TECHNICAL REPORT

Scientific Evaluation of Potential Environmental Impacts of Contact Water Generated from Composting Source Separated Organic Material

CARVER COUNTY

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January 2, 2015

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I. Project Objectives

There has been continued interest in increasing organics composting capacity in Minnesota since the Minnesota Pollution Control Agency's (MPCA) set an organics diversion goal of 15% by 2020 in the 2010-2030 Metropolitan Solid Waste Management Plan. Organic materials that have the potential to be diverted from landfills accounts for a total of 41% of what Minnesotan's continue to throw in the garbage.[1] Thus expanded access to composting and other organics management methods in Minnesota has the potential to divert over 1.4 million ton of waste in Minnesota annually.

Carver County Environmental Services applied for an Environmental Assistance Grant through the MPCA to continue and expand on previous research conducted on quantifying potential environmental impacts of source-separated organics composting. In September 2012, the State of Minnesota, acting through its Commissioner of the MPCA, entered into a grant agreement with Carver County Environmental Services to expand on its 2008 and 2012 research in order to scientifically address questions related to compost technology and environmental impacts of composting source-separated organics with yard waste. The grant agreement can be found in Appendix A. The results of the previous water quality monitoring studies indicated that static aerated windrow composting of source-separated organics can be practiced with minimal impacts on ground and surface water quality. The objective of this study was to develop a more complete understanding of the environmental implications of contact water and storm water from source-separated organic material (SSOM) composting facilities. Specifically the MPCA requested investigation of the following questions to provide a better understanding of the composting process:

1. Is there a need for a pad in the curing area or will a drivable surface over certain soil types and depth to the water table is enough to protect the water table below a facility?
2. What is the chemical composition of contact water from various areas (i.e. the mixing, active [both under windrows and in between the windrows], and curing area) of the compost facility?
3. Is there infiltration into the soil in the areas that have a pad vs. those that don't have a pad? Is there a difference in infiltration rates?

The stated objectives were put in place to provide support and assist in the decision-making process in regards to engineering requirements for SSOM compost facilities including soil type and distance to the water table. Engineering requirements mitigate potential contamination risks in protecting groundwater resources in Minnesota. With a thorough evaluation of these questions as part of this study as well as examining existing research conducted by Carver County and others, the MPCA would have a more comprehensive understanding of the environmental impacts of composting operations. They could use this information to revise current composting regulation with more appropriate permitting requirement thereby facilitating the expansion of SSOM composting within the state.

[1] "MPCA Minnesota Statewide Waste Characterization Study," 2013, Minnesota Pollution Control Agency. 2014 <http://www.pca.state.mn.us/index.php/waste/waste-and-cleanup/waste-management/solid-waste/integrated-solid-waste-management/minnesota-msw-composition-study/index.html>

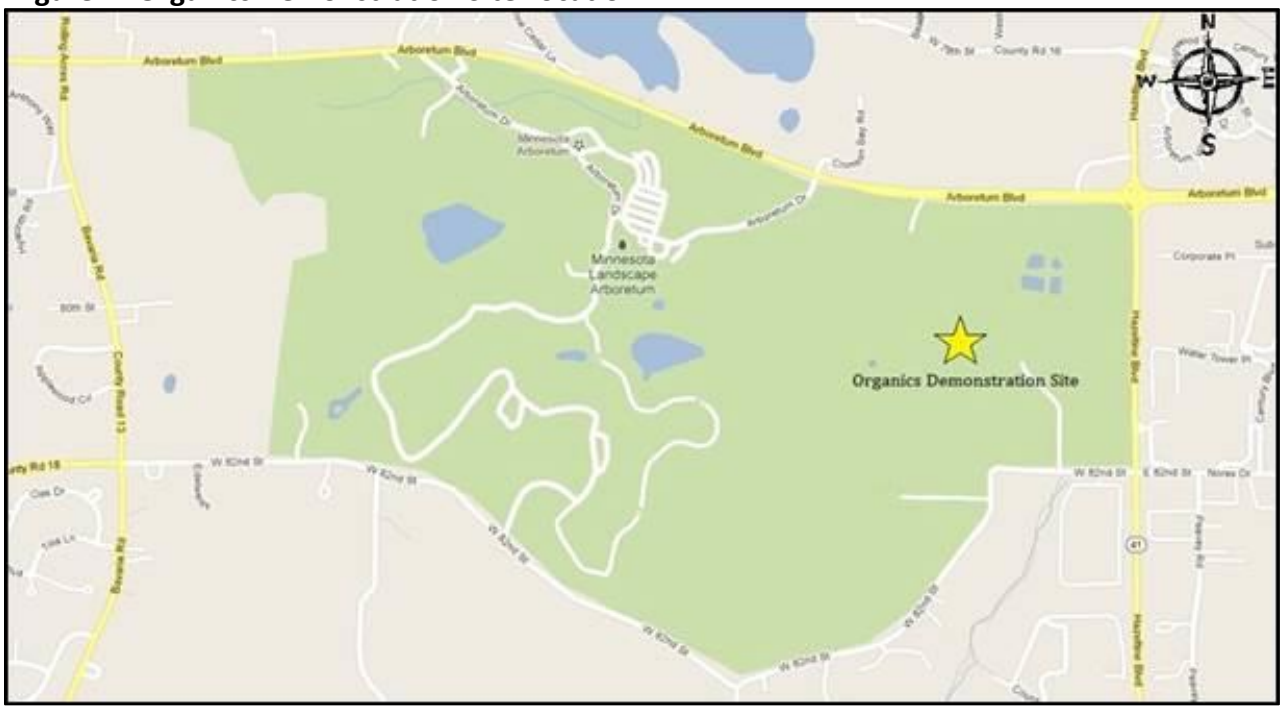
II. Site Overview

A. Organics Composting Demonstration Site Description

i. Location

The Carver County/Specialized Environmental Technology (SET) Organics Composting Demonstration Site is located at the University of Minnesota Landscape Arboretum in Chanhassen, MN. The University of Minnesota Landscape Arboretum is part of the College of Food, Agricultural and Natural Resource Sciences at the University of Minnesota. The Organics Composting Demonstration Site occupies two acres of the Minnesota Landscape Arboretum which was previously undeveloped. Figure A shows the location of the Organics Composting Demonstration Site on Arboretum property. The nearest residential home not owned by the University of Minnesota Landscape Arboretum is approximately 1,800 feet away from the site.

Figure A: Organics Demonstration Site Location



ii. Soils

The site is constructed on Lester-Kilkenny Loam soil that has a 12% - 18% slope and a 25% - 40% slope respectively. The USDA Soil Survey for the Organics Composting Demonstration Site location lists the depth to the water table and the depth to any soil restrictive layer at >200 centimeters (>78.7 inches). The USDA's Soil Survey refers to the water table as "the saturated zone in the soil that occurs during specified months". The mean annual precipitation in the area is about 28 inches, and the mean annual soil temperature is about 49 degrees Fahrenheit.

Above: *A senior environmentalist performs soil boring at the site.*

A senior environmentalist for Carver County performed soil borings on the site in December 2013 to verify the USDA Soil Survey for the area. The soil survey performed showed that there were loam soils to a depth of fifty-seven centimeters (57 cm). The soil boring observation log is listed in Table 1.

Table 1: Soil Boring Observation Log

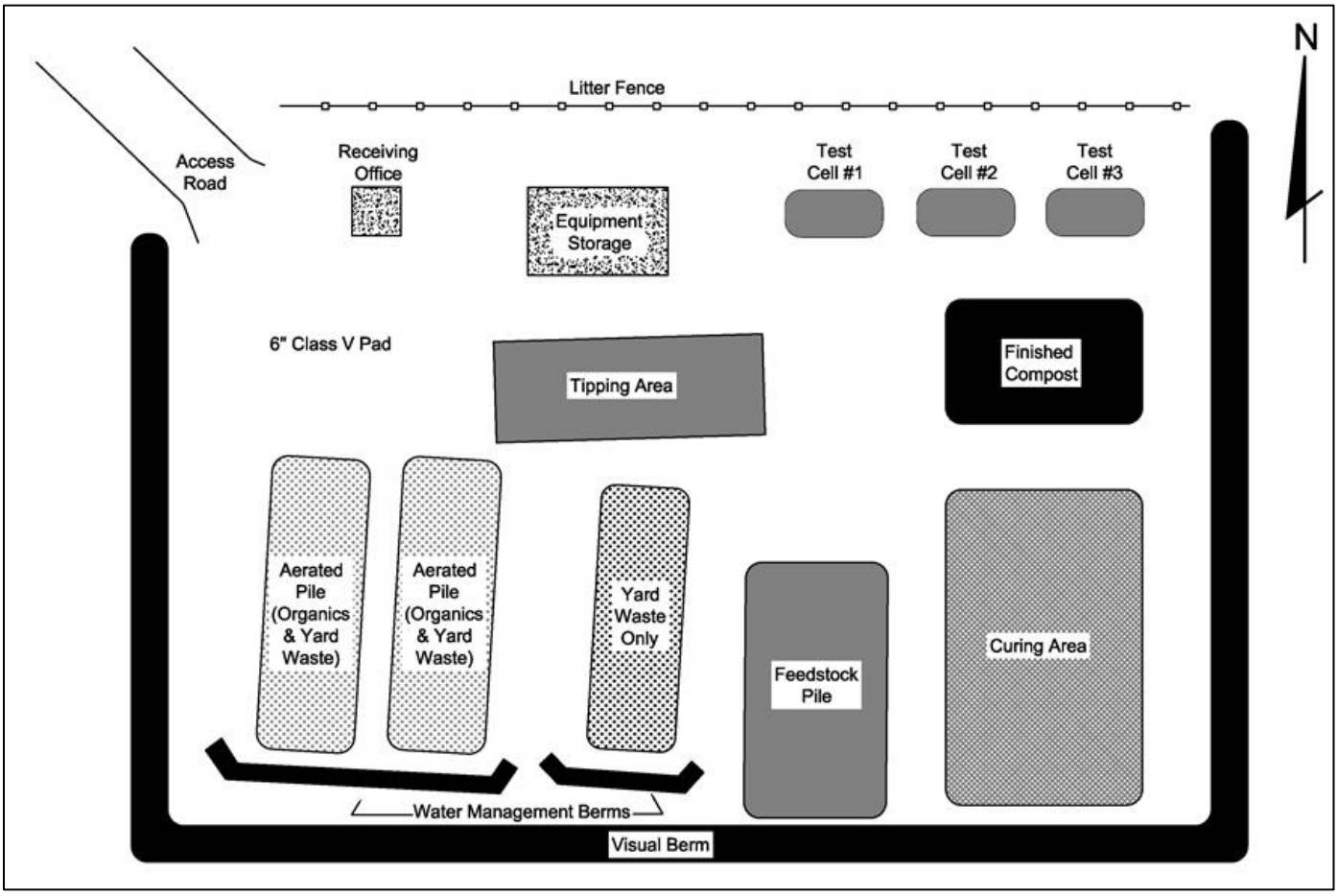
Depth (in)	Texture	Matrix Color(s)	Mottle Color(s)	Redox Kind(s)	Structure Shape	Structure Grade	Consistence
0-4	Loam	10 YR 2/2			Blocky	Moderate	Friable
4-18	Loam	10 YR 3/4			Blocky	Moderate	Friable
18-23	Loam	10 YR 4/3	20''	Concentrations Depletions	Blocky	Strong	Firm
23-57	Loam	10 YR 5/4			Blocky	Strong	Friable
57-60	Clay Loam	10 YR 5/4			Blocky	Strong	Firm

B. Site Design and Operations

i. Site Operations

The Arboretum Organics Composting Demonstration Site began accepting materials on September 1, 2011. SET, the site operator, accepts materials on site from commercial waste haulers and from the University of Minnesota Landscape Arboretum through pre-arranged agreements. Residentially generated source-separated organic (SSO) material and yard waste, brush and stumps delivered by waste haulers and SSO and yard waste generated the Arboretum cafeteria and from the grounds respectively are accepted at the site. No public drop off is allowed at the site.

Figure B: Organics Composting Demonstration Site Layout



The Organics Composting Demonstration Site is permitted to process 13,000 cubic yards annually, of which 20% or 2,600 cubic yards may consist of SSO material. The volumes of material are recorded by material type in cubic yards (yd^3) on a ticket by a gate attendant for all loads entering and leaving the site. There is no scale for recording the weight of materials. The type and volumes of material delivered to the site in 2012-2013 are listed in Table 2. The tipping area for yard waste, SSO, brush, and stumps are indicated on Figure B. A mixer, front-end loader and screener are used for processing materials. A windrow turner was used to process incoming materials during the first several years of operation at the site.

Table 2: 2012-2013 UMN Arboretum Quantity of Materials Received (in yd^3)

Year	Yard Waste (leaves and grass clippings)	Source-separated Organics	Total Waste Collected	Percent (Yd waste/SSO)
2012	1533	639	2172	70.5%/29.5%
2013	843	642	1485	56.7%/43.2%

The Organics Composting Demonstration Site was designed to gather data regarding the differing environmental impacts of composting yard waste by itself versus composting SSO with yard waste.

Yard waste is ground and transported to the composting area and either mixed with SSO or by itself and is placed into aerated static piles using a front-end loader. Brush and stumps are ground into mulch and used in the composting process, sold to be used for biomass to generate electricity or are sold as mulch products. Fall leaves are stockpiled in the Feedstock Pile area indicated on the Figure 2. Leaves are used the following season to mix with the grass and other SSO to reduce the potential generation of nuisance odors.

Aerated static piles and stockpiles do not exceed twelve feet (12') in height. Composting materials are turned when temperature and moisture conditions indicate it is necessary to do so. A turning strategy based on processing parameters such as temperature also helps control nuisance odor generation. These and additional site operation details can be found in the Site Operations Plan that is included as Appendix B.

Finished compost is screened and sold to both commercial and residential customers. Mulch is also sold to both commercial and residential customers.

ii. Acceptable Materials

The material to be composted include source-separated residential organics commingled with yard waste and limited commercial organics generated primarily from the University of Minnesota Arboretum cafeteria. The SSO materials are made up of the following:

Source-separated organics including:

- Vegetables and fruits;
- Bread, rice, cereals, and pasta;
- Dairy products;
- Eggs, fish, shellfish, meat, and bones; and
- Coffee grounds, filters, and tea bags.

Food soiled and non-recyclable paper including:

- Food-soiled paper;
- Paper napkins, plates, cups;
- Paper towels;
- Wax coated boxes; and
- Paper egg cartons.

Other compostable items including:

- Certified compostable plastics and compostable plastic lined paper products (meeting ASTM D6400 or ASTM D6868 certification);
- Dryer lint;
- Cotton swabs; and
- Wood toothpicks, chop sticks, and Popsicle sticks.

iii. Site Working Pad

The Organics Composting Demonstration Site naturally slopes to the southwest. The pad is graded to ensure drainage is directed toward water management berms installed at the toe of each aerated static pile and toward compost socks installed on the site. The pad is constructed of six inches (6") of rock consisting of one and a half inch minus (1 ½-) limestone under Class 5 gravel. The gravel originally covered the tipping, processing and active composting areas of the facility. The curing and finished compost areas as well as equipment storage consisted of compacted soil when the Organics Composting Demonstration Site was originally constructed. Class 5 gravel was added to these areas to allow for year-round operations in December 2011. Braun Intertec conducted permeability testing of the pad utilizing a double ring infiltrometer, a nuclear density gage as well as laboratory testing in 2013. Testing was performed in accordance with ASTM International (ASTM) D2434-68. Braun estimated that infiltration rate of the working pad to be $1.34X10^{-4}$(cm/sec) which is considered slow. The full Braun Intertec report can be found in Appendix C.

Above: *Braun Intertec staff test compaction level at the site using a nuclear density gauge*.

Above: *Braun Intertec staff use a double-ring infiltrometer to estimate the soil infiltration rate*.

iv. Stormwater & Contact Water Management

The Organics Composting Demonstration Site is graded to prevent the ponding of water. The general grade of the site runs from northeast, the high point, to southwest, the low point. Contact water and storm water are managed by two by two foot (2'x2') compost water management mini-berms on the southwest end of each of the SSO and yard waste aerated static piles. In addition a two-inch (2") seeded compost blanket was installed on the north and south side of the berm to absorb runoff before it leaves the site.

A four foot tall by six feet (4'x6') wide visual berm runs the length of the East, South and West sides of the Organics Demonstration Composting Site. The visual berm is seeded and also acts as a secondary water filtration system for storm water.

Compost socks were installed along the South-West boarder of the site to provide additional treatment of contact water, water that comes off the aerated static piles and mixes with storm water on the site. The site is graded to ensure all contact water passes through a series of EnvirSoxx compost socks prior to leaving the site. The EnvirSoxx consist of sediment control material which also removes pollutants. Testing of this product has confirmed up to 99% removal of bacteria, 92% removal of nutrients, 99% removal of hydrocarbons and 73% metals.[2]

Above: *Compost socks were installed when the pad was created and graded. Since this time, the seeds spread on the visual berm have grown through the compost socks.*

[2] "EnviroSoxx for Targeted Pollutant Removal," Filtrexx, 2014, <http://www.filtrexx.com/pollutant-removal/>

III. Sampling Methods

A. Project Team

Work on this grant project was completed by the Project Team consisting of:

Marcus Zbinden, Project Manager	Carver County Environmental Services
Kellie Kish, Project Staff	Carver County Environmental Services
Anne Ludvik, Site Manager	Specialized Environmental Technologies (SET)
Thomas Halbach, Technical Advisor	University of Minnesota Dep. of Soil, Water& Climate
Ginny Black, Composting Specialist	Black Gold Recycling, LLC.
Mark Zumwinkle, Sustainable Ag. Specialist	Minnesota Department of Agriculture
Maria Karis, Intern	Carver County Environmental Services
Amanda Bednar, Intern	Carver County Environmental Services
Sidney Stock, Intern	Carver County Environmental Services
Marissa Mahoney, Intern	Carver County Environmental Services

In addition, the MPCA Technical Staff included:

