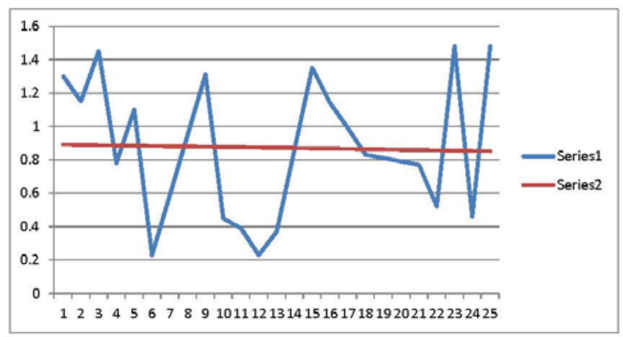
SOUTHWEST BIOFILTER



NORTHEAST BIOFILTER



ENERGY GARDEN BIOFILTER



SCREENER BIOFILTER

3.4 VOC Loading and Removal Efficiencies

Species of VOCs were identified in (Source 3) taken on July 29, 2013. Predominant non-methane compounds are listed below. In most of the samples, methane was predominant. None of the other compounds are unusual for wood and green waste composting and none of them are especially difficult to remove in a compost biofilter. One exception is limonene, which is difficult to remove. Many of these compounds, including limonene and ketone are found in mulch drying operations and are generated by the wood itself, probably including the wood in the biofilter media.

- Ketone
- Ethanol
- Butyl and Propyl Acetate
- Toluene
- Ethylbenzene
- Xylene
- Heptanal
- Limonene
- Nonanal
- 2-Butoxyethanol
- Acetic Acid
- Isobutytric acid

Results from the same sampling round, on July 2013, were then analyzed for total VOCs in (RD- 5). Values are summarized in Table 3-5. Total mass is expressed as the molecular weight of methane. Three samples were analyzed, and the values in the table represent the mean of all three analytical results.

Table 3-5 Summary of VOC Loading and Removal

Location	VOC- Inlet concentrations Mg/m^3	VOC- outlet concentrations Mg/m^3	Calculated VOC removal efficiencies %	Calculated VOC mass loading per unit volume of media Grams/m^3-hour
Southwest	36.4	1.1	41 %	0.49
Northeast	45.8	23.0	40 %	0.62
Energy garden	2.22	2.35	Data is inconclusive	0.06
Screener	0.75	0.46	38 %	Media volume not measured

VOCs must be absorbed onto the liquid film in the biofilter media. If the inlet concentrations are low, as is the case with these biofilters, there is relatively little driving force for absorption, and removal rates are correspondingly low. In addition, VOCs emitted by the wood in the media itself can mask the removal of VOCs in the inlet air. There appeared to be some sampling errors that made it not possible to calculate the removal efficiency for the Energy Garden biofilter.

The VOC loading per unit volume of media was calculated in order to compare with published ranges of upper limits to this value, representing the best removal efficiencies that may be expected for each compound. For most VOCs identified in these analyses, the values are in the range of 10 – 230 grams/M^3- hour. (Devinny et. al)It does not appear that the biofilters are approaching the limits of their theoretical VOC removal capacities.

3.5 Odour Removal Efficiency

Odour concentrations were reported in both Sources 5 and 6 and are summarized in Table 3-6. RD 5 only reports outlet odour concentrations. In each cell of the table, the first row shows the values reported in RD 6 and the second row summarizes the values reported in RD 5 (outlet only).

Table 3-6 Odour Removal Efficiencies

Location	Inlet Odour Dilutions to threshold (ou)	Outlet Odour Dilutions to threshold (ou)	Removal Efficiency %
Southwest	98,880	900 812	99 %
Northeast	106,452	924 2,990	99 %
Energy garden	32,260	13,560 1,949	58 %
Screener	5,136	396 451	92 %

The SW and NE biofilters have high odour removal efficiency. The screener biofilter also has good removal efficiency but is very lightly loaded, so the residual odour of the media probably dominates the results. The Energy Garden biofilter does not have effective odour removal performance.

Section 4

Summary and Conclusions

4.1 Aeration and Capture Efficiency

- The SW and NE biofilters are effectively capturing pile exhaust while providing aeration, but it is not possible from the reported data to determine what percentage of the odour emissions are being captured and what percentage escape through convective air flow. There is no data on oxygen concentrations deep in the windrows to determine if the aeration systems are maintaining sufficient oxygen. The presence of methane and carbon monoxide would suggest that there are, at least, pockets of anaerobic activity. The new compost turning machine that may be demonstrated early in 2014 is expected to provide more thorough and uniform mixing.

- When a door is left open in the Energy Garden tipping floor, the ventilation rate is not sufficient to prevent odour escaping from the building. The odour concentration in the tipping area is high.

- The screener is treating odorous air, but much of the odor is probably escaping because the screener enclosure mostly open.