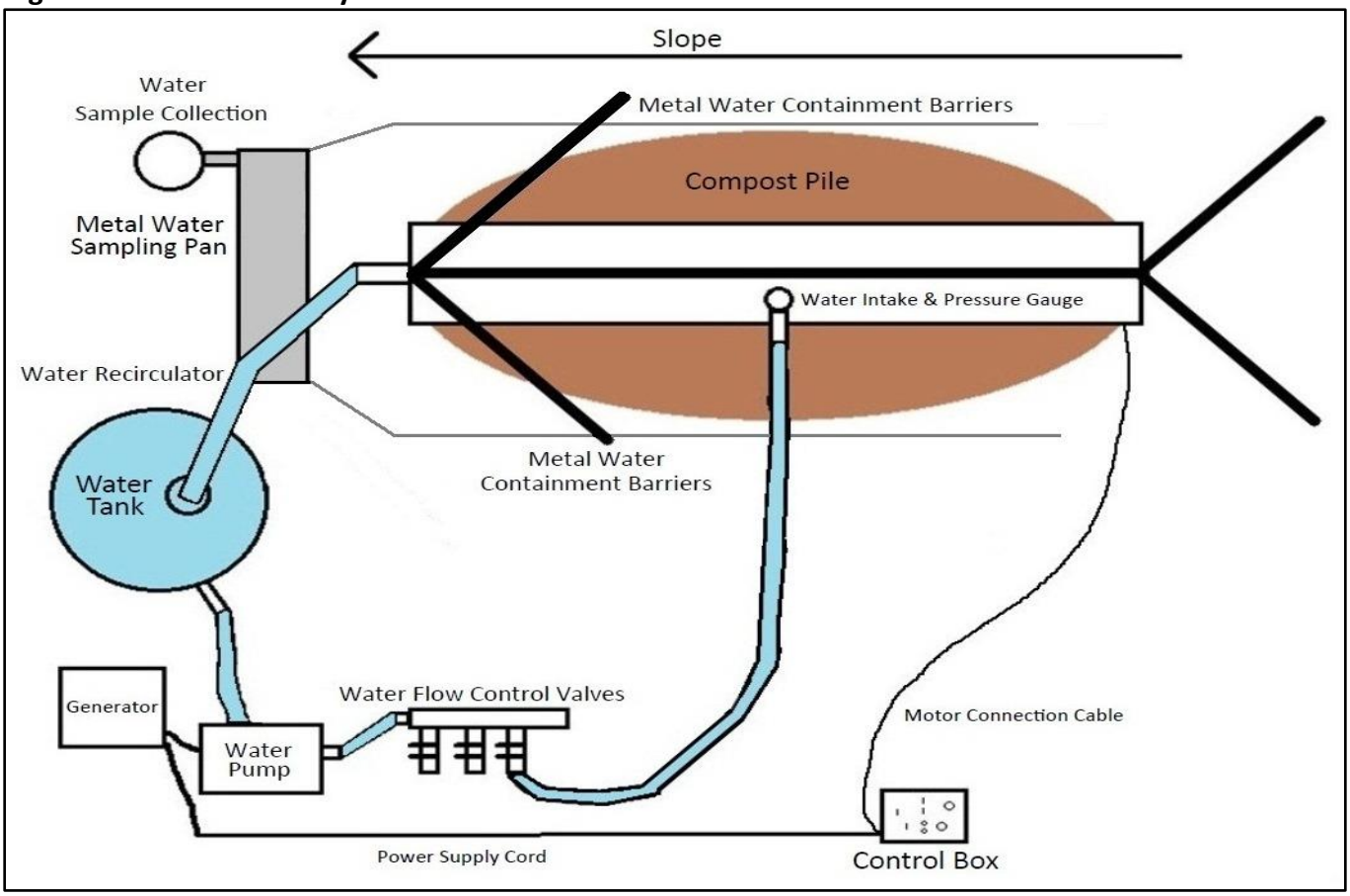
Tim Farnan, Grant Manager
Emily Barker, Organics and Recycling Specialist
Lisa Mojsiej, Engineer
John Elks, Hydrologist
Neal Wilson, Hydrogeologist

B. Rainfall Simulator

The average rainfall in Minnesota between May 1st and August 1st is approximately eleven inches (11”), about three inches (3”) per month. However, drought conditions were prevalent in 2011 and 2012 limiting sample collection at the Organics Composting Demonstration Site. The request for proposals for the grant, found in Appendix A, required the use of a rainfall simulator to allow for an organized sampling plan and ensure sufficient volumes to sample for all requested parameters.

For the field study, an eight foot (8’) USDA Purdue-style rainfall simulator was used. The USDA Purdue-style rainfall simulator is commonly used to test run-off on agricultural plots and is widely used in agricultural research. The Project Team, with the expertise of Mark Zumwinkle from the Minnesota Department of Agriculture, determined how to best utilize the USDA Purdue-style rainfall simulator to simulate storm events of different frequency and intensity over a compost pile with the goal of collecting contact water that goes through the compost pile for analysis. A diagram illustrating the set-up of the rainfall simulator this project can be found in Figure C.

Figure C: USDA Purdue-style Rainfall Simulator



The Purdue-style rainfall simulator is engineered to accurately represent rain droplet size, velocity and kinetic energy of actual rainfall. Pressure and frequency settings determine the volume of droplets. The simulator is designed for rainfall distribution over a five by eight foot (5'x8') test area. Prior to each rainfall simulation, the rainfall simulator was placed directly over the center of test pile and the test area of the rainfall simulator was marked. The edge effect applied to the test area of rainfall and verifies the tendency for greater variation along the perimeter of five foot by eight foot (5'x8') distribution area of the simulator. In the context of this study, there was uniform distribution with some non-uniformity near the edges of where the rain fell on the compost piles.

The Purdue-style rainfall simulator produces natural rain drop size and velocity when positioned eight feet (8') over the test area. Because a compost pile is not a flat surface, the Project Team determined that the best option was to have the rainfall simulator eight feet (8') above the vertical center of each pile. Because the rainfall simulator could not be safely raised high enough to be eight feet (8') above the top of the test pile, the Project Team, with input from the MPCA, agreed that the test pile size would have to be reduced to meet the height limitation of the rainfall simulator. For this reason, the piles tested were not representative of operating compost facilities in Minnesota and were much shorter being between three and a half feet (3.5') to four and a half feet (4.5') tall. Typical commercial composting piles are usually between 5.0 ft. and 7.5 ft. and in some cases are up to 12 ft. in height.

Taller piles hold more rainfall at the same moisture content below their Water Holding Capacity(WHC) than shorter piles.

C. Rainfall Simulator Calibration

The Purdue-style rainfall simulator was calibrated before each phase of sampling. The approved method, calibration method 1, was utilized by the Project Team in Phase I and II. Two other methods were employed but disregarded. . A three and a half hour (3.5 hr) rainfall event was selected based on an MPCA request to apply the volume of rain representative a 100 year/24 hour storm event in manageable time frame. Table 3 provides context for considering the volume of rain in this study.[3] For both phases of rainfall simulations, the Project Team utilized the manufacture recommend calibration method utilizing the effective five foot by eight foot (5'x8') area of the spray nozzles.

Table 3: PDS-based precipitation frequency estimates with 90% confidence intervals (in inches)

Duration	Average recurrence interval (years)									
	1	2	5	10	25	50	100	200	500	1000
60-min	**1.16** (0.895-1.51)	**1.38** (1.06-1.79)	**1.77** (1.36-2.30)	**2.13** (1.62-2.78)	**2.68** (2.01-3.66)	**3.15** (2.30-4.32)	**3.66** (2.58-5.10)	**4.22** (2.86-5.97)	**5.01** (3.27-7.23)	**5.66** (3.58-8.18)
2-hr	**1.43** (1.12-1.84)	**1.69** (1.32-2.17)	**2.18** (1.69-2.80)	**2.64** (2.04-3.40)	**3.36** (2.56-4.55)	**3.99** (2.95-5.42)	**4.68** (3.35-6.47)	**5.45** (3.74-7.66)	**6.55** (4.32-9.38)	**7.46** (4.77-10.7)
3-hr	**1.6** (1.26-2.03)	**1.88** (1.47-2.39)	**2.42** (1.90-3.09)	**2.95** (2.30-3.78)	**3.81** (2.93-5.14)	**4.56** (3.40-6.18)	**5.4** (3.89-7.43)	**6.33** (4.38-8.87)	**7.7** (5.12-11.0)	**8.83** (5.68-12.6)
6-hr	**1.88** (1.50-2.36)	**2.2** (1.75-2.76)	**2.83** (2.24-3.56)	**3.46** (2.73-4.37)	**4.47** (3.49-5.99)	**5.38** (4.07-7.22)	**6.4** (4.67-8.73)	**7.54** (5.28-10.5)	**9.21** (6.20-13.0)	**10.6** (6.90-15.0)
12-hr	**2.13** (1.72-2.64)	**2.52** (2.03-3.12)	**3.24** (2.60-4.02)	**3.93** (3.14-4.89)	**4.99** (3.92-6.54)	**5.92** (4.51-7.79)	**6.93** (5.10-9.29)	**8.04** (5.68-11.0)	**9.65** (6.55-13.5)	**11** (7.21-15.4)
24-hr	**2.49** (2.04-3.04)	**2.85** (2.33-3.49)	**3.55** (2.89-4.35)	**4.23** (3.42-5.20)	**5.3** (4.23-6.87)	**6.25** (4.83-8.14)	**7.29** (5.44-9.68)	**8.45** (6.05-11.5)	**10.1** (6.97-14.1)	**11.5** (7.67-16.0)

[3] "NOAA Atlas 14 Point Precipitation Frequency" National Ocean and Atmospheric Administration, 2014. <http://hdsc.nws.noaa.gov/hdsc/pfds/pfds_map_cont.html?bkmrk=mn>

i. Calibration Method 1

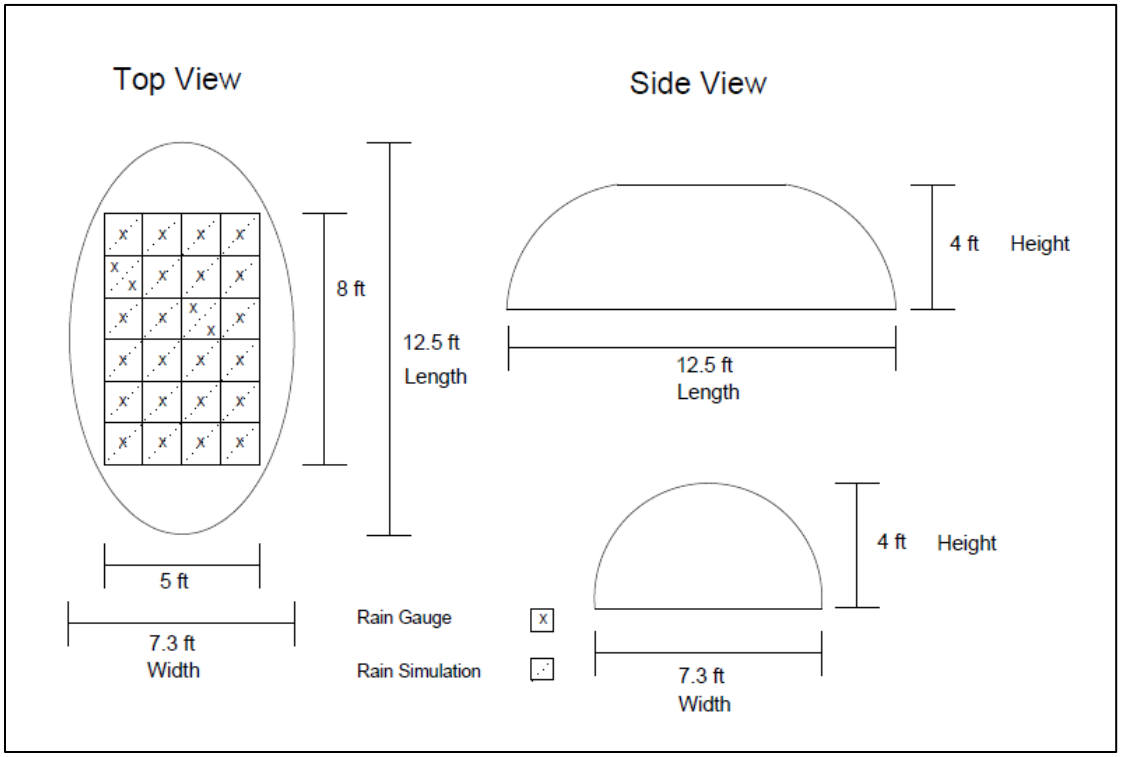
Mark Zumwinkle from the Minnesota Department of Agriculture directed the calibration process. Rainfall was collected in rain gauges that were evenly distributed in one by one foot (1'x1') blocks within the five by eight foot (5'x8') area for one hour (1 hr). Table 4 provides a detail volume of water collected in each of the twenty six (26) rain gauges over a one hour (1 hr) time frame.

Table 4: Rain Gauge Data Using Five by Eight Foot Equipment Specification

Rain Gauge ID (#)	Rain collected (in/hr)	Rain Gauge ID (#)	Rain collected (in/hr)
1	1.1	14	2.1
2	1.9	15	3
3	1.55	16	3.5
4	2	17	2
5	0.8	18	0.65
6	1.2	19	3.2
7	2.5	20	3.4
8	2.2	21	1.4
9	1.85	22	0.8
10	1.3	23	1.8
11	3	24	2
12	2.9	25	1.35
13	1.4	26	1.7

In an effort to comply with the MPCA request of applying a 100 year rain event on the pile, the rainfall simulator was run with a frequency setting of five (5) at six (6) psi on a single sweep setting. Simulations were run for a minimum three and a half hours (3.5 hr), distributing approximately 6.83 inches.
Figure D illustrates the distribution of rain gauges in the five by eight foot (5'x8') area. The figure also provides an overlay of the calibration area over the top view of piles used in Phase II of the study.

Figure D: Calibration Method 1: Manufacturer Recommended Method



Based on the total volume calibration method amount of rain that fell from both nozzles in three and a half hours (3.5 hrs) was 193.2 gallons. The rain gauge calibration method estimated that 171.3 gallons

of rain fell within the five by eight foot (5'x8') area. When the volume that fell within five by eight foot (5'x8') area is subtracted from the total volume collected, the remaining amount is 22.9 gallons. This calculation provides an approximate percentage of rain that fell within the calibrated area at 88.15% , with the balance falling off the pile or lost to drift at 11.85%.

ii. Calibration Method 2

All of the water spraying out of the nozzle of the rainfall simulator over ten (10) minutes was collected in a five-gallon (5 gal) bucket and weight to calibrate in one method. Density was used to calculate the volume. Total volume of water collected was divided by five feet by eight feet (5'x8') area was the second method used to calibrate the rainfall simulator. The calibration data is below in Table 5.

Above (left and right): A five gallon bucket was used to collect all water from the spray nozzles to calibrate the rainfall simulator in calibration method 2.

Table 5: Rainfall Simulator calibration using total volume of water collected from spray nozzles over time

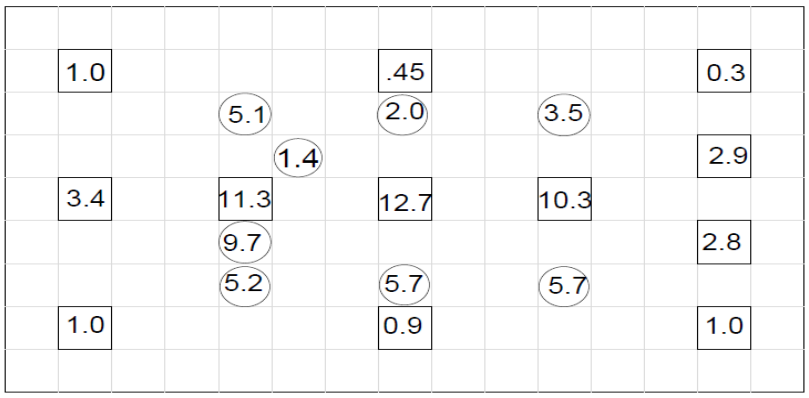
Volume (L)	ml/L	In^3/ml	Calibrator Area (in2) 5'x8'	Calibration Time (min)	min/hr	in/hr
35.47	1000	0.0610237	5760	10	60	2.25
34.13	1000	0.0610237	5760	10	60	2.17
35.06	1000	0.0610237	5760	10	60	2.23
					Average	2.22

The total volume method averaged 7.76 inches of water per simulation where the rain gauge calibration method measured 6.83 inches per simulation. One reason for the lower volume in the rain gauge calibration was that the number of rain gauges placed in the perimeter (18) compared to the interior (8) volume measurements, which are lower and more variable than interior measurements.

iii. Calibration Method 3 (Rejected)

Rain gauges were placed outside the five by eight foot (5'x8') area specified by equipment manufacturer to measure the water that fell on the 7.3'x12.5' pile used in Phase II. Figure 6 shows the distribution and of rain gauges and the amounts collected. When rain gauges were place outside the recommend five feet by eight feet (5'x8') area, the average precipitation was 3.9 inches of rain during 3.5 hours simulation event. This calibration grossly underestimates the amount of rain that fell over the center core of the pile and as a result was disregarded as an accurate method for calibration for the purposes of this project. Figure E shows rain gauge placement and volume of water collected for this calibration method.

Figure E: Calibration Method 3 rain gauge placement and volume of water collected

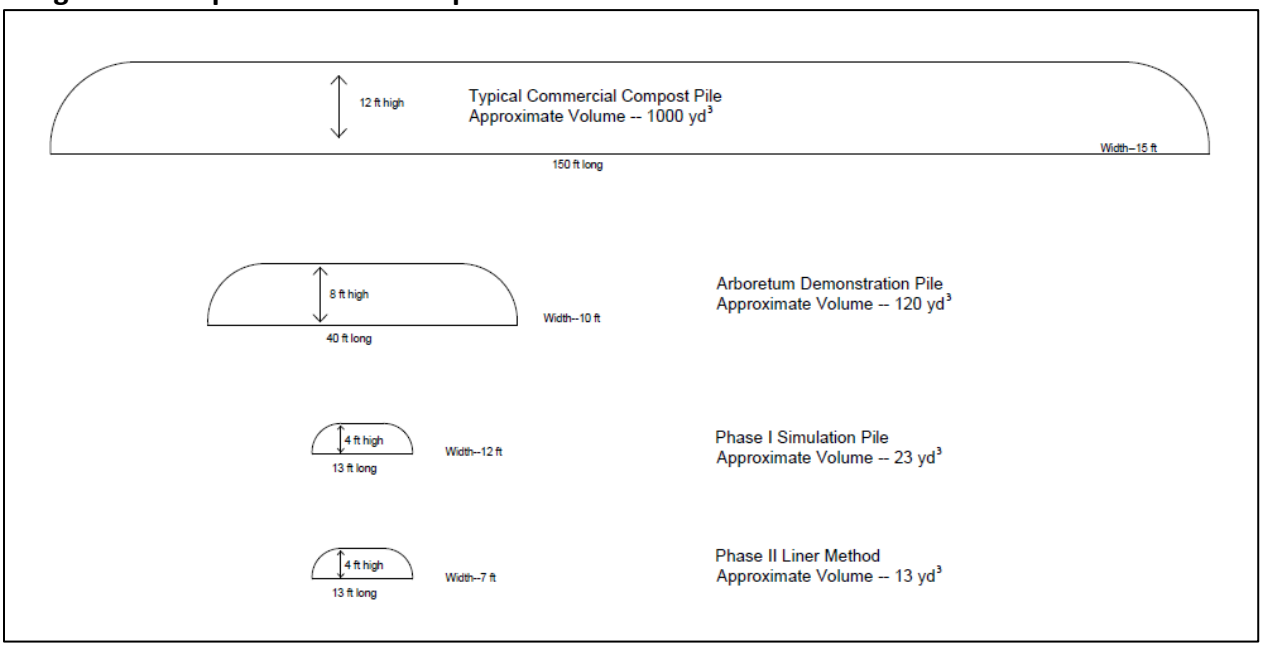


Square rain gauge placement was measured and recorded. Round rain gauges were randomly placed and location on figure is an estimate. The gauges read volumes in inches.

D. Test Piles

Figure F shows the difference in pile dimensions and volume from an operating compost facility in Minnesota to the pile sizes used in Phase I and Phase II of rainfall simulations. The pile size denoted in Phase II was that of the day of pile creation. The pile mass and height decrease as the subsequent simulations were conducted. On day one of Phase II, the pile dimensions were approximately seven feet wide, thirteen feet long and four feet tall (7'x13'x4') with a volume of thirteen cubic yards ($13yd^3$). The volumes of the Phase II piles were 77 times smaller than a typical commercial pile.

Figure F: Compost Pile Size Comparisons



Small piles of compost can produce more contact water than larger piles given the smaller mass to absorb and utilize added moisture. The heat of composting in a well-managed compost pile evaporates water and reduce the volume of contact water generation. The small piles used in Phase II in conjunction with high moisture content and added water from rainfall simulation did not allow the pile to heat up within 24 hours as expected but rather took over seven days to reach and maintain a temperature of 50°C. Lower pile temperatures result in lower evaporation rates.

E. Sub-Surface Collection of Contact Water

The MPCA designated lysimeters as the method for sub-surface contact water collection as part of the project Request for Proposal as well as the grant agreement specifying project objectives and sampling methods.

The extraction of soil water using the ceramic suction-cup lysimeter method has become well-developed over the past 40 years. It allows continuous sampling during any period and, if necessary, at several different depths of a soil profile. The installation of the suction probe is easy and the gravel surface and sub-soil profile is only negligibly disturbed.

Above: *Lysimeters prepared for installation.*

Porous ceramic cup lysimeters are preferable for field plots and studies confirm that they do not alter concentrations of parameters such as calcium (Ca), magnesium (Mg), or phosphates (PO_4-P) during collection.

F. Lysimeters

i. Description

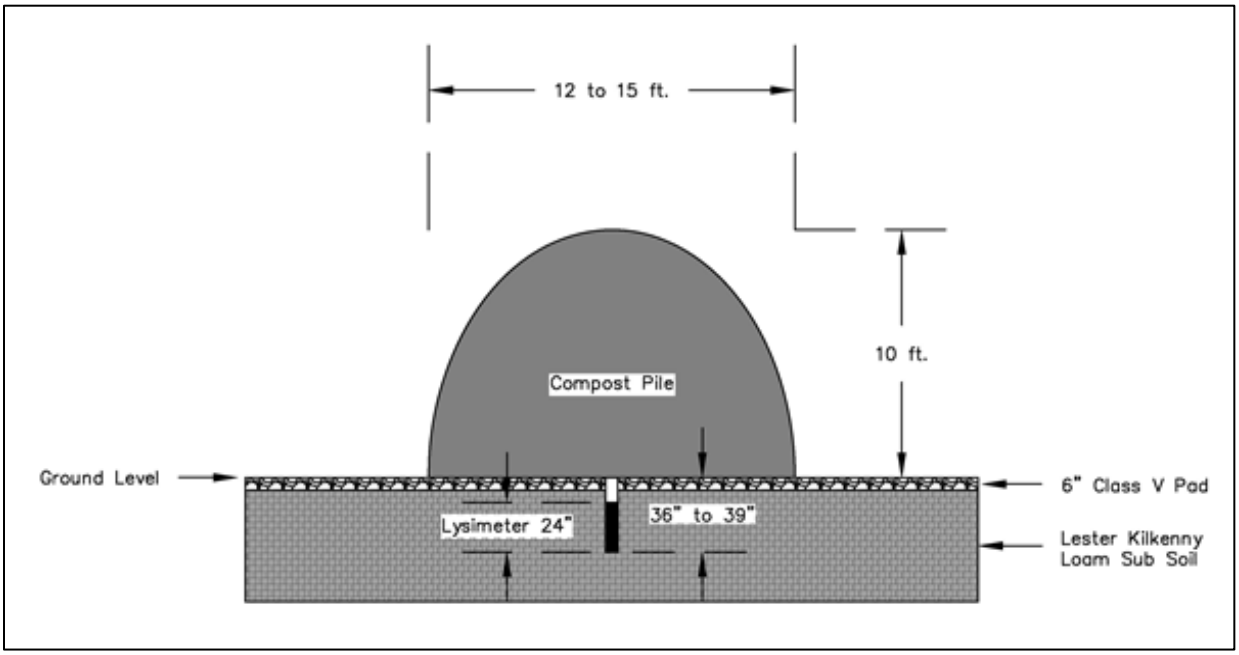
Above: *Installing lysimeters under the compost site pad*.

Lysimeters are ceramic suction tubes designed to capture water through sub-surface flow/drainage by a reverse pressurized system. Lysimeters collect water for analysis of chemical and biological parameters but cannot measure total volume of water moving through sub-surface matrices.

The twenty-four inch (24") lysimeters used for this study were buried thirty six inches (36") below the surface of the facility pad. Figure G shows a cross section of how the lysimeters were installed to collect sub-surface contact water that infiltrated through the pad and sub-soils. Bentonite clay plugs were used to backfill holes to prevent channeling. A hand pump was used to evacuate the tube and to blow out samples.

The lysimeters used are each capable of collecting one liter (1L) of water. Two tubes are attached to each lysimeter. One tube is used to apply a reverse pressure and a second is used to draw water that has collected within the lysimeter. Lysimeter collection and pressurization tubes were lined in PVC pipe underneath the soil pad and were moved to centralized water sampling locations.

Figure G: Sub-Surface Contact Water Collection Method via Lysimeters (Cross Section)



ii. Lysimeter Locations

Lysimeters were installed during the 2012 grant project at the Organics Composting Demonstration Site. They were strategically located to collect contact water after natural rain events that filter through the compost, contact water that was shed of the pile during rain events and precipitation that fell on the pad and naturally mixes with contact water as it moves off the pad. As controls, three (3) lysimeters were also placed off the facility pad in an open area on the north and south side of the site.

Specifically, lysimeters were installed in locations under the yard waste only as well as under one pile containing SSOM. Two lysimeters were installed down gradient of pile and in front of the compost water management berm (The contact water management berm was constructed as recommended by the MPCA including a 3-inch seeded compost blanket on the north and south sides of this berm to help absorb runoff.) One lysimeter was installed down gradient behind the compost water management berm to determine effectiveness of berm. Three additional lysimeters were installed off the compost pad as controls.

Figure H: Demonstration Site Contact Water Lysimeters Locations (Top View)

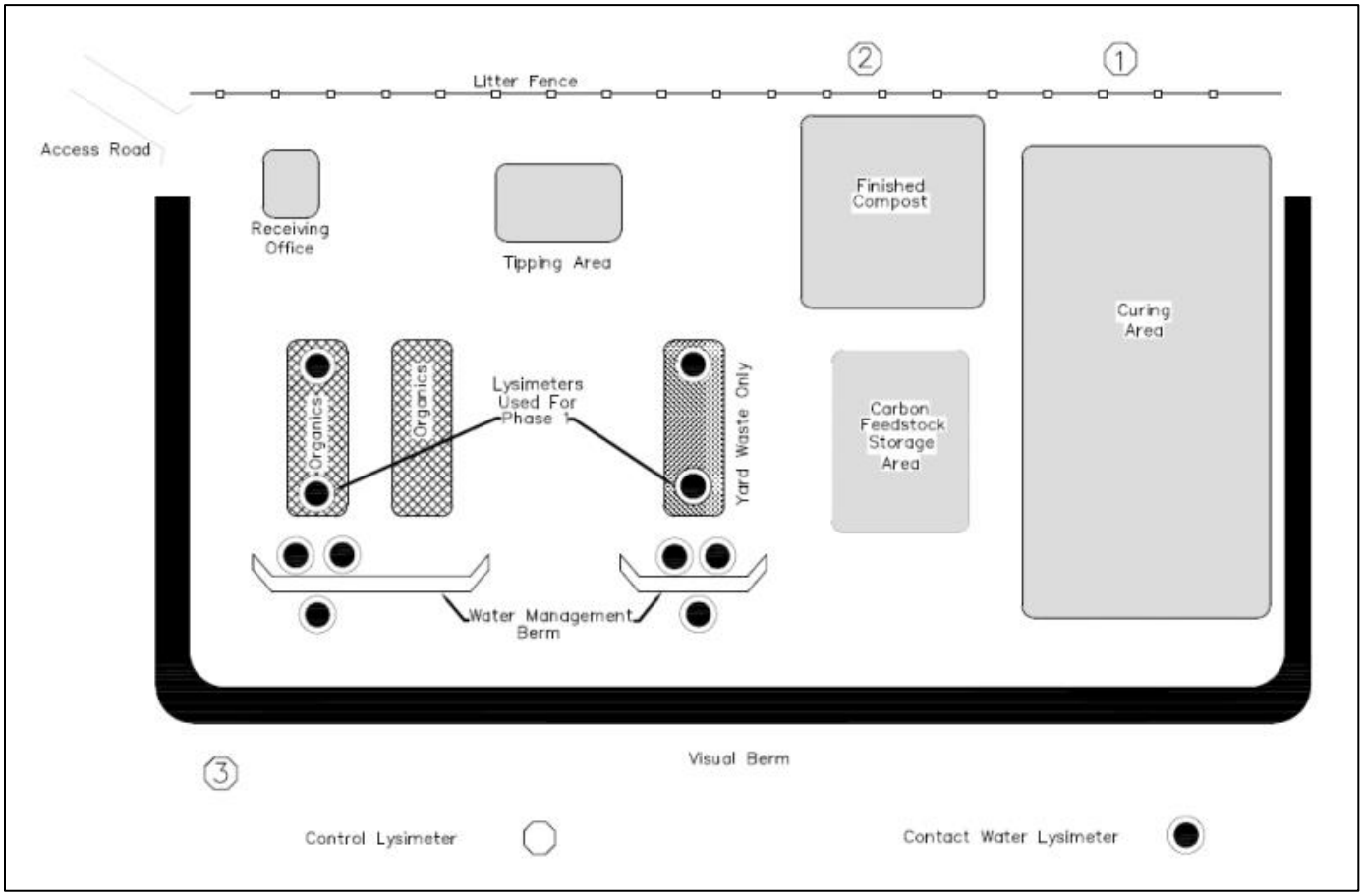


Figure H shows the top view of lysimeters placement for the 2012 project. When the MPCA required the use of a rainfall simulator and moved away from natural rain event, it limited the number of

lysimeters that could be used in the study. This was due to relatively small size of the simulator equipment. As a result of the size constraints, the rainfall simulator was placed directly over the lysimeters on the down gradient side of the organics and yard waste only piles as well as Control 1.

G. Surface Collection of Contact Water

As a result of limitations of the equipment and the inability to collect representative storm water samples, the rainfall simulator samples collected are not considered sheet flow sample but rather simply surface samples.

Surface samples were collected directly from the toe of the compost pile after they became saturated by simulated rain in Phase I. A small stream of contact water accumulated in metal collection pan installed down gradient of the pile. Samples were collected from the outlet of the collection pan. The surface samples collected with the use of the rainfall simulator represent point source pollution.[4] Due to limitations of the rainfall simulator, rain was applied only on the pile and not onto the surrounding pad. This prevented the collection of representative surface samples during natural rain events which would be considered non-point source pollution. The term non-point source is used to identify source of pollution that are diffused and do not have a point of origin or that are not introduced into a receiving stream from a standard outlet. The USEPA details common non-point pollution sources as: rain water, runoff from agricultural lands, industrial sites, parking lots, and timber operations.[5]

H. Moisture Content Analysis

The maximum moisture content for satisfactory aerobic composting varies with the feedstock. When strong fibrous materials are used, the maximum moisture content can be much larger without destroying structural qualities or causing material to become soggy, compact and unable to contain enough air in the interstices. But if it contains lots of paper or grass clippings, which have little structural strength when wet, or granular items such as ash and soil are used, lower moisture content is required.

In addition, weather can play a significant role in the moisture content of the feed stocks. Drought conditions can result in very dry feed stocks and wet weather in very wet feed stocks.

Too low or too high moisture content will slow the composting process. Moisture also helps to regulate temperature changes. Drier piles tend to heat up and cool down more rapidly than wetter piles; wetter piles take much longer to heat up since the pore spaces in the compost pile will be filled with water rather than air which limits aerobic decomposition.

When deciding what proportions of various materials to mix together in making compost piles, the moisture of the resulting mixture is one of the critical factors to consider. In Phase II of this project, samples were collected of each test cell piles and were brought to the University of Minnesota for

[4] "Point Source Pollution," 2009, U.S. Geological Survey, <http:toxics.usgs.gov/definitions/point-source.html>
[5] U.S. Environmental Protection Agency, 2010b

moisture analysis using the TMECC method. The construction of these piles was near or above the water holding capacities of the compost mixtures. This is a situation that compost operators should strive to avoid.

Above (left): *Professor Thomas Halbach prepares feedstock samples for moisture content analysis.* ***Above (right):*** *Samples after 24 hours drying in oven at University of Minnesota Lab.*

I. Bulk Density Analysis

Bulk density refers to the ratio of total weight (mass) of compost compared to its volume. Bulk density is used to convert compost recipes from weight to volume for field mixing. Bulk density directly affects the transportation and storage of compost. The amount of moisture strongly affects bulk density, with moist materials having a higher bulk density compared to dry materials. The optimal bulk density for compost range is 700-885 lbs/yd^3. Bulk density of the pile materials were measured utilizing the bucket method after pile creation and before and after each rainfall simulation. The bucket method is described in the Site Operations Plan in Appendix B.

Above: *Water is poured into a bucket of compost materials for the bucket test.*

J. Temperature

Temperature is a very good indicator of the process occurring within the composting material. The temperature increases due to the microbial activity and is noticeable within a few hours of forming a pile as easily degradable compounds are consumed. The temperature usually increases rapidly to 50 - 65°C (122°F - 149°F) where it is maintained for several weeks. This is called the active composting stage. Biochemical reaction rates approximately double with each 10°C (50°F) increase in temperature, yet higher temperatures will increase ammonia loss during the composting process. The temperature gradually drops to 40°C (104°F) as the active composting slows down and the curing stage begins. Eventually, the temperature will become that of the surrounding air.

Above: *Reo-Temp data logger used to track test compost pile temperatures on an hourly basis.*

The highest rates of decomposition occur when temperatures are in the range of 43 - 66°C (110 - 150°F). During the active composting stage, the temperature may start to fall because of a lack of oxygen. Turning mixes the material and reduces zonation. It also introduces higher levels of oxygen into the pile and the active composting stage continues. The temperatures in excess of 70°C (158°F) cause many microorganisms to die, which stops the active composting stage. Cooling the material by turning the pile helps to keep the temperature from reaching these damaging levels. Heat loss occurs primarily because of water evaporation from the material. Heat loss can also occur if the pile is too small or is exposed to cold weather. If the moisture content falls too low, microbial growth slows.

Minnesota compost rules for aerated static pile composting requires pile temperature must be maintained at 55°C (131°F) or higher for seven (7) days to destroy the viability of many pathogens and weed seeds. This requirement is called Process to Further Reduce Pathogens (PFRP). The testing protocol in Phase II called for the second rainfall simulation to be conducted after pile met PFRP. This was done to test compost entering the curing stage. To determine if the PFRP requirement was met, ReoTemp Data Loggers were utilized. These thermometers are left in place in the piles to track their temperatures on an hourly basis. One Data Logger probe was placed three feet (3') into the center of each pile.

K. Feedstock Analysis

The Project Team completed a compost recipe analysis of the proposed feedstock to ensure that the proposed feedstock had the appropriate carbon to nitrogen (C: N) ratio. The optimum range for the C:N ratio is thirty to one (30:1) to thirty five to one (35:1).

Feedstocks used in phase one included co-collected residential yard waste and SSO, leaf heavy yard waste, grass heavy yard waste, and commercial organics from the Arboretum cafeteria. Feedstocks including grass clippings, leaves, wood chips, co-collected residential yard waste and SSO, and commercial organics were used in Phase II test compost piles.

IV. Phase I - Fall 2012 Contact Water Collection Utilizing Rainfall Simulator with Lysimeters and Surface Water Collection Pan

Phase I rainfall simulations were conducted in the Fall of 2012 after MPCA technical staff approved the Sampling Protocol found in Appendix D. The objective was to collect both surface and sub-surface contact water samples. The ability to sample sub-surface water was necessary to determine if contact water was infiltrating the pad. Chemical and biological analysis of contact water collected from the lysimeters would also provide data on the effectiveness of a six inch (6") compacted Class 5 gravel pad and three feet (3') of loam soils mitigating potential ground water contamination.

A. Feedstock and Compost Mixes

For Phase I rainfall simulations conducted in the Fall of 2012, the MPCA approved the following rainfall simulation locations and feed stock mixes:

1. Native Soil the Organics Composting Demonstration Site was constructed on
2. Pad Only
3. Organics (Grass Heavy)
4. Organics (Leaf Heavy)
5. Yard Waste Only (Grass Heavy)
6. Yard Waste Leaf Feedstock
7. Arboretum Cafeteria Commercial Organics

Above (from left to right): *Organics (grass heavy) pile contents, Yard Waste Leaf Feedstock, Arboretum Cafeteria Commercial Organics test pile compositions*.

B. Pre-Simulation Data & Sample Collection

For analysis, grab samples were collected from piles before and after water was applied to determine pre and post simulation moisture content.

To determine the impact of the rainfall simulation on the size and temperature of the pile, the temperature and the height of the pile was recorded pre and post simulation in at least three different locations of the pile.

Above: *Pre-simulation measurements taken of a yard waste only pile.*

C. Contact Water Sampling

Sub-surface contact water samples were drawn from the lysimeters, twenty four (24) and forty eight (48) hours following the rainfall simulation events. To collect sub-surface samples, the test piles had to be strategically placed above and next to lysimeters. The Project Team measured and marked the location of the lysimeters
prior to aligning the rainfall simulator above the pile to be sure the lysimeter location was used as the center of the test area.

Surface contact water, water that migrated through the compost pile, was collected from the spout of the metal sampling pan installed at the toe of the pile.

Above: *Rainfall simulator set up with metal side walls and metal sampling pan at the toe of the pile.*

Above: *Sample collected from metal sampling pan at toe of the pile.*

Contact water samples were analyzed for the following parameters: pH, nitrogen (N), phosphorus (P), potassium (K), total dissolved solids (TDS), total suspended solids (TSS), carbaceous biological oxygen demand (cBOD), biological oxygen demand (BOD), chemical oxygen demand (COD), fecal coliform, total coliform, semi-volatile organic compounds (SVOCs), total phenols, pesticides, herbicides, and perfluorochemicals (PFCs). Pace Analytical was the primary laboratory used for analysis of all aqueous parameters other than PFCs, which were submitted to Test America for analysis. The City of Chanhassen's drinking water was used to supply the rainfall simulator and was also analyzed for the same analytical parameters as all other surface contact water samples.

During all seven rainfall simulations, rain was applied until sufficient sample volumes were collected from the surface of the pad through the metal sampling pan. Lysimeters were also used to collect contact water that may have infiltrated the pad and enter the sub-soils beneath the piles for Organics (grass heavy), Organics (leaf heavy), Yard Waste Only (grass heavy) and Yard Waste Leaf Feedstock. Contact water samples from rainfall simulations were all collected on the surface since no samples were found in lysimeters. . The only sub-surface water analyzed was from the control lysimeter off the Organics Composting Demonstration Site pad twenty-four (24) hours after the rainfall simulation. The lysimeter collected water sample volumes so low it allowed for the analysis of nitrogen, phosphorus and COD only.

Table 7 outlines the Phase I rainfall simulations including the pre and post simulation pile heights and temperatures, the rainfall simulator settings and run time, and the total volume of water that was applied to each pile type in order to obtain sufficient surface water sample volumes to test all parameters.