4.2 Biofilter Design, Loading, and Performance

4.2.1 Southwest Biofilter

- Air and VOC loading are not excessive. The biofilter is conservatively designed and loaded

- Air distribution is not uniform

- Media appears to be in good physical and microbial condition and is in an oxidizing state

- Pressure is increasing over time and may need to be replaced after one more year's operation.

- VOC removal is 41%. This low value is probably due to low inlet concentration and residual VOCs from the biofilter media.

- Odour removal is 99 %, which is excellent.

4.2.2 Northeast Biofilter

- Air and VOC loading are not excessive. The biofilter is conservatively designed and loaded

- Air distribution is more uniform than in the southwest biofilter

- Media appears to be in good physical and microbial condition and is in an oxidizing state

- Pressure is increasing over time and may need to be replaced after one more year's operation.

- VOC removal is 40%. This low value is probably due to low inlet concentration and residual VOCs from the biofilter media.

- Odour removal is 99 %, which is excellent.

4.2.3 Energy Garden Biofilter

- The empty bed residence time is lower and the face velocity is higher than the normal design ranges for organic media biofilter beds. Air distribution is relatively uniform
- Media shows much less physical evidence of microbial activity than the media in the windrow composting biofilters. It appears to be in good condition structurally
- Pressure s increasing over time, but the trend is not as pronounced as for the SW and NE biofilters.
- VOC removal could not be calculated due to possible sampling errors.
- Odour removal is only 58 %.

4.2.4 Screener Biofilter

- Air loading is conservatively designed and loaded. Pollutant loading is light due to poor capture. It is mostly treating ambient air.
- Air distribution could not be determined from FID/PID sweep because all values were zero.
- Pressure does not appear to be increasing over time based on the limited pressure data.
- VOC removal rate is 38 %
- Odour removal rate is 92 % which is acceptable, given the light loading

Table 4-1 shows a comparison of biofilter operating conditions with requirements in the Air Permit. Bold type indicates whether the biofilter is in compliance with the permit with respect to each specific requirement.

Table 4-1 Compliance with Permit Conditions

	Southwest Permit conditions	Northeast Permit conditions	Energy Garden Permit conditions	Screener Permit conditions
Max. air flow	1,200 **Complies**	1,200 **Complies**	1,150 **Complies**	552 **Complies**
Moisture content	40-70 % **Complies**	40-70 % **Complies**	40-70 % **Complies**	40-70 % **Complies**
pH	5.0-8.0 **Complies**	5.0-8.0 **Complies**	5.0-8.0 **Complies**	5.0-8.0 **Complies**
Media Temperature Note (1)	24 – 45 deg. C	24 – 45 deg. C	10-45 deg. C	10-45 deg.C
Max. outlet VOC Mg/M^3	7.6 mg/M^3 **Complies**	7.6 mg/M^3 **Out of Compliance**	0.53 mg/M^3 **Complies**	28.8 mg/M^3 **Complies**
VOC removal efficiency	60 % **Out of Compliance**	60 % **Out of Compliance**	60% **Out of Compliance**	60% **Out of Compliance**
Note(1) Temperature data is for air temperature rather than media temperature, so data is not available to compare with permit conditions				

Based on odour removal performance, the composting and screening biofilters are effective. Biofilter performance should be evaluated more on odor removal than on VOC removal, since inlet VOC concentrations are low and much of the VOCs in the outlet may be from the media itself.

The media is suitable for the applications at the Harvest Power site. It is holding up well structurally and, in the case of the aerated windrow composting biofilters, supporting a robust microbial population. There is no need to change the media type, although the media at the Energy Garden biofilter may need some additional attention. This is discussed in the next section.

Media temperature should be monitored with a long temperature probe, rather than from inlet air temperature.

Section 5

Additional Recommendations

- The windrow composting biofilters and the Energy Garden biofilter are equipped with misters as required in the Air Permit. All of the biofilters should have effective irrigation systems if they become dry in the summer months. At the time of the site visit, they had sufficiently high moisture content.

- The Energy Garden biofilter is a not functioning well and requires further investigation. This is one case in which a microbial population assay might be helpful. It appears visually that there is little biological activity, but that should be confirmed. One contributing factor may be the intermittent loading. The loading decreases significantly during shifts when there is no activity in the building. Several measures may be considered:

  - Re-innoculating the biofilter

  - Irrigation with addition of nitrogen fertilizer. Some studies indicate that methane oxidation is more heavily dependent on nitrogen than oxidation of other compounds. Digestate may be a suitable source of nitrogen.

- The screener biofilter is treating odor but probably having limited benefit as currently configured. It would be possible obtain some capture by routing the collection duct over the top of the screen, above the movement of the loader. If the screen were fed by a conveyor, it would be possible to complete the closure of the building. If the fan were to actually capture the screening exhaust, it would be important to make sure no dust enters the biofilter. If screening creates dust during dry conditions, sprayers would be needed to knock down the dust.

Section 6

Published References

Compost Facility Operating Guide U.S. Composting Council 1994

Devinny,J.S., Dehusses, M.A., Webster,T.S. *Biofiltration for Air Pollution Control* Lewis Publishers 1999