Table 7: Phase I Timeline and Description of Rainfall Simulation Events

Date	Material	Material Dimensions	Simulator Settings	Volume H_2O (gallons)
10.8.2012	Facility Pad	Not Applicable	Freq. 5; single sweep; 6psi, 2 hrs (3.4")	84.78
10.8.2012	Arboretum Organics	Height: 9.8", 9.4", 10.02", 6.25"	Freq. 5; single sweep, 6psi, 2 hrs (3.4")	84.78
10.9.2012	Residential Organics (Grass Heavy)	Before: 4' x 11'4" After:2'7" x 11'4"	Freq. 5; single sweep, 6psi, 3hrs 32min (6"); Freq. 5, double sweep, 6psi, 48min (2.72")	149.61 67.82 Total: 217.43
10.10.2012	Yard Waste (Grass Heavy)	Before: 3'7", 3'5", 3'3"x 7'6" After: 3'2.5", 3'8", 3'7"x 7'6"	Freq. 5; single sweep, 6psi, 7hrs 8min (18.3")	456.31
10.22.2012	Native Soil	Not Applicable	Freq. 5; single sweep, 6psi, 3hrs 32min (6")	149.61
10.23.2012	Residential Organics (Leaf Heavy)	3'7", 3'6", 3'5.5"	Freq. 5; double sweep, 6psi, 170 gallons H_2O	170
10.24.2012	Feedstock Leaves	3'4", 3'3", 3'6"	Freq. 5; single sweep, 6psi, (7.78")	194

D. Phase I Results

Phase I results refer to 2012 rainfall simulation events that took place over several different compost mixes and feedstocks.

The following tables show results of the seven rainfall simulation conducted. Seven included samples collected on the surface of the pad and one of sub-surface contact water samples from the lysimeter Control 1 where the rainfall simulator was positioned over the native soils adjacent to the Organics Composting Demonstration Site. The City water used for simulations was also tested. All simulations with the exception of the Pad Only, Leaf Feedstock, and the Arboretum Cafeteria material simulations were performed over existing site lysimeters. The absence of liquid collected in lysimeters located under the pad is consistent with results found in the 2008 and 2012 Carver County grant projects that suggest that contact water does not move vertically through the pad into the sub-soil below a compost pile under the soil moisture conditions at the time of the tests.

The parameters analyzed in this phase of the project included moisture, pH, nitrogen (N), phosphorus (P), potassium (K), total dissolved solids (TDS), total suspended solids (TSS), carbaceous biological oxygen demand (cBOD), biological oxygen demand (BOD), chemical oxygen demand (COD), fecal coliform, total coliform, semi-volatile organic compounds (SVOCs), total phenols, pesticides, herbicides, and perfluorochemicals (PFCs). The MPCA required the use of Minnesota Department of Health (MDH) Risk Limits (HRLs) for drinking water to compare the contact water and surface water samples. In addition, Minnesota surface water and irrigation limits were referenced when available. Laboratory reports can be found at www.mncompostingcouncil.org/research.

Phase I Analyte Qualifiers:

(>)	Parameter was not detected within the sample. The value following the less than (>) symbol is the detection limit reported by the lab for that parameter in that sample set.
~~S~~	Samples not filtered prior to analysis
SW	Surface Water Sample
LY	Lysimeter Sub-surface Water Sample
NA	Not Applicable
NR	Not Reported
NT	Not Tested
©	Fecal Coliform was run at CFU/100 mL
TNTC	Too Numerous To Count

i. 503 Metals

Of the 503 metals analyzed for in compost mixes and feedstocks: barium, copper, lead, silver and mercury results did not exceed MDH HRL drinking water standards. Table 8 shows the metal test results from all Phase I rainfall simulations.

Of the 503 metals reported for, commercial organics samples did not exceed MDH HRL's. For compost mixes and feedstocks: Grass heavy yard waste and residential organics (grass heavy) show arsenic results are above the MDH HRL drinking water standard (10 µg/L) but within the range of surface water limits (2-720 µg/L). Composts that are not grass heavy returned arsenic levels less than the 10 µg/L drinking water standard. Grass heavy and leaf heavy residential organics compost mixes returned cadmium results above drinking water standards (10 µg/L) but within the range of surface water limits (1.1-7.8 µg/L). Cafeteria organics, yard waste only (grass heavy) and feedstock leaves resulted in <4 µg/L detections. Residential organics, leaf and grass heavy as well as grass heavy yard waste returned nickel results above drinking water standard (100 µg/L) but below or within the range of surface water limits (158-2,836 µg/L). Leaf feedstock and cafeteria organics nickel results were <100 µg/L. Residential organics and grass heavy yard waste had boron results above MDH HRL (1,000 µg/L) and irrigation limits (500 µg/L). Cafeteria organics and leaf feedstock were below drinking water and irrigation limits. Residential organics and grass heavy yard waste had selenium results above drinking water (30 µg/L) limits and leaf heavy residential organics and grass heavy yard waste were above surface water limits (5-50 µg/L). Cafeteria organics and feedstock leaves results were <30 µg/L.

Surface samples of native soil showed high levels for lead and nickel but these values cannot be related to contact water since contact water did not infiltrate through the pad into lysimeters. Commercial organics feedstocks were found below detection limits for many parameters and below MDH HRL's for all parameters.

Table 8: Phase I Rainfall Simulation Results - Metals (µg/L) [9]

Date	10.23.12	10.24.12	10.8.12	10.8.12	10.8.12	10.9.12	10.23.12	10.10.12	10.24.12	MDH HRL (µg/L)
Sample Type	SW	LY	Control	SW	SW	SW	SW	SW	SW	
Sample ID	Native Soil	Control -1	RS Control City Water	Pad Only	Commercial Organics	Residential Organics (grass heavy)	Residential Organics (leaf heavy)	Yard Waste (grass heavy)	Feedstock-leaves	
Arsenic	<10	NT	<10	<10	<10	137	<10	1120	<10	10
Barium	302	NT	132	137	96.2	447	346	236	102	2000
Boron	501	NT	<150	<150	156	1740	1790	2190	360	1000
Cadmium	<2	NT	<2	<2	<2	7.4	4.1	<4	<2	4
Copper	484	NT	<10	15.6	39	150	182	153	35	1300
Lead	18.3	NT	<3	7.4	<3	<3	<3	67	<3	15
Molybdenum	<15	NT	<10	<15	<15	37.9	59.1	77.7	<15	30
Nickel	38.9	NT	<20	<20	<20	120	104	163	25.4	100
Selenium	23.7	NT	<20	30.6	28.8	37.3	62.1	56.8	28.5	30
Silver	n/a	NT	<10	<10	<10	<10	NR	NR	NR	30
Zinc	NT	NT	448	296	246	1570	4320	9970	316	2000

Mercury	<0.2	NT	<0.2	<0.2	<0.2	<0.6	<0.2	<0.6	<0.2	2

ii. Nitrogen and Phosphorus and TKN

Results for nitrate are all below the HRL value of 10 mg/L and are shown in Table 9. Total Kjeldhal Nitrogen (TKN) does not have an HRL or surface water limits. Values ranged from 27.3 mg/L (feedstock leaves) to 1,470 mg/L (grass heavy yard waste). Phosphorus does not have a MDH HRL or surface water limit. The range for phosphorus was 18.5 mg/L (commercial organics) to 71.3 mg/L (grass heavy yard waste). TKN and phosphorus do not have MDH HRLs or a range of surface water limits for comprehensive comparison of results.

Table 9: Phase I Rainfall Simulation Results – Nitrogen, Phosphorus & Potassium(NPK) (µg/L) [8]

Date	10.23.12	10.24.12	10.8.12	10.8.12	10.8.12	10.9.12	10.23.12	10.10.12	10.24.12	MDH HRL (µg/L)
Sample Type	SW	LY	Control	SW	SW	SW	SW	SW	SW	
Sample ID	Native Soil	Control C - N1	RS Control City Water	Pad Only	Commercial Organics	Residential Organics (grass heavy)	Residential Organics (leaf heavy)	Yard Waste (grass heavy)	Feedstock-leaves	
Nitrate	2.9	1.50	<0.1	<0.1	<0.1	7.2	<1.0	<5.0	<1.0	10
Nitrite	<0.1	<0.1	<0.1	<0.1	0.15	7.4	1.8	<5.0	<1.0	NA
Nitrogen	.30	1.5	<0.1	<0.1	0.11	7.4	<1.0	<2.0	<1.0	NA
Phosphorus	6.8	<0.1	.40	9.9	18.5	30.8	40.4	71.3	1009	NA
Potassium	12.6	NT	2.86	10.6	118	2310	1400	2880	319	NA
TKN	1.5	1.2	<0.1	<0.4	65.2	526	404	1470	27.3	NA

iii. Bacteria

Fecal coliform was too numerous to count (TNTC) for residential compost that was leaf heavy and for leaf feedstock. Fecal coliform samples were not tested for the other compost piles therefore data is incomplete and inconclusive. Total coliform was unsafe in the native soil but absent from the facility pad itself, as well as <1 CFU/100mL for cafeteria organics.

Table 10: Phase I Rainfall Simulation Results - Bacteria (µg/L) [a]									
Date	10.23.12	10.24.12	10.8.12	10.8.12	10.8.12	10.9.12	10.23.12	10.10.12	10.24.12
Sample Type	SW	LY	Control	SW	SW	SW	SW	SW	SW
Sample ID	Native Soil	Control -1	RS Control City Water	Pad Only	Commercial Organics	Residential Organics (grass heavy)	Residential Organics (leaf heavy)	Yard Waste (grass heavy)	Feedstock-leaves
pH	7.9	NT	8.2	8.2	4.6	6.9	4.9	5.4	6.2
Fecal Coliform©	NT	NT	NT	NT	NT	NT	TNTC	NT	TNTC
Total Coliform©	Unsafe	NT	Absent	<1 CFU/ 100ml	<1 CFU/ 100ml	Unable to run	NT	Unable to run	200000
E-Coli	NT	NT	NT	Unable to run	NT	NT	NT	NT	NT

iv. Solids and Oxygen Demand

All compost piles and feedstocks exceed the 500 mg/L direct consumption surface water limit. There are no drinking water or surface water standards for carbaceous biological oxygen demand (cBOD), biological oxygen demand (BOD), chemical oxygen demand (COD), or total suspended solids (TSS). Currently, MPCA is in the rulemaking process for TSS regulations to reduce river eutrophication. Results have limited application without standards against which they can be applied.

Table 11: Phase I Rainfall Simulation Results – Solids & Oxygen Demand (µg/L) [a]									
Date	10.23.12	10.24.12	10.8.12	10.8.12	10.8.12	10.9.12	10.23.12	10.10.12	10.24.12
Sample Type	SW	LY	Control	SW	SW	SW	SW	SW	SW
Sample ID	Native Soil	Control - 1	RS Control City Water	Pad Only	Commercial Organics	Residential Organics (grass heavy)	Residential Organics (leaf heavy)	Yard Waste (grass heavy)	Feedstock-leaves
TDS	345000	NT	334000	NT	NT	NT	13000000	25400000	2020000
TSS	554000	NT	<10000	371000	3120000	14200000	178000	50500	56400
cBOD	<60000	NT	<2000	411000	201000	275000	8400000	232000	979000
BOD	NT	NT	<2000	NT	NT	NT	NT	NT	NT
COD	138000	<50000	<50000	11200	3110000	4600000	45300000	35600000	2530000

v. Semi-Volatile Organic Compounds (SVOCs)

Surface contact water from all Phase 1 rainfall simulation events were analyzed for a variety of semi-volatile organic compounds (SVOCs). A single Phase I rainfall simulation sample returned a detectable amount. Phenols were detected in the grass heavy residential organics compost mix at 159 µg/L; all other samples were below detection limits. This concentration is within the surface water limits 123-4,428 µg/L. There is MDH HRL for phenols. The SVOC results from all Phase I rainfall simulations, showing the varying detection limits and the one detected sample are in Table 12.

Table 12: Phase I Rainfall Simulation Results – Semi-Volatile Organic Compounds (µg/L) [a]

Date	10.23.12	10.8.12	10.8.12	10.8.12	10.9.12	10.23.12	10.10.12	10.24.12
Sample Type	SW	Control	SW	SW	SW	SW	SW	SW
Sample ID	Native Soil	RS Control City Water	Pad Only	Commercial Organics	Residential Organics (grass heavy)	Residential Organics (leaf heavy)	Yard Waste (grass heavy)	Feedstock-leaves
1,2,4-Trichlorobenzene	<10.4	<10.2	<10.4	<10.2	<51.0	<1010	<1020	<102
1,2-Dichlorobenzene	<10.4	<10.2	<10.4	<10.2	<51.0	<1010	<1020	<102
1,2-Diphenylhydrazine	<10.4	<10.2	<10.4	<10.2	<51.0	<1010	<1020	<102
1,3-Dichlorobenzene	<10.4	<10.2	<10.4	<10.2	<51.0	<1010	<1020	<102
1,4-Dichlorobenzene	<10.4	<10.2	<10.4	<10.2	<51.0	<1010	<1020	<102
1-Methylnaphthalene	<10.4	<10.2	<10.4	<10.2	<51.0	<1010	<1020	<102
2,4,5-Trichlorophenol	<10.4	<10.2	<10.4	<10.2	<51.0	<1010	<1020	<102
2,4,6-Trichlorophenol	<10.4	<10.2	<10.4	<10.2	<51.0	<1010	<1020	<102
2,4-Dichlorophenol	<10.4	<10.2	<10.4	<10.2	<51.0	<1010	<1020	<102
2,4-Dimethylphenol	<10.4	<10.2	<10.4	<10.2	<51.0	<1010	<1020	<102
2,4-Dinitrophenol	<10.4	<10.2	<10.4	<10.2	<51.0	<1010	<1020	<102
2,4-Dinitrotoluene	<10.4	<10.2	<10.4	<10.2	<51.0	<1010	<1020	<102
2,6-Dinitrotoluene	<10.4	<10.2	<10.4	<10.2	<51.0	<1010	<1020	<102
2-Chloronaphthalene	<10.4	<10.2	<10.4	<10.2	<51.0	<1010	<1020	<102
2-Chlorophenol	<10.4	<10.2	<10.4	<10.2	<51.0	<1010	<1020	<102
2-Methylnaphthalene	<10.4	<10.2	<10.4	<10.2	<51.0	<1010	<1020	<102
2-Methylphenol(o-Cresol)	<10.4	<10.2	<10.4	<10.2	<51.0	<1010	<1020	<102
2-Nitroaniline	<10.4	<10.2	<10.4	<10.2	<51.0	<1010	<1020	<102
2-Nitrophenol	<10.4	<10.2	<10.4	<10.2	<51.0	<1010	<1020	<102
3&4-Methylphenol	<20.8	<20.4	<20.8	<20.3	<102	<2010	<2030	<204
3,3'-Dichlorobenzidine	<10.4	<10.2	<10.4	<10.2	<51.0	<1010	<1020	<102
3-Nitroaniline	<10.4	<10.2	<10.4	<10.2	<51.0	<1010	<1020	<102
4,6-Dinitro-2-methylphenol	<10.4	<10.2	<10.4	<10.2	<51.0	<1010	<1020	<102
4-Bromophenylphenyl ether	<10.4	<10.2	<10.4	<10.2	<51.0	<1010	<1020	<102
4-Chloro-3-methylphenol	<10.4	<10.2	<10.4	<10.2	<51.0	<1010	<1020	<102
4-Chloroaniline	<10.4	<10.2	<10.4	<10.2	<51.0	<1010	<1020	<102
4-Chlorophenylphenyl ether	<10.4	<10.2	<10.4	<10.2	<51.0	<1010	<1020	<102
4-Nitroaniline	<10.4	<10.2	<10.4	<10.2	<51.0	<1010	<1020	<102
4-Nitrophenol	<10.4	<10.2	<10.4	<10.2	<51.0	<1010	<1020	<102

Table 12 Continued: Phase I Rainfall Simulation Results – SVOCs (µg/L) [a]

Date	10.23.12	10.8.12	10.8.12	10.8.12	10.9.12	10.23.12	10.10.12	10.24.12
Sample Type	SW	Control	SW	SW	SW	SW	SW	SW
Sample ID	Native Soil	RS Control City Water	Pad Only	Commercial Organics	Residential Organics (grass heavy)	Residential Organics (leaf heavy)	Yard Waste (grass heavy)	Feedstock-leaves
bis(2-Chloroethyl) ether	<10.4	<10.2	<10.4	<10.2	<51.0	<1010	<1020	<102
Acenaphthene	<10.4	<10.2	<10.4	<10.2	<51.0	<1010	<1020	<102
Acenaphthylene	<10.4	<10.2	<10.4	<10.2	<51.0	<1010	<1020	<102
Anthracene	<10.4	<10.2	<10.4	<10.2	<51.0	<1010	<1020	<102
Benzo(a)anthracene	<10.4	<10.2	<10.4	<10.2	<51.0	<1010	<1020	<102
Benzo(a)pyrene	<10.4	<10.2	<10.4	<10.2	<51.0	<1010	<1020	<102
Benzo(b)fluoranthene	<10.4	<10.2	<10.4	<10.2	<51.0	<1010	<1020	<102
Benzo(g,h,i)perylene	<10.4	<10.2	<10.4	<10.2	<51.0	<1010	<1020	<102
Benzo(k)fluoranthene	<10.4	<10.2	<10.4	<10.2	<51.0	<1010	<1020	<102
bis(2-Chloroethoxy)methane	<10.4	<10.2	<10.4	<10.2	<51.0	<1010	<1020	<102
bis(2-Chloroisopropyl) ether	<10.4	<10.2	<10.4	<10.2	<51.0	<1010	<1020	<102
bis(2-Ethylhexyl)phthalate	<10.4	<10.2	<10.4	<10.2	<51.0	<1010	<1020	<102
Butylbenzylphthalate	<10.4	<10.2	<10.4	<10.2	<51.0	<1010	<1020	<102
Carbazole	<10.4	<10.2	<10.4	<10.2	<51.0	<1010	<1020	<102
Chrysene	<10.4	<10.2	<10.4	<10.2	<51.0	<1010	<1020	<102
Di-n-butylphthalate	<10.4	<10.2	<10.4	<10.2	<51.0	<1010	<1020	<102
Di-n-octylphthalate	<10.4	<10.2	<10.4	<10.2	<51.0	<1010	<1020	<102
Dibenz(a,h)anthracene	<10.4	<10.2	<10.4	<10.2	<51.0	<1010	<1020	<102
Dibenzofuran	<10.4	<10.2	<10.4	<10.2	<51.0	<1010	<1020	<102
Diethylphthalate	<10.4	<10.2	<10.4	<10.2	<51.0	<1010	<1020	<102
Dimethylphthalate	<10.4	<10.2	<10.4	<10.2	<51.0	<1010	<1020	<102
Fluoranthene	<10.4	<10.2	<10.4	<10.2	<51.0	<1010	<1020	<102
Fluorene	<10.4	<10.2	<10.4	<10.2	<51.0	<1010	<1020	<102
Hexachloro-1,3-butadiene	<10.4	<10.2	<10.4	<10.2	<51.0	<1010	<1020	<102
Hexachlorobenzene	<10.4	<10.2	<10.4	<10.2	<51.0	<1010	<1020	<102
Hexachloroethane	<10.4	<10.2	<10.4	<10.2	<51.0	<1010	<1020	<102
Indeno(1,2,3-cd)pyrene	<10.4	<10.2	<10.4	<10.2	<51.0	<1010	<1020	<102
Isophorone	<10.4	<10.2	<10.4	<10.2	<51.0	<1010	<1020	<102
N-Nitroso-di-n-propylamine	<10.4	<10.2	<10.4	<10.2	<51.0	<1010	<1020	<102
N-Nitrosodimethylamine	<10.4	<10.2	<10.4	<10.2	<51.0	<1010	<1020	<102
N-Nitrosodiphenylamine	<10.4	<10.2	<10.4	<10.2	<51.0	<1010	<1020	<102
Naphthalene	<10.4	<10.2	<10.4	<10.2	<51.0	<1010	<1020	<102
Nitrobenzene	<10.4	<10.2	<10.4	<10.2	<51.0	<1010	<1020	<102
Pentachlorophenol	<20.8	<20.4	<20.8	<20.3	<102	<2010	<2030	<204
Phenanthrene	<10.4	<10.2	<10.4	<10.2	<51.0	<1010	<1020	<102
Phenol	<10.4	<10.2	<10.4	<10.2	159	<1010	<1020	<102
Phenolics	<10.4	<10.2	<10.4	<10.2	<51.0	<1010	<1020	<102
Pyrene	<10.4	<10.2	<10.4	<10.2	<51.0	<1010	<1020	<102

vi. Pesticides and Herbicides

All pesticides were non-detected at the reporting limits. Only one of the herbicides analyzed, the herbicide 2,4-dichlorophenoxyacetic acid (2,4-D), was detected. It was found in three different samples that all contained yard waste. 2,4-D levels exceed Minnesota drinking water standards (70 µg/L) for residential grass and leaf heavy organics as well as grass heavy yard waste. Feedstock leaves and cafeteria organics did not show presence of herbicides. Sub-surface samples from lysimeters could not be tested as there was insufficient water.

The National Pesticide Information Center (NPIC) refers to 2,4-D as an herbicide and secondarily a plant growth regulator that is commonly used for broadleaf week control in agricultural and nonagricultural settings, and it is registered for use in both terrestrial and aquatic environments[6]. Major sites include pasture and rangeland, residential lawns, roadways, and cropland.

From its common uses detailed by the NPIC, it is logical that if 2,4-D were detected, that it would be detected in samples that contained yard waste including grasses. The University of Minnesota Landscape Arboretum does not use any pesticides or herbicides on the grasses of the premises, therefore, it is also logical that 2,4-D was not found in contact water samples from the Native Control (Over Lysimeter C) location. All pesticides and herbicides analyzed for are shown in Table 13.

Table 13: Phase I Rainfall Simulation Results - Pesticide and Herbicide (µg/L) [a]

Date	10.23.12	10.8.12	10.8.12	10.8.12	10.9.12	10.23.12	10.10.12	10.24.12	10.23.12
Sample Type	SW	Control	SW	SW	SW	SW	SW	SW	SW
Sample ID	Native Soil	Control C - N1	RS Control City Water	Pad Only	Commercial Organics	Residential Organics (grass heavy)	Residential Organics (leaf heavy)	Yard Waste (grass heavy)	Feedstock-leaves
Bolstar	<1	NT	<1	<1	<1	<1	<1	<1	<1
Chlorpyrifos	<1	NT	<1	<1	<1	<1	<1	<1	<1
Coumaphos	<1	NT	<1	<1	<1	<1	<1	<1	<1
Demeton	<2	NT	<2	<2	<2	<2	<2	<2	<2
Diazinon	<1	NT	<1	<1	<1	<1	<1	<1	<1
Dichlorvos	<1	NT	<1	<1	<1	<1	<1	<1	<1
Disulfoton	<2	NT	<2	<2	<2	<2	<2	<2	<2
EPN (ENT)	<1	NT	<1	<1	<1	<1	<1	<1	<1
Ethoprop	<1	NT	<1	<1	<1	<1	<1	<1	<1
Famphur	<1	NT	<1	<1	<1	<1	<1	<1	<1
Fensulfthion	<1	NT	<1	<1	<1	<1	<1	<1	<1
Fenthion	<1	NT	<1	<1	<1	<1	<1	<1	<1
Malathion	<1	NT	<1	<1	<1	<1	<1	<1	<1
Merphos	<1	NT	<1	<1	<1	<1	<1	<1	<1
Methyl Azinphos	<1	NT	<1	<1	<1	<1	<1	<1	<1

[6] National Pesticide Information Center. 2,4-D Technical Fact Sheet. <http://npic.orst.edu/factsheets/2,4-DTech.pdf>

Table 13 Continued: Phase I Rainfall Simulation Results - Pesticide and Herbicide (µg/L)									
Date	10.23.12	10.8.12	10.8.12	10.8.12	10.9.12	10.23.12	10.10.12	10.24.12	10.23.12
Sample Type	SW	Control	SW	SW	SW	SW	SW	SW	SW
Sample ID	Native Soil	Control C - N1	RS Control City Water	Pad Only	Commercial Organics	Residential Organics (grass heavy)	Residential Organics (leaf heavy)	Yard Waste (grass heavy)	Feedstock-leaves
Methyl parathion	<2	NT	<2	<2	<2	<2	<2	<2	<2
Mevinphos	<1	NT	<1	<1	<1	<1	<1	<1	<1
O,O,O-Triethylphophorothioate	<1	NT	<1	<1	<1	<1	<1	<1	<1
Parathion (Ethyl parathion)	<2	NT	<2	<2	<2	<2	<2	<2	<2
Phorate	<2	NT	<2	<2	<2	<2	<2	<2	<2
Ronnel	<1	NT	<1	<1	<1	<1	<1	<1	<1
Sulfotepp (Thiodiphosphoric Acid)	<2	NT	<2	<2	<2	<2	<2	<2	<2
Tetrachlorovinphos	<1	NT	<1	<1	<1	<1	<1	<1	<1
Thionazin	<1	NT	<1	<1	<1	<1	<1	<1	<1
Tokuthion (Prothiofos)	<2	NT	<2	<2	<2	<2	<2	<2	<2
Trichloronate	<2	NT	<2	<2	<2	<2	<2	<2	<2
2,4-D	<2	NT	<2	<2	<2	8.47	2.54	46.8	<2
2,4,5-T	<2	NT	<2	<2	<2	<2	<2	<2	<2
2,4,5-TP (Silvex)	<2	NT	<2	<2	<2	<2	<2	<2	<2

vii. Perfluorinated Compounds (PFCs)

Each PFC was detected in one or more rainfall simulations. Only one hit for PFOA at 1.2 µg/L was above the health based value (HBV) of 0.3 µg/L. HBVs are available for PFBA, PFBS, PFOA, and PFOS but do not exist for the other six PFCs tested. Sub-surface samples from lysimeters were not analyzed for PFCs due to a lack of water collected for analysis of any parameters.

Table 14 shows the PFC full name and its abbreviated identifier and Table 15 shows the results from all Phase I rainfall simulations.

Table 14: PFC Full Name and Abbreviated Identifier

PFC	Identifier
Perfluorobutane Sulfonate	PFBS
Perfluorobutanoic acid	PFBS
Perfluorodecanoic acid	PFDA
Perfluorododecanoic acid	PFDoA
Perfluoroheptanoic acid	PFHpA
Perfluorohexane Sulfonate	PFHxS
Perfluorohexanoic acid	PFHxA
Perfluorononanoic acid	PFNA
Perfluorooctanoic acid	PFOA
Perfluorooctane Sulfonate	PFOS

Table 15: Phase I Rainfall Simulation Results – PFCs (µg/L) [a]										
Date*	10.23.12	10.8.12	10.8.12	10.8.12	10.9.12	10.23.12	10.10.12	10.24.12	HBV (Health Based Value)	IL (Intervention Limit)
Sample Type	SW	Control	SW	SW	SW	SW	SW	SW		
Sample ID	Native Soil	Control C - N1	RS Control City Water	Pad Only	Commercial Organics	Residential Organics (grass heavy)	Residential Organics (leaf heavy)	Yard Waste (grass heavy)		
PFBS	<0.020	<0.019	<0.020	<0.021	0.071	0.025	0.011	0.017	7	---
PFBA	0.025	<0.019	0.01	0.02	<0.020	4.1	0.45	1	7	---
PFDA	<0.020	<0.019	<0.020	<0.021	0.059	0.013	0.0084	0.018		---
PFDoA	<0.030	<0.029	<0.030	<0.031	0.015	<0.029	<0.029	0.03	*7*	1.75
PFHpA	<0.030	<0.029	<0.030	<0.031	0.36	0.062	0.015	0.026	*7*	1.75
PFHxS	<0.030	<0.029	<0.030	<0.031	0.037	0.03	<0.029	0.0091	NA	---
PFHxA	<0.020	<0.031	0.0047	0.006	1	0.37	0.041	0.11	---	---
PFNA	<0.040	<0.039	<0.020	<0.042	0.067	0.017	0.039	0.04	---	---
PFOA	<0.020	<0.019	<0.020	<0.021	1.2	0.19	0.043	0.094	0.3	---
PFOS	<0.030	<0.029	0.027	0.19	0.1	0.061	0.013	0.055	0.3	---

viii. Moisture

Moisture content for feedstocks and compost shows increasing values from pre- to post-rainfall simulation events. Beginning moisture ranges from 24.81%-36.61% and final moisture ranges from 30.80%-69.35%. When initial moisture is around 30%, feedstocks and compost piles are able to absorb almost double their starting moisture.

Table 16: Phase 1 Rainfall Simulation Moisture Content Analysis			
Pile	Moisture Content Before Simulation	Moisture Content After Simulation (12”-24”)	Moisture Content After Simulation (0-12”)
Organics (Grass Heavy)	24.83%	39.08%	59.17%
Organics (Leaf Heavy)	44.63%	48.03%	n/a
Yard Waste (Grass Heavy)	36.61%	67.97%	n/a
Yard Waste (Leaf Feedstock)	30.79%	31.30%	69.38%

V. Phase II: Liner Method Rain Simulation

The second phase of rainfall simulations also utilized the Purdue-style rainfall simulator. The test cell design was a closed system, which was able to collect surface and sub-surface contact water from compost piles during each rainfall simulation (Figure H). Three identical test cells were constructed.

The base of each cell was excavated on native soil and was graded with a 5% slope. The slope led to an eight inch (8") polyvinyl chloride (PVC) pipe at the toe of the system. The base, edges and side berms of the test cell as well as the eight inch (8") PVC pipe were covered with a 40-mil high density polyethylene (HDPE) landfill liner. The PVC pipe directed collection of sub-surface contact water into a sub-surface 55-gallon plastic drum. Over the 40-mil HDPE liner, twelve inches (12") of sand was laid to prevent punctures through the liner. Over the sand layer, twelve inches (12") of gravel was laid and compacted in four inch (4") lifts using a single-direction plate compactor. The gravel layer was graded with a 2% slope. The surface of the gravel layer led to a surface contact water collection pan that drained into a 55-gallon plastic drum. Sheet metal was used to close the gap between the collection pan and the test cell berm.

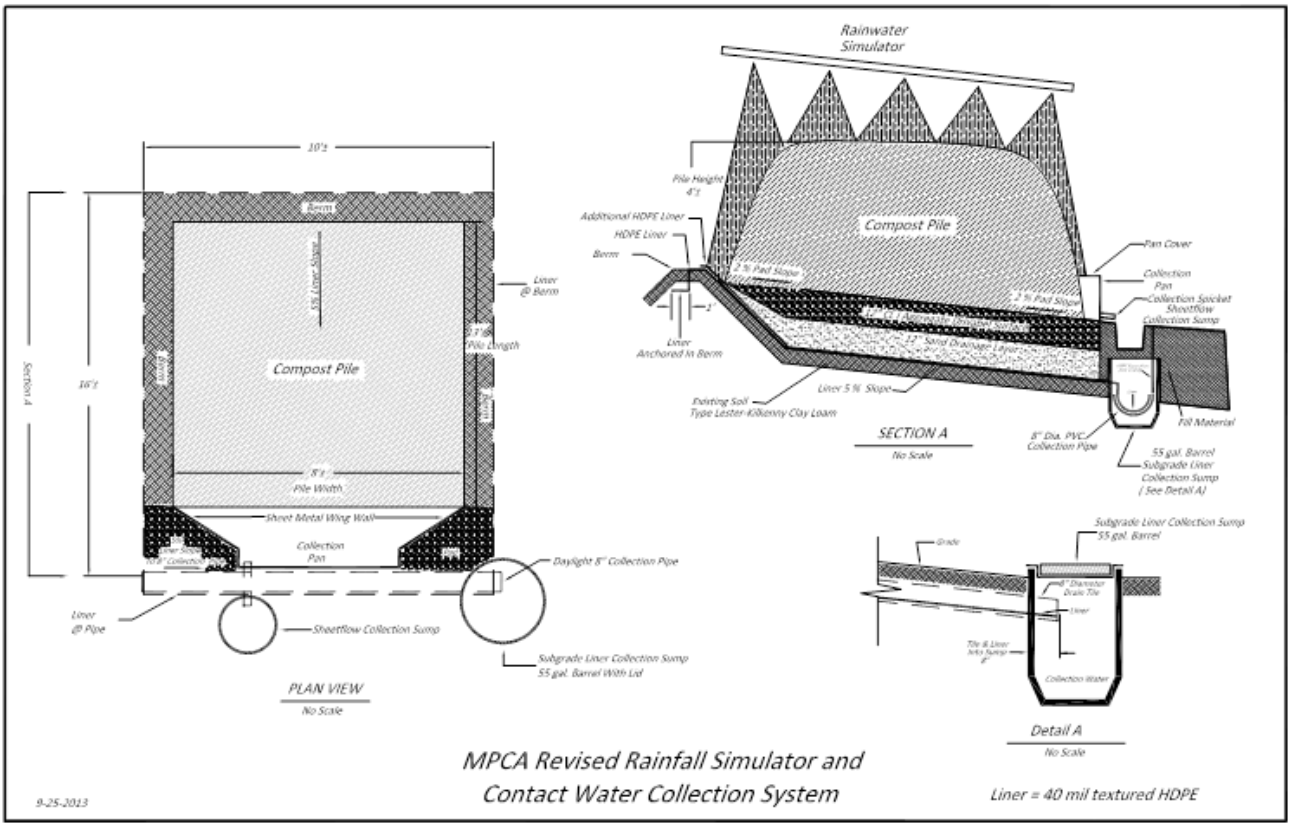
The following photographs show the test pads construction process:

1. The base of the test cells were covered with sand to protect the 40 mil landfill from being punctures by sharp rocks.
2. Contact water collection sumps were installed
3. The liner was placed over the sand base and the side berms.
4. A one foot (1') sand drainage layer was placed on the top of the liner for protection
5. One foot (1') of gravel was placed and compacted in six inch (4") lifts. A portable tapper was used for compaction because the roller used for a real pad was too big.

Above (left): *The test cells were created to specific dimensions.* ***Above (right):*** *A 40-mil HDPE liner lined the bottom of the test cell.*

Above (left): *A contact water collection system was installed to collect water that infiltrated through the compost pile and through the test cell fill.* ***Above (right)****: A portable tapper was used to compact the test cell fill above the liner.*

Figure H: Phase II Test Cell Design



Test cells were designed so the gravel surface was completely covered by the compost pile. No space remained from the edge of the compost pile to the berm of test cell #1 and #2. Test cell #3 was wider and some space remained between the edge of the compost pile and the edge of the berm. The test cell was designed to collect all contact water running off the gravel surface. The design also allowed

for the collection of contact water infiltrating through the gravel surface. Test cells were capable of collecting surface and sub-surface contact water separately.
Actual measurements of each test cell show some variation in total area:

Test Cell #1: 13’ long x 7’ 3” wide
Test Cell #2: 12’ 5” long x 7’ 3” wide
Test Cell #3: 12’ 10.5” long x 10’9” wide

A. Feedstock and Compost Materials

A front-end was loader used to bring ingredients to the Supreme Rotomix VTX 745 double-bladed mixer. SET staff made recommends for the proportions of ingredients that would be typical for standard operating procedures. Frontend buckets (3yd^3) from the loader measured the mix. SET staff placed one bucket of commercial food waste, one bucket of leaves, one bucket of green grass, and one half bucket of wood chips into the mixer. A digital readout on the mixer provided the actual weight added to the mixture from each ingredient. Three separate mixes using the same ingredients went onto each of the three test cells.

Above (left): *The front-end loader scoops compost feedstocks to be used.* ***Above (right):*** *The front-end loader places feedstocks into the mixer to create a homogenous compost mix for the pile.*
Below (left): *The front-end loader creates compost piles on the test cells with the compost mix.*
Below (right): *Completed test cells ready for testing to begin.*

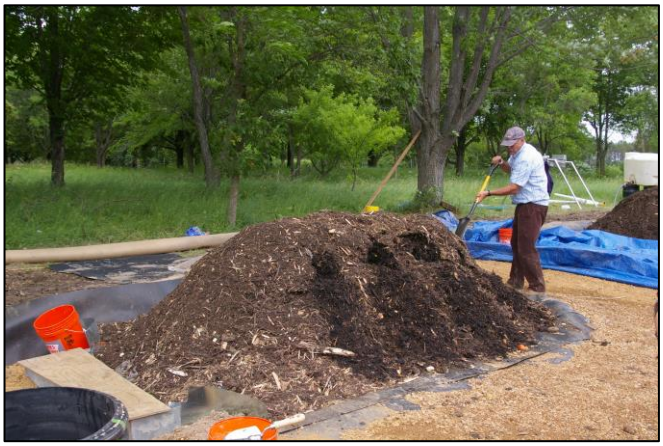
Table 17: Phase II Test Cell Recipe & Weight (lbs) for compost mixes			
Type of Feedstock	Cell #1	Cell #2	Cell #3
Commercial food waste	2,950	3,600	2,600
Grass	980	1,070	1,320
Co-collected food and grass	600	680	920
Leaves	3,970	3,650	3,320
Woodchips	685*	750	620
Total Weight	9,185	9,750	8,780
Measured % Moisture	61.73%	60.19%	59.16%
Measured Water Holding Capacity	65.02%	59.40%	61.70%

*For the first recipe woodchips were added subsequent to mixing due to a conversation with Tom Halbach, and were not weighed. This number is an average of 2nd and 3rd woodchip weights.

B. Pre-Simulation Sample & Data Collection

Two methods of analysis were used for solid sampling: synthetic precipitate leaching potential (SPLP), which includes an acid pre-treatment; and the test method for evaluating composting and compost (TMECC) which does not use any sample preparation. Parameters include: pH, TNK, total P, 503 metals, mercury, coliform, E. coli, total phenols, SVOC, pesticides, herbicides, PFC and BPA.

Samples were taken for solids and represent the edge, middle and core regions of the compost pile or feedstock pile. Samples from each region of the pile were mixed together for a representative sample. Laboratory jars and labels were provided for each parameter. Once sealed in the jar, samples were immediately placed in a cooler on ice. Coolers with samples were delivered to the laboratory on the day of sampling to meet all holding times according to EPA and laboratory standards. All samples were delivered to Pace Analytical on the day of sampling with the exception of BPA that was shipped overnight to AXYS (British Colombia) and Soil Control Laboratories (California).

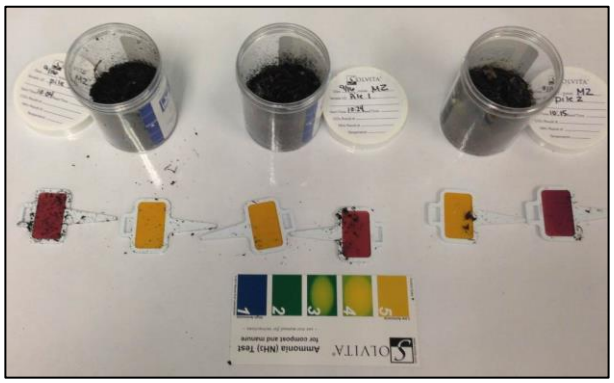


Above: *Samples taken for solid analysis from mixed compost materials.*

Table 18 details when and from which pile or compost materials SPLP and TMECC samples were taken during Phase II of this study.

Table 18: Phase II Solid Compost Materials & Feedstock Analysis							
Date	Compost Mix Day 1	Compost Mix Day 94	Commercial Organics	Wood-chips	Grass	Leaves	Co-Collected Organics
7.10.13	SPLP						
10.9.13			SPLP, TMECC	SPLP, TMECC	SPLP, TMECC	SPLP, TMECC	SPLP, TMECC
10.10.13		SPLP, TMECC					

C. Contact Water Sampling



Above: *Solvita sample test used to determine compost maturity.*

The Phase II rainfall simulation timeline was based on the stages of compost. The first round of simulations occurred on the day of mixing to represent material at tipping. The second round occurred at PFRP (Process to Further Reduce Pathogens), which is the critical stage for killing bacteria. The third round was conducted at maturity, determined by Solvita index higher than 5, to evaluate if compost at a mature stage can be removed from an impermeable surface.

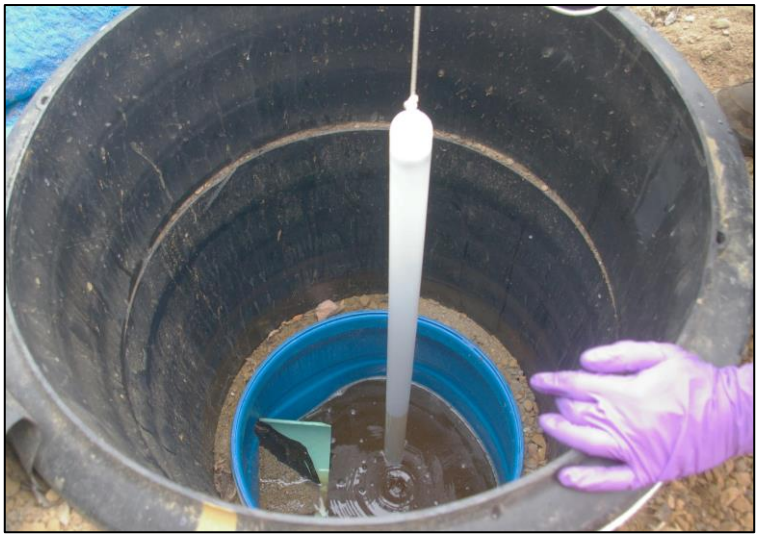
The first rainfall simulation produced surface contact water due to the collection pan not being covered. Samples taken from the surface sump during the first simulation were sent to the lab for analysis. None of the other simulation generated surface contact water. Samples were drawn from the sub-surface sump on the day following the rainfall simulation event.

Parameters analized include: temperature, moisture (pre- and post-simulation), bulk density, pH, cBOD, BOD, COD, TSS, TDS, TNK, total P, 503 metals, mercury, coliform, E. coli, total phenolics, SVOC, pesticides, herbicides, PFC and BPA were analyzed.

Above (left): *Rainfall simulator assembled over a Phase II test cell.* ***Above (right):*** *Visual of rain gauges and metal sampling pan in Phase II of rainfall simulations.*

Table 19: Phase II Rainfall Simulation Timeline and Description of Material					
Date	Test Cell	Material Dimensions	Simulator	Total Volume of H_2O Applied (gallons)	Volume collected From sub-surface Sump (gallons)
7.10.2013 Day 1 Mixing	3	13' 5" x 7'3"	Freq. 5; single sweep; 6psi, 212 minutes; 7.29"	181.77	70.5
7.11.2013 Day 1 Mixing	2	12'5" x 7'3"	Freq. 5; single sweep, 6psi, 212 minutes; 7.29"	181.77	71.6
7.12.2013 Day 1 Mixing	1	10'9" x 10'5"	Freq. 5; single sweep, 6psi, 212 minutes; 7.29"	181.77	68.0
8.14.2013 Day 38 PFRP	3	12'7" x 9'1" x 3'	Freq. 5; single sweep, 6psi, 212 minutes; 7.29"	181.77	99.5
8.15.2013 Day 38 PFRP	1	13'5" x 7'3" x 2'7"	Freq. 5; single sweep, 6psi, 242 minutes; 8.4"	209.45	93.5
8.16.2013 Day 38 PFRP	2	13'5" x 7'3"	Freq. 5; double sweep, 6psi, 212 minutes; 7.29"	181.77	87.0
9.17.2013 Day 72 Solvita: 5	1	13'11" x 8'8" x 2'3"	Freq. 5; double sweep, 6psi, 212 minutes; 7.29"	181.77	58.0
9.18.2013 Day 72 Solvita: 5	2	13'4"x 7'6.5" x 2'5"	Freq. 5; double sweep, 6psi, 212 minutes; 7.29"	181.77	63.0
9.19.2013 Day 72 Solvita: 5	3	No data	Freq. 5; double sweep, 6psi, 212 minutes; 7.29"	181.77	80.0

An average of the total volume and rain gauge calibration was used to report inches of rain per simulation. Project Staff and MPCA Technical Staff monitored the rainfall simulator throughout each procedure. Field notes and observations were recorded such as the time it took for contact water to break-through the system and drain into the collection sump, color and smell of contact water and total volume of water moving through the system. At the time of sampling, field parameters were observed and recorded for temperature, specific conductivity, pH, ORP, dissolved oxygen, and turbidity.



Above (left): *Disposable bailers collecting samples from sub-surface sump.*
Above (right): *Metal surface water collection pan.*

Contact water sample collections on the first round of simulations were drawn with a vacuum pump. Contact water samples for the second and third round of sample collection used a bailer. Samples were sealed in appropriate laboratory bottles and delivered to the laboratory. Laboratory jars and labels were provided for each parameter. Once sealed in the jar, samples were immediately placed in a cooler on ice. Coolers with samples were delivered to the laboratory on the day of sampling to meet all holding times according to EPA and laboratory standards. All samples were delivered to Pace Analytical on the day of sampling with the exception of PFC samples that were shipped overnight to AXYS (British Colombia).

The amount precipitation that is filtered through compost piles depends on the amount and intensity of rainfall, the moisture content of the compost, and the size of the pile. The pile sizes consisted of approximately thirteen cubic yards ($13yd^3$) of material which was 77 times smaller than a typical Specialized Environmental Technologies commercial compost pile. The moisture content of the Phase II test piles was close to the material water holding capacity and the amount and intensity of rain applied to the five foot by eight foot (5'x8') center of the pile exceeded a 200 year rain event. These parameters are not typical of an operating compost facility.

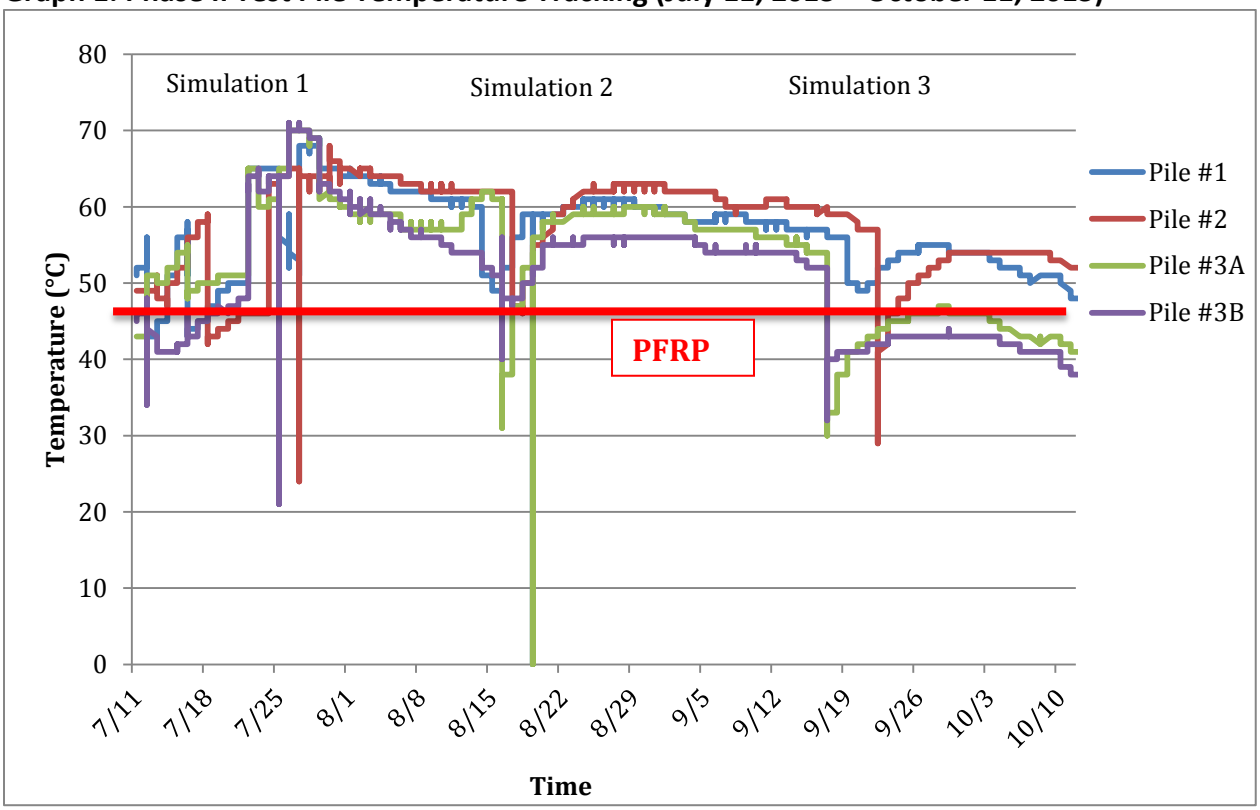
The amount of contact water infiltrating the pad of the test cell depends on percent grade, permeability of gravel and sub-surface soils. According to C.B Wilson, of EOR, Inc. Report "Gravel Road, Pad infiltration Characteristics April 7, 2014", the vast majority of rainfall from the working pad at the Organics Composting Demonstration Site would be converted to surface runoff with very small amounts of infiltration. The report can be found as Appendix E. With 37%-55% percent of rain applied to piles being collected in sub-surface sumps and none in surface sumps make evident that the test cells are not representative of a working compost site pad.

D. Phase II Temperature & Moisture Observations

i. Temperature 2013

Compost pile temperature records show decreases in temperature after rainfall simulation events. Compost piles typically range between 55°C- 60°C and fall below 50° C after rain events. After the first two rainfall simulations, compost pile temperatures initially decrease and then increased above 55°C after several days. After the third rainfall simulation in September, the piles did not consistently increase above 50° C. Toward the end of September and beginning of October, compost pile temperatures steadily decrease below 40° C. Temperatures of the Phase II test piles are tracked in Graph 1.

Graph 1: Phase II Test Pile Temperature Tracking (July 11, 2013 – October 11, 2013)



**Large dips in the graph signify the thermometer being removed from the compost piles and display a reading of the air temperature at that time.*

***The largest dip represents a dead thermometer battery.*

ii. Moisture Content

Moisture content, water holding capacity and bulk density describe physical properties of compost. Table 20 shows average values for moisture content and water holding capacity for Phase II test cell compost materials. When the moisture content is equal to the water holding capacity, compost is saturated and cannot absorb any more water to its particles. When compost saturates, water flows

downward by gravity through macro-pores in the composted material. In Round 1 the post simulation moisture content exceeded the water holding capacity.

Table 20: Phase II Moisture Content and Water Holding Capacity of Test Cell Compost Materials			
	1st Round	2nd Round	3rd Round
Pre-Simulation	56.66%	45.31%	41.18%
Post-Simulation	62.56%	59.12%	54.44%
"n size" pre/post	7/7	6/6	8/6
Water Holding Capacity	62.04	Not Tested	Not Tested

The recommend moisture content for a compost pile is 40% - 60% depending on the water holding capacity of the feedstock and compost materials. The greater the water holding capacity the higher the moisture content can be during the active composting phase. Higher moisture content can speed up the composting process; it is recommend to keep moisture content 10% below optimum level as a an effective technique for reducing contact water generation.

Table 21 shows bulk density for each round of simulations.

Table 21: Phase II Bulk Density of Test Cell Compost Materials prior to each Rainfall Simulation (g/mL)			
Test Cell #	1	2	3
1st Round	0.37	0.52	0.45
2nd Round	0.43	0.41	0.47
3rd Round	0.44	0.47	0.51

E. Phase II Contact Water Results

The following tables show results from sub-surface compost contact water samples for all three Phase II rainfall simulation events. Potential contaminants include: cBOD, BOD, COD, TSS, TDS, TNK, total P, 503 metals, mercury, coliform, E. coli, total phenolics, SVOC, pesticides, herbicides, PFC and BPA. Individual parameters are discussed in detail below. Laboratory reports can be found at www.mncompostingcouncil.org/research.

Phase II Definitions & Analyte Qualifiers:

(>) Parameter was not detected within the sample. The value following the less than (>) symbol is the detection limit reported by the lab for that parameter in that sample set.

s Samples not filtered prior to analysis

NA Not Applicable

NR Not Reported

NT Not Tested

e Defects in sampling and collection method invalidated results

C2 The relative percent difference between the two detectors is greater than 40%, indicating the interference on one of the detectors. The lower of the two values is reported.

C3 The relative percent difference between the two detectors is greater than 40%, indicating the interference on one of the detectors. The higher of the two values is reported.
D2 The reporting limit was reduced by half.
NQ Non-quantifiable due to matrix issues with contact water
D Reporting limit was halved
P12 A reduced sample aliquot was prepared because of observed nature of sample matrix.
DF Dilution Factor, if reported the factor applied to the reported data due to changes in sample preparation, dilution of the sample aliquot, or moisture content.

i. 503 Metals

The 503 metals from the second phase of rainfall simulations show a wide range of results. Metals that do not exceed drinking water standards for all three rounds included: chromium, copper, selenium, sliver and zinc. Cadmium, lead and mercury have median values less than the MDH HRL but some values exceeded the standard. Over half of the results for arsenic, barium, boron and molybdenum exceeded drinking water standards. All of the nickel results exceed MDH HRL values.

Table 22: Phase II Rainfall Simulation Results - Sub-Surface 1 - Metals and Biological Elements (µg/L)[a]

Aqueous Test Cell #	1 Sub-surface	1 Sub-surface	1 Sub-surface	2 Sub-Surface	2 Sub-Surface	2 Sub-Surface	3 Sub-Surface	3 Sub-Surface	3 Sub-Surface	MDH HRL
Date	7.13.13	8.15.13	9.18.2013	7.12.13	8.16.13	9.19.13	7.11.13	8.17.13	9.20.13	
Arsenic	13.6	57.3	20.2	17	76.5	30	5.5	37.4	30	10
Barium	2500	12000	1600	4210	13700	1060	1220	4670	1060	2000
Boron	1130	1770	731	1530	1730	996	680	980	996	1000
Cadmium	4.2	6.7	0.5	6.8	7.6	0.67	1.7	2.6	0.67	4
Chromium	26.8	18.7	3.6	41.1	27.1	4.4	14.9	12	4.4	100
Copper	757	554	236	770	413	317	222	319	317	1300
Lead	1.1	86.7	3.1	1.8	111	6.7	0.88	33.96	6.7	15
Mercury	<.60	1.5	<.20	0.88	2	0.49	<.20	0.48	0.49	2
Molybdenum	89	29.2	20.5	157	21.4	32.8	32.4	25.1	32.8	30
Nickel	1110	1200	266	1170	1120	296	220	629	296	100
Potassium	144000	1800000	830000	400000	2040000	927000	135000	1010000	927000	NA
Selenium	6.6	6.7	3.5	8.6	<10	3.9	4.3	3.5	3.9	30
Silver	<2.5	<2.5	<2.5	<2.5	<10	<2.5	<2.5	<2.5	<2.5	30
Zinc	113	96.7	<25.0	183	115	<25.0	327	47.7	<25.0	2,000

ii. Nitrogen and Phosphorus

Results for nitrogen are divided into nitrate (NO_3-), nitrite (NO_2-) and TKN (organic N). Nitrate results range from 1-32.6 mg/L; nitrite ranges from 0.49-28.6 mg/L; TKN ranges from 111-572 mg/L for sub-surface contact water. One third of nitrate levels are above the drinking water limit. Over half of the results for nitrite are above the HRL. There is no MDH HRL or surface water limit for comparing TKN values. Phosphorus results range from 0.48-1.8 mg/L but there are no water standards for comparison.

Table 23: Phase II Rainfall Simulation Results - Sub-Surface: NPK (µg/L)[a]										
Aqueous Test Cell #	1 Sub-surface	1 Sub-surface	1 Sub-surface	2 Sub-Surface	2 Sub-Surface	2 Sub-Surface	3 Sub-Surface	3 Sub-Surface	3 Sub-Surface	MDH HRL
Date	7.13.13	8.15.13	9.18.2013	7.12.13	8.16.13	9.19.13	7.11.13	8.17.13	9.20.13	
Nitrate as N	20.2	NT	2.2	32.6	NT	NT	18.1	NT	NT	10
NO2&NO3	20.4	NT	2.2	32.8	NT	8.3	18.8	NT	8.3	10
Nitrite	17.2	NT	NT	28.6	NT	9.1	3.5	NT	9.1	1
TKN	205	481	143	303	572	120	111	250	120	NA
Phosphorous	1	<1	1.2	1.8	1.4	0.91	1.2	1	0.91	NA

iii. Bacteria

Bacteria were present in all three rain simulations. This finding contradicted the well-established practice of PFRP (Process to Further Reduce Pathogens). As a result, Dr. Michael Sandowsky, Chair of the BioTechnology Institute of the University of Minnesota, was asked to conduct an independent review of the test methods as well as the results. He cited the following issues with Liner Method and the corresponding results.

- "Elevated temperatures (about 55C) generated during composting are not conducive to life of gram negative bacteria such as total coliforms and E. coli. Consequently, any bacteria seen post composting are almost certainly due to growth of contaminating bacteria in the collection system (the sump) which has temperatures more conducive for microbial growth 25-37C."
- "The growth you saw in your collection sump is made even more conducive to microbial growth as leachate entering the sump would be rich in organic matter (N, P, and S) that would help facilitate microbial growth."

Based on these issues, he found that the Liner Method is not useful for measuring bacterial loading of the compost pile following a normal composting cycle.

Table 24: Phase II Rainfall Simulation Results – Bacteria (MPN/100 mL)[a]										
Aqueous Test Cell #	1 Sub-surface	1 Sub-surface	1 Sub-surface	2 Sub-Surface	2 Sub-Surface	2 Sub-Surface	3 Sub-Surface	3 Sub-Surface	3 Sub-Surface	MDH HRL
Date	7.13.13	8.15.13	9.18.2013	7.12.13	8.16.13	9.19.13	7.11.13	8.17.13	9.20.13	
Total Coliform	242000[e]	200500[e]	200500[e]	242000 [e]	200500[e]	20000[e]	242000[e]	200500[e]	20000[e]	Absent
E-Coli	242000[e]	2005,00[e]	65900[e]	242000[e]	200500[e]	870[e]	242000[e]	200500[e]	870[e]	Absent

iv. Solids and Oxygen Demands

There are few standards for comparing solids and oxygen demands in waters of Minnesota. Total dissolved solids (TDS) rage from 3,440-27,400 mg/L and exceed the surface water limit of 500 mg/L . Total suspended solids (TSS) range from 18.2-131 and there for no MDH HRL for this parameter. Carbonaceous oxygen demand (cBOD) rages from 1,280-21,000 mg/L but there is no HRL or surface water limit for cBOD. Biological oxygen demand (BOD) ranges from non-detect-15,600 mg/L. While

there is not MDH HRL for BOD, surface water limits are 7 mg/L and only one data point in the third simulation fell below this limit. Chemical oxygen demand (COD) ranges from 2,190-303,000 mg/L, however, there are no standards for this parameter.

Table 25: Phase II Rainfall Simulation Results - Sub-Surface Test Cell 1: SVOCs (mg/L)[a]

Aqueous Test Cell #	1 Sub-surface	1 Sub-surface	1 Sub-surface	2 Sub-Surface	2 Sub-Surface	2 Sub-Surface	3 Sub-Surface	3 Sub-Surface	3 Sub-Surface
Date	7.13.13	8.15.13	9.18.2013	7.12.13	8.16.13	9.19.13	7.11.13	8.17.13	9.20.13
TDS	20000	17100	3440	27400	21100	3810	9980	11300	3810
TSS	18.2	131	55.6	29.1	164	32.2	23.4	30.4	32.2
cBOD	6870	18700	1720	6950	21200	ND	2180	15500	ND
BOD	7070	5220	786	7080	15600	<1200	2190	14700	<1200
COD	24400	303000	2190	45300	58000	2900	14700	13700	2900

v. Phenols and Semi-Volatile Organic Compounds

Phenols are natural products of decomposition and the samples collected range from <500-4,610 µg/L. While there are no drinking water limits for phenols, surface water limits range from 123-4,428 µg/L. Only one data point from one rainfall simulation event shows results for SVOCs. The single result for 882 µg/L 2-methylphenol (o-Cresol) comes from the surface water collection sump which was deemed as an outlier.

Table 26: Phase II - Sub-Surface: SVOCs (µg/L)[a]

Aqueous Test Cell #	1 Sub-surface	1 Sub-surface	1 Sub-surface	2 Sub-Surface	2 Sub-Surface	2 Sub-Surface	3 Sub-Surface	3 Sub-Surface
Date	7.13.13	8.15.13	9.18.13	7.12.13	8.16.13	9.19.13	7.11.13	8.17.13
1,2,4-Trichlorobenzene	<1030	<21300	<10	<1040	<22200	<10	<207	<10300
1,2-Dichlorobenzene	<1030	<21300	<10	<1040	<22200	<10	<207	<10300
1,2-Diphenylhydrazine	<1030	<21300	<10	<1040	<22200	91.5	<207	<10300
1,3-Dichlorobenzene	<1030	<21300	<10	<1040	<22200	<10	<207	<10300
1,4-Dichlorobenzene	<1030	<21300	<10	<1040	<22200	<10	<207	<10300
1-Methylnaphthalene	<1030	<21300	<10	<1040	<22200	<10	<207	<10300
2,4,5-Trichlorophenol	<1030	<21300	<10	<1040	<22200	<10	<207	<10300
2,4,6-Trichlorophenol	<1030	<21300	<10	<1040	<22200	<10	<207	<10300
2,4-Dichlorophenol	<1030	<21300	<10	<1040	<22200	<10	<207	<10300
2,4-Dimethylphenol	<1030	<21300	<10	<1040	<22200	<10	<207	<10300
2,4-Dinitrophenol	<1030	<21300	<10	<1040	<22200	<10	<207	<10300
2,4-Dinitrotoluene	<1030	<21300	<10	<1040	<22200	<10	<207	<10300
2,6-Dinitrotoluene	<1030	<21300	<10	<1040	<22200	<10	<207	<10300
2-Chloronaphthalene	<1030	<21300	<10	<1040	<22200	<10	<207	<10300
2-Chlorophenol	<1030	<21300	<10	<1040	<22200	<10	<207	<10300
2-Methylnaphthalene	<1030	<21300	<10	<1040	<22200	<10	<207	<10300
2-Methylphenol(o-Cresol)	<1030	<21300	<10	<1040	<22200		<207	<10300
2-Nitroaniline	<1030	<21300	<10	<1040	<22200	155	<207	<10300
2-Nitrophenol	<1030	<21300	<10	<1040	<22200	55	<207	<10300
3&4-Methylphenol	<2060	<42600	<10	<2070	<44400	<10	<415	<20600
3,3'-Dichlorobenzidine	<1030	<21300	<10	<1040	<22200	<10	<207	<10300

Table 26 Continued: Phase II - Sub-Surface: SVOCs (µg/L)[a]								
Aqueous Test Cell #	1 Sub-surface	1 Sub-surface	1 Sub-surface	2 Sub-Surface	2 Sub-Surface	2 Sub-Surface	3 Sub-Surface	3 Sub-Surface
Date	7.13.13	8.15.13	9.18.13	7.12.13	8.16.13	9.19.13	7.11.13	8.17.13
3-Nitroaniline	<1030	<21300	<10	<1040	<22200	<10	<207	<10300
4,6-Dinitro-2-methylphenol	<1030	<21300	<10	<1040	<22200	<10	<207	<10300
4-Bromophenylphenyl ether	<1030	<21300	<10	<1040	<22200	<10	<207	<10300
4-Chloro-3-methylphenol	<1030	<21300	<10	<1040	<22200	<10	<207	<10300
4-Chloroaniline	<1030	<21300	<10	<1040	<22200	<10	<207	<10300
4-Chlorophenylphenyl ether	<1030	<21300	<10	<1040	<22200	<10	<207	<10300
4-Nitroaniline	<1030	<21300	<10	<1040	<22200	<10	<207	<10300
4-Nitrophenol	<1030	<21300	<10	<1040	<22200	<10	<207	<10300
Acenaphthene	<1030	<21300	<10	<1040	<22200	<10	<207	<10300
Acenaphthylene	<1030	<21300	<10	<1040	<22200	<10	<207	<10300
Anthracene	<1030	<21300	<10	<1040	<22200	<10	<207	<10300
Benzo(a)anthracene	<1030	<21300	<10	<1040	<22200	<10	<207	<10300
Benzo(a)pyrene	<1030	<21300	<20	<1040	<22200	<10	<207	<10300
Benzo(b)fluoranthene	<1030	<21300	<10	<1040	<22200	<10	<207	<10300
Benzo(g,h,i)perylene	<1030	<21300	<10	<1040	<22200	<20	<207	<10300
Benzo(k)fluoranthene	<1030	<21300	<10	<1040	<22200	<10	<207	<10300
bis(2-Chloroethoxy)methane	<1030	<21300	<10	<1040	<22200	<10	<207	<10300
bis(2-Chloroethyl) ether	<1030	<21300	<10	<1040	<22200	<10	<207	<10300
bis(2-Chloroisopropyl) ether	<1030	<21300	<10	<1040	<22200	<10	<207	<10300
bis(2-Ethylhexyl)phthalate	<1030	<21300	<10	<1040	<22200	<10	<207	<10300
Butylbenzylphthalate	<1030	<21300	<10	<1040	<22200	<10	<207	<10300
Carbazole	<1030	<21300	<10	<1040	<22200	<10	<207	<10300
Chrysene	<1030	<21300	<10	<1040	<22200	<10	<207	<10300
Di-n-butylphthalate	<1030	<21300	<10	<1040	<22200	<10	<207	<10300
Di-n-octylphthalate	<1030	<21300	<10	<1040	<22200	<10	<207	<10300
Dibenz(a,h)anthracene	<1030	<21300	<10	<1040	<22200	<10	<207	<10300
Dibenzofuran	<1030	<21300	20.7	<1040	<22200	67.7	<207	<10300
Diethylphthalate	<1030	<21300	<10	<1040	<22200	<10	<207	<10300
Dimethylphthalate	<1030	<21300	<10	<1040	<22200	<10	<207	<10300
Fluoranthene	<1030	<21300	<10	<1040	<22200	<10	<207	<10300
Fluorene	<1030	<21300	<10	<1040	<22200	<10	<207	<10300
Hexachloro-1,3-butadiene	<1030	<21300	<10	<1040	<22200	<10	<207	<10300
Hexachlorobenzene	<1030	<21300	<10	<1040	<22200	<10	<207	<10300
Hexachloroethane	<1030	<21300	<10	<1040	<22200	<10	<207	<10300
Indeno(1,2,3-cd)pyrene	<1030	<21300	<10	<1040	<22200	<10	<207	<10300
Isophorone	<1030	<21300	<10	<1040	<22200	<10	<207	<10300
N-Nitroso-di-n-propylamine	<1030	<21300	<10	<1040	<22200	<10	<207	<10300
N-Nitrosodimethylamine	<1030	<21300	<10	<1040	<22200	<10	<207	<10300
N-Nitrosodiphenylamine	<1030	<21300	<10	<1040	<22200	<10	<207	<10300
Naphthalene	<1030	<21300	<10	<1040	<22200	<10	<207	<10300
Nitrobenzene	<1030	<21300	<10	<1040	<22200	<10	<207	<10300
Pentachlorophenol	<2060	<42600	<10	<2070	<44400	<10	<415	<20600
Phenanthrene	<1030	<21300	<10	<1040	<22200	<10	<207	<10300
Phenol	<1030	<21300	278	<1040	<22200	255	<207	<10300
Pyrene	<1030	<21300	<10	<1040	<22200	<10	<207	<10300

vi. Pesticides and Herbicides

Analysis of 21 pesticides shows four were present in contact water collected in sub-surface sumps. Pesticides present in contact water are: alpha-BHC, delta-BHC, gamma-BHC (Lindane) and alpha-Chlordane. Lindane breaks down into alpha- and delta-BHC. Lindane is a pesticide that has been taken out of most uses since 2006. Lindane is a persistent pesticide and breaks down slowly in water and extremely slow in soil. Lindane results range from non-detect <0.0500- .363 µg/L. Alpha-BHC ranges from non-detect <0.0500-0.0836 µg/L and delta-BHC is present from non-detect <0.0500-.316 µg/L. MDH HRL for Lindane is 0.200 µg/L, which is exceeded in two cases of contact water samples. Lindane (<0.0500-0.363 µg/L) has surface water standards that range from 0.0087-2 µg/L. Alpha-Chlordane is present in contact water ranging from non-detect <0.0500-.403 µg/L and has surface water limits ranging from 0.073- 2,400 µg/L.

Analysis of three herbicides showed only 2,4-D present in sub-surface sump. Ranges for 2,4-D are <2.00-33.3 µg/L with a median of 4.23 µg/L. There is no MDH HRL or surface water limit for 2,4-D.

Table 27: Phase II - Sub-Surface 1-3: Pesticides/Herbicides (µg/L)

Aqueous Test Cell #	1 Sub-surface	1 Sub-surface	1 Sub-surface	2 Sub-Surface	2 Sub-Surface	2 Sub-Surface	3 Sub-Surface	3 Sub-Surface	3 Sub-Surface
Date	7.13.13	8.15.13	9.18.13	7.12.13	8.16.13	9.19.13	7.11.13	8.17.13	9.20.13
Aldrin	<0.0500	NT	<0.0500	<0.0500	<0.0500	<0.0500	<0.250 P12	<0.0500	<0.0500
alpha-BHC	0.0836	NT	<0.0500	<0.0500	<0.0500	<0.0500	<0.250 P12	<0.0500	<0.0500
beta-BHC	<0.0500	NT	<0.0500	<0.0500	<0.0500	<0.0500	0.842 C3, P12	<0.0500	<0.0500
delta-BHC	0.157 C2	NT	0.143 C3	<0.0500	<0.0500	0.316 C3	<0.250 P12	<0.0500	0.117 C3
gamma-BHC (Lindane)	0.107 C2	NT	0.215 C3	0.0823 C2	<0.0500	0.363 C3	<0.250 P12	<0.0500	0.18 C3
alpha-Chlordane	<0.0500	NT	<0.0500	<0.0500	<0.0500	0.403 C3	<0.250 P12	0.135 C2	0.0618 C3
gamma-Chlordane	<0.100	NT	<0.100	<0.100	<0.100	<0.100	<0.250 P12	<0.100	<0.100
4,4'-DDD	<0.100	NT	<0.100	<0.100	<0.100	<0.100	<0.500 P12	<0.100	<0.100
4,4'-DDE	<0.100	NT	<0.100	<0.100	<0.100	<0.100	<0.500 P12	<0.100	<0.100
4,4'-DDT	<0.100	NT	<0.100	<0.100	<0.100	<0.100	<0.500 P12	<0.100	<0.100
Dieldrin	<0.100	NT	<0.100	<0.100	<0.100	<0.100	<0.500 P12	<0.100	<0.100
Endosulfan I	<0.0500	NT	<0.0500	<0.0500	<0.0500	<0.0500	<0.250 P12	<0.0500	<0.0500
Endosulfan II	<0.100	NT	<0.100	<0.100	<0.100	<0.100	<0.500 P12	<0.100	<0.100
Endosulfan sulfate	<0.100	NT	<0.100	<0.100	<0.100	<0.100	<0.500 P12	<0.100	<0.100

Table 27 Continued: Phase II - Sub-Surface 1-3: Pesticides/Herbicides (µg/L) [a]									
Endrin	<0.100	NT	<0.100	<0.100	<0.100	<0.100	<0.500 P12	<0.100	<0.100
Endrin aldehyde	<0.100	NT	<0.100	<0.100	<0.100	<0.100	<0.500 P12	<0.100	<0.100
Endrin ketone	<0.100	NT	<0.100	<0.100	<0.100	<0.100	<0.500 P12	<0.100	<0.100
Heptachlor	<0.0500	NT	<0.0500	<0.0500	<0.0500	<0.0500	<0.250 P12	<0.0500	<0.0500
Heptachlor epoxide	<0.0500	NT	<0.0500	<0.0500	<0.0500	<0.0500	<0.250 P12	<0.0500	<0.0500
Methoxychlor	<0.500	NT	<0.500	<0.500	<0.500	<0.500	<2.50 P11	<0.500	<0.500
Toxaphene	<2.00	NT	<2.00	<2.00	<2.00	<2.01	<10 P12	<2.00	<2.02
2,4-D	7.74	2.75	4.23	29.6	<2.00 D2	3.85 C3	33.3 C3, P12	<2.00 D2	7.18
2,4,5-T	<2.00	<2.00	<2.00	<2.00	<2.00 D2	<2.00	<10 P12	<2.00 D2	<2.00
2,4,5-TP (Silvex)	<2.00	<2.00	<2.00	<2.00	<2.00 D2	<2.00	<10 P12	<2.00 D2	<2.00

vii. PFCs Perfluorinated Compounds (PFC) and Bisphenol A (BPA)

Seven of thirteen PFCs tested show results above lab reporting limits. PFNA, PFDA, PFUnA, PFBoA, PFHxS and PFOS do not have results above reporting limits. PFBA results were non-quantifiable due to matrix issues with contact water. PFPeA, PFHxA, PFHpA, and PFOSA range from <12.9-301 ng/L and do not have HRL or surface water limits. PFOA ranges from <11.3-34 ng/L which is below the HRL at 300 ng/L. PFBS ranges between 38.4-326.4 ng/L and is below the HRL value of 7,000 ng/L.

Table 28: Phase II - Sub-Surface 1-3: PFCs (µg/L) [a]									
Aqueous Test Cell #	1 Sub-surface	1 Sub-surface	1 Sub-surface	2 Sub-Surface	2 Sub-Surface	2 Sub-Surface	3 Sub-Surface	3 Sub-Surface	3 Sub-Surface
Date	7.13.13	8.15.13	9.18.13	7.12.13	8.16.13	9.19.13	7.11.13	8.17.13	9.20.13
PFBA	NQ	NQ	NQ	NQ	NQ	NQ	NQ	NQ	NQ
PFPeA	46	101.6	55.1	39.6	< 78.64	< 25.2	24.6	< 71.66	<25.8
PFHxA	54.6	123.9	301	45.8	120.8	282	23.4	200.1	297
PFHpA	18	< 34.47	J 47.5	<12.9	< 37.08	38.6	<12.9	< 51.05	<42
PFOA	< 11.3	< 24.47	J 34	<12.9	<28.73	<25.2	<12.9	<38.60	<25.8
PFNA	< 11.3	<24.47	<24.9	<12.9	< 24.09	<25.2	<12.9	<24.90	< 25.8
Date	7.13.13	8.15.13	9.18.13	7.12.13	8.16.13	9.19.13	7.11.13	8.17.13	9.20.13
PFDA	< 11.3	<24.47	<24.9	<12.9	< 24.09	< 25.2	<12.9	<24.90	< 25.8
PFUnA	< 11.3	< 24.47	< 24.9	<12.9	< 24.09	<25.2	<12.9	< 24.90	<25.8
PFDoA	< 11.3	<24.47	<24.9	<12.9	<24.09	< 25.2	<12.9	< 24.90	< 25.8
PFBS	77.2	326.4	159	73.8	119.6	226	38.4	243	254
PFHxS	<22.5	<48.93	< 49.8	< 25.7	<48.19	<50.4	<25.8	< 49.79	< 51.5
PFOS	<22.5	< 48.93	<49.8	< 25.7	< 48.19	< 50.4	< 25.8	< 49.79	< 51.5
PFOSA	< 11.3	<24.47	<24.9	<12.9	< 24.09	<25.2	<12.9	<24.90	< 25.8
BPA	5.55	106.4	140.26	9.66	171.4	166.26	8.79	269.4	92.16

viii. Surface Sample

The Liner Method test cells were designed with the objective of collecting contact water from both the surface of the pad as well as contact water that has infiltrated through the gravel pad and drainage layer of sand. Surface contact water was only observed and collected during the first simulation conduced on Test Cell #3 on July 10, 2013. All other rainfall simulations conducted in Phase II produced no contact water for collection from the surface of the pad. Since the production of surface water was not replicated it is considered an anomaly.

Table 29: Test Cell #3 Aqueous Surface Sample: Metals[a] (µg/L)

Parameter	7.10.2013
Arsenic	366
Barium	2,340
Boron	5,090
Cadmium	10.8
Chromium	93.8
Copper	169
Lead	135
Mercury	<1.2
Molybdenum	80.6
Nickel	278
Selenium	15.1
Silver	<10
Zinc	192,000

Table 30: Test Cell #3 Aqueous Surface Sample: Nitrogen, Phosphorus & pH[a]

Parameter	7.10.2013
Nitrate as N	<10
Nitrite	<10
Nitrogen, NO2 plus NO3	<10
Phosphorous	342
Potassium	3,450,000
TKN	832
pH	4.7

Table 32: Test Cell #3 Aqueous Surface Sample: SVOC[a] (µg/L)

Parameter	7.10.2013
2-Methylphenol (o-Cresol)	882
Dibenzofurun	<100
2-Nitrophenol	<100
3-Nitoaniline	<100
1,2-Diphenylhydrazine	<100

Table 31: Test Cell #3 Aqueous Surface Sample: Total Coliform, E-Coli, TDS, TSS, BOD, & CBOD[a]

Parameter	Reporting Units	7.10.2013
Total Coliform	MPN/100/ml	242,000
E-Coli	MPN/100/ml	242,000
TDS	mg/L	47,700
TSS	mg/L	358
Carbonaceous BOD	mg/L	2,180
BOD-Hach 10360 Rev 1.1	mg/L	2,170
COD	mg/L	114,000

Table 33: Test Cell #3 Aqueous Surface Sample: Pesticides [a] (µg/L)

Parameter	7.10.2013
Alpha-BHC	2.68
Delta-BHC	1.86
Lindane	2.23
Endrin	0.691
Alpha-Chlordane	<0.05

Table 34: Test Cell #3 Aqueous Surface Sample: PFC's[a] (ng/L)

Parameter	7.10.2013
Bisphenol A (BPA)	271
PFBA	Not Quantifable
PFPeA	39.6
PFHxA	45.8
PFHpA	<12.9
PFOA	<12.9
PFNA	<12.9
PFDA	<12.9
PFUnA	<12.9
PFDoA	<12.9
PFBS	73.8
PFHxS	<25.7
PFOS	<25.7
PFOSA	<12.9

A. Solids: Compost & Feedstocks 2013

i. Synthetic Precipitation Leaching Procedure (SPLP)

Results in Table 35 shows SPLP concentrations for compost and test cell surface gravel on Day 1 (7.9.13) at mixing, and compost on Day 87 (10.10.13) after maturity of a Solvita test. Results from SPLP represent a laboratory sampling method that includes sample preparation with acid before analysis. Pre-treatment of the samples means these results do not have direct comparison to Compost Limits under rule 7035.2836.

SPLP results show presence of a persistent pesticide called Lindane, and metabolites of Lindane called BHC. Lindane is restricted and taken out of most uses in 2006. Lindane is extremely persistent with a soil degradation half-life of DT_{50}= 980 days. This means it takes 2.7 years for the amount of Lindane in soil to reduce by one-half and it will take another 2.7 years for to reduce another 50%. BHC compounds are isomers of Lindane, with the same chemical bonds and atoms but slightly different orientation of bonds and atoms in space. 2,4-D is a common broadleaf herbicide used in commercial and residential lawns. It is not very persistent and has a (soil half-life) DT_{50}= 10 days. Tables 35 – 39 below show SPLP results for Day 1 and Day 87 of solid compost from Phase II.

Table 35: Synthetic Precipitation Leaching Procedure (SPLP) results for Phase II: Test Cell compost on Day 1 and Day 87 and test cell gravel pad material - Metals and Biologic Elements (µg/L)

SPLP Solid	Compost Pile 1	Compost Pile 2	Compost Pile 3	Pad 1 Material	Pad 2 Material	3 pad Material	Compost Pile 1	Compost Pile 2	Compost Pile 3
Date	7.9.13	7.9.13	7.9.13	7.9.13	7.9.13	7.9.13	10.10.13	10.10.13	10.10.13
Arsenic	<20.0	<20.0	<20.0	<20.0	<20.0	<20.0	<20.0	<20.0	<20.0
Barium	494	464	488	58.8	26	13.8	46.5	123	74.9
Cadmium	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
Chromium	<10.0	<10.0	11.2	<10.0	<10.0	<10.0	<10.0	<10.0	<10.0
Lead	<10.0	12.2	18.6	<10.0	<10.0	<10.0		23.9	16.2
Mercury	<0.60	<0.60	<0.60	<0.60	<0.60	<0.60	<0.60	<0.60	<0.60
Selenium	<20.0	<20.0	<20.0	<20.0	<20.0	<20.0	<20.0	<20.0	<20.0
Silver	<10.0	<10.0	<10.0	<10.0	<10.0	<10.0	<10.0	<10.0	<10.0
Nitrate as N NO2&NO3 SM4500	19.6	30.7	16.9	12.7	11.6	9.7	45	<30.5	<31.4
TKN	15500	13500	12800	75.3	DF	DF	17100	15300	14900
Phosphorous	1810	1870	2010	309	324	497	1860	2100	1740

Table 36: Synthetic Precipitation Leaching Procedure (SPLP) results for Phase II: Test Cell compost on Day 1 and Day 87 and test cell gravel pad material – SVOC (µg/L)									
SPLP Solid	Compost Pile 1	Compost Pile 2	Compost Pile 3	Pad 1 Material	Pad 2 Material	Pad 3 material	Compost Pile 1	Compost Pile 2	Compost Pile 3
Date	7.9.13	7.9.13	7.9.13	7.9.13	7.9.13	7.9.13	10.10.13	10.10.13	10.10.13
Acenaphthene	<100	<100	<100	<100	<100	<100	<100	<100	<100
Anthracene	<100	<100	<100	<100	<100	<100	<100	<100	<100
Benzo(a)anthracene	<100	<100	<100	<100	<100	<100	<100	<100	<100
Benzo(a)pyrene	<100	<100	<100	<100	<100	<100	<100	<100	<100
Benzo(b)fluoranthene	<100	<100	<100	<100	<100	<100	<100	<100	<100
Benzo(g,h,i)perylene	<100	<100	<100	<100	<100	<100	<100	<100	<100
Benzo(k)fluoranthene	<100	<100	<100	<100	<100	<100	<100	<100	<100
Chrysene	<100	<100	<100	<100	<100	<100	<100	<100	<100
Dibenz(a,h)anthracene	<100	<100	<100	<100	<100	<100	<100	<100	<100
Fluoranthene	<100	<100	<100	<100	<100	<100	<100	<100	<100
Indeno(1,2,3-cd)pyrene	<100	<100	<100	<100	<100	<100	<100	<100	<100
1-Methylnaphthalene	<100	<100	<100	<100	<100	<100	<100	<100	<100
2-Methylnaphthalene	<100	<100	<100	<100	<100	<100	<100	<100	<100
Naphthalene	<100	<100	<100	<100	<100	<100	<100	<100	<100
Phenanthrene	<100	<100	<100	<100	<100	<100	<100	<100	<100
Pyrene	<100	<100	<100	<100	<100	<100	<100	<100	<100

Table 37: Synthetic Precipitation Leaching Procedure (SPLP) results for Phase II: Test Cell compost on Day 1 and Day 87 and test cell gravel pad material – VOC (µg/L)									
SPLP Solid	Compost Pile 1	Compost Pile 2	Compost Pile 3	Pad 1 Material	Pad 2 Material	3 pad Material	Compost Pile 1	Compost Pile 2	Compost Pile 3
Date	7.9.13	7.9.13	7.9.13	7.9.13	7.9.13	7.9.13	10.10.13	10.10.13	10.10.13
Acetone	1290	<500	<500	<500	3150	3350	NT	NT	NT
Acetonitrile	<2000	<2000	<2000	<2000	<2000	<2000	NT	NT	NT
Benzene	<50	<50	<50	<50	<50	<50	NT	NT	NT
2-Butanone (MEK)	<200	<200	<200	<200	<200	<200	NT	NT	NT
Carbon tentrachloride	<200	<200	<200	<200	<200	<200	NT	NT	NT
Chlorobenzene	<50	<50	<50	<50	<50	<50	NT	NT	NT
Chloroform	<50	<50	<50	<50	<50	<50	NT	NT	NT
1,4-Dichlorobenzene	<50	<50	<50	<50	<50	<50	NT	NT	NT
1,2-Dichloroethane	<50	<50	<50	<50	<50	<50	NT	NT	NT
1,1-Dichloroethene	<50	<50	<50	<50	<50	<50	NT	NT	NT
Tetrachloroethene	<50	<50	<50	<50	<50	<50	NT	NT	NT
Toluene	<50	<50	<50	<50	<50	<50	NT	NT	NT
Trichloroethene	<50	<50	<50	<50	<50	<50	NT	NT	NT
Vinyl Chloride	<20	<20	<20	<20	<20	<20	NT	NT	NT

Table 38: Synthetic Precipitation Leaching Procedure (SPLP) results for Phase II: Test Cell compost on Day 1 and Day 87 and test cell gravel pad material - Pesticides and Herbicides (µg/L)									
SPLP Solid	Compost Pile 1	Compost Pile 2	Compost Pile 3	Pad 1 Material	Pad 2 Material	Pad 3 Material	Compost Pile 1	Compost Pile 2	Compost Pile 3
Date	7.9.13	7.9.13	7.9.13	7.9.13	7.9.13	7.9.13	10.10.13	10.10.13	10.10.13
Aldrin	<0.0500	<0.0500	<0.0500	<0.0500	<0.0500	<0.0500	<0.0500	<0.0500	<0.0500
alpha-BHC	<0.0500	<0.0500	<0.0500	<0.0500	<0.0500	<0.0500	<0.0500	<0.0500	<0.0500
beta-BHC	<0.0500	<0.0500	<0.0500	<0.0500	<0.0500	<0.0500	<0.0500	<0.0500	<0.0500
delta-BHC	<0.0500	0.319 C3, N	<0.0500	<0.0500	<0.0500	<0.0500	<0.0500	<0.0500	<0.0500
amma-BHC (Lindane)	0.542 C3	<0.0500	<0.0500	<0.0500	<0.0500	<0.0500	<0.0500	<0.0500	<0.0500
alpha-Chlordane	<0.0500	<0.0500	<0.0500	<0.0500	<0.0500	<0.0500	<0.0500	<0.0500	<0.0500
gamma-Chlordane	<0.0500	<0.0500	<0.0500	<0.0500	<0.0500	<0.0500	<0.0500	<0.0500	<0.0500
4,4'-DDD	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100
4,4'-DDE	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100
4,4'-DDT	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100

Table 38 Continued: Synthetic Precipitation Leaching Procedure (SPLP) results for Phase II: Test Cell compost on Day 1 and Day 87 and test cell gravel pad material - Pesticides and Herbicides (µg/L)									
Dieldrin	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100
Endosulfan I	<0.0500	<0.0500	<0.0500	<0.0500	<0.0500	<0.0500	<0.0500	<0.0500	<0.0500
Endosulfan II	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100
Endosulfan sulfate	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100
Endrin	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100
Endrin aldehyde	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100
Endrin ketone	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100
Heptachlor	<0.0500	<0.0500	<0.0500	<0.0500	<0.0500	<0.0500	<0.0500	<0.0500	<0.0500
Heptachlor epoxide	<0.0500	<0.0500	<0.0500	<0.0500	<0.0500	<0.0500	<0.0500	<0.0500	<0.0500
Methoxychlor	<0.500	<0.500	<0.500	<0.500	<0.500	<0.500	<0.500	<0.500	<0.500
Toxaphene	<2.00	<2.00	<2.00	<2.00	<2.00	<2.00	<2.00	<2.00	<2.00
2,4-D	8.41 N	8.95 N	6.88 N	<4.00 N	<4.00 N	<4.00 N	<2.00	<2.00	<2.00
2,4,5-T	<4.00 N	<4.00 N	<4.00 N	<4.00 N	<4.00 N	<4.00 N	<2.00	<2.00	<2.00
2,4,5-TP (Silvex)	<4.00 N	<4.00 N	<4.00 N	<4.00 N	<4.00 N	<4.00 N	<2.00	<2.00	<2.00

Table 39: Synthetic Precipitation Leaching Procedure (SPLP) results for Phase II: Test Cell compost on Day 1 and Day 87 and test cell gravel pad material – PFC (µg/L)									
SPLP Solid	Compost Pile 1	Compost Pile 2	Compost Pile 3	Pad 1 Material	Pad 2 Material	Pad 3 Material	Compost Pile 1	Compost Pile 2	Compost Pile 3
Date	7.9.13	7.9.13	7.9.13	7.9.13	7.9.13	7.9.13	10.10.13	10.10.13	10.10.13
PFBA	6.42	6.66	9.01	<0.106	<0.107	<0.105	5.551	4.148	6.797
PFPeA	2.58	2.67	<0.838	<0.106	<0.107	<0.105	<0.4198	<0.3573	<0.4145
PFHxA	<0.215	<0.214	1.62	<0.106	<0.107	<0.105	3.351	5.212	2.636
PFHpA	<0.687	<0.777	<1.24	<0.106	<0.107	<0.105	<0.7609	<0.4481	<0.8179
PFOA	<1.47	0.693	<0.323	<0.106	<0.107	<0.105	0.7052	2.156	0.8807
PFNA	<0.603	<0.214	<0.212	<0.106	<0.107	<0.105	<0.4198	<1.130	<0.4145
PFDA	<0.266	<0.214	<0.212	<0.106	<0.107	<0.105	<0.4198	<0.4569	<0.4145
PFUnA	<0.215	<0.214	<0.212	<0.106	<0.107	<0.105	<0.4198	<0.3573	<0.4145
PFDoA	<0.215	<0.214	<0.212	<0.106	<0.107	<0.105	<0.4198	0.4343	<0.4145
PFBS	<0.43	<0.715	<0.424	<0.212	<0.215	<0.21	<0.8396	<0.7146	<0.8289
PFHxS	<0.43	<0.585	<0.996	<0.212	<0.215	<0.21	<0.8396	<0.7429	<0.8289
PFOS	<0.43	0.442	0.515	<0.212	<0.215	<0.21	1.073	1.439	<0.8289
PFOSA	<0.215	<0.214	<0.212	<0.106	<0.107	<0.105	<0.4198	<0.3573	<0.4145
BPA	D45.5	D 21.5	D 29.5	NT	<11.6	<13.6	<12.8	<13.4	<12.4

ii. Finished Compost Analysis Utilizing Test Methods for the Examination of Composting and Compost (TMECC)

TMECC results for compost on day 87 after reaching the required maturity level are reported in Table 40. Several metals tested do not have Class I compost limits. None of the metals tested from compost exceed limits listed in MN statute 7025.2826 Compost Limit Class I. Some values for Coliform are greater than >1700 MPN/g but exact quantity is not determined. The range for Coliform is 550-1600 MPN/g for samples that are quantifiable and they are below the Class I limits.

Table 40: Phase II Test Cell Compost Results on Day 87 - TMECC (MPN/g)

Solid	Units	Compost Pile 1	Compost Pile 2	Compost Pile 3	MPCA Class I Limit
Date		10.10.13	10.10.13	10.10.13	
Arsenic	mg/kg	3.4	3	3.1	41
Boron	mg/kg	33	32	32	---
Cadmium	mg/kg	<1.0	<1.0	<1.0	39
Chromium	mg/kg	12	12	20	---
Copper	mg/kg	20	47	36	---
Lead	mg/kg	21	25	21	300
Selenium	mg/kg	<1.0	<1.0	<1.0	100
Mercury	mg/kg	<1.0	<1.0	<1.0	5
Molybdenum	mg/kg	1.9	1.4	1.2	---
Potassium	mg/kg	6400	6100	5200	---
Nitrate as N	mg/kg	78	44	14	---
NH4+	mg/kg	47	29	22	---
Org-N	%	1.9	1.8	1.9	---
Phosphorous	mg/kg	2000	2100	1900	---
Fecal Coliform	MPN/g	1600	>1700	550	---
Total Coliform	MPN/g	1600	>1700	>1700	2,800
Salmonella	MPN/4g	<3	<3	<3	---
E. coli	MPN/g	2	2	<2	6
Moisture	%	50.6	50.6	55.8	---

iii. Finished Compost Analysis

The finished compost from this project was analyzed for both metals as well as any potential contamination from pathogens. After contact water sampling was completed in October 2013, the compost was removed from the test cells and incorporated into the curing pile. In February 2014, the finished compost was screened and samples were collected using the Test Method for the Examination of Composting and Compost (TMECC) . Samples were sent to the Soil Control Lab for analysis that included metals, pathogens, pH and maturity. The results are given in Table 41.

(1) Metals

Regulations governing the metal content of composts are set by both the Minnesota Pollution Control Agency as well as the EPA. Heavy metals include arsenic, cadmium, chromium, copper, lead, mercury, molybdenum nickel, selenium, and zinc. The quantity of these elements are measured on a dry weight basis and expressed as mg/kg (milligram per kilogram).

Several of these metals are needed by plants in limited amounts for normal development. Consequently, quantifying the concentration of these elements can provide valuable management data relevant to the fertilizer requirements. In addition, heavy metals are known to cause phytotoxic effects in plants (when present in very high quantities), and specific plant species are known to be more sensitive than others. These elements include boron, manganese, molybdenum, nickel, and selenium. However, these elements are not typically found in compost in detrimental quantities. All composts that contain regulated feedstocks must meet state environmental standards in order to be marketed.[7]

Table 41: Phase II Finished Compost Sample: Metals (mg/kg)

Parameter	Result	MPCA Class I Limit	EPA Class I Limits
Aluminum (Al)	2,500	NA	NA
Arsenic (As)	5.2	41	41
Cadmium (Cd)	<1.0	39	39
Chromium (Cr)	26	NA	1200
Cobalt (Co)	3.5	NA	NA
Copper (Cu)	66	1,500	1500
Iron (Fe)	7,100	NA	NA
Lead (Pb)	20	300	300
Manganese (Mn)	830	NA	NA
Mercury (Hg)	<1.0	5	17
Molybdenum (Mo)	1.2	18	75
Nickel (Ni)	15	420	420
Selenium (Se)	<1.0	100	36
Zinc (Zn)	110	2,800	2,800

The results confirm that the finished compost, which included feedstocks of both commercial and residential source-separated organics material, has met both Federal EPA as well as Minnesota Pollution Control Agency safety standard and can be marketed as Class I compost. Class I compost is the highest grade compost, and can be distributed to public for widespread use on horticulture and agricultural uses. Moreover, the metal concentration in the compost is well within the range of background concentrations in soils.

[7] http://compostingcouncil.org/test-methods-parameters/

(2) pH

pH is the measure of acidity (or alkalinity), or hydrogen ion activity of a soil or compost (on a logarithmic scale). The pH scale ranges from 0 to 14, with a pH of 7 indicating neutrality. Most compost has a pH of between 6 and 8. Each specific plant species requires a specific pH range. Soil pH is often adjusted through the utilization of materials such as lime (to raise pH) and sulfur (to lower pH).[9] The pH result of 8.1 confirms that the finished compost falls within normal range.

(3) Pathogens

Pathogens are disease causing organisms including, bacteria, viruses, fungi, helminthes, and protozoa which may be present in raw wastes or by-products. Both plant and human pathogens are found in living organisms and are present at some background levels in the environment. Therefore, the composting process must eliminate or reduce pathogens to a level that is below the threshold where the danger of transmitting diseases will occur. Pathogens are inactivated or destroyed by elevated temperatures over a period of time within the composting process. The time-temperature relationship used as the Process to Further Reduce Pathogens (PRFP) effectively destroyed the pathogens in the compost. The time-temperature requirement ensures plant and human pathogen destruction in compost.[8] The finished compost produced was tested for Fecal Coliform and Salmonella. The compost passed for both parameters with a level of 1.9 MPN/g for Fecal Coliform and a <3 MPN/4g level for Salmonella. The results concluded that the compost process used by SET at Organics Demonstration Composting Site at the University of Minnesota Landscape Arboretum has effectively destroyed the pathogens in organics compost.

A. Feedstocks 2013

Feedstock data is presented as supplemental information to provide observational data on five separate source-separated organic feedstocks. These include: commercial waste, woodchips, grass, leaves and co-collected food waste and yard waste. While these are single data points without a basis for comparison, it is interesting to note the pesticide beta-hexa chlorocyclohexane (BHC) is detected in leaves. PFCs are found in grass, leaves and co-collected waste and non-quantifiable (due to matrix issues) in commercial waste. Samples of the commercial organics, woodchips, grass and leaves were collected at Shakopee Mdewakanton Sioux Community SSOM compost facility in Prior Lake, Minnesota. Tables 42 – 46 show results from the SPLP on the feedstocks used in Phase II.

[8] http://compostingcouncil.org/test-methods-parameters/

i. Synthetic Precipitation Leaching Procedure (SPLP): Feedstock 2013

Table 42: SPLP Results for Individual Feedstocks: Metals (mg/kg)					
SPLP Solid	Commercial Organics	Woodchips	Grass	Leaves	Co-Collected
Date	10.9.2013	10.9.2013	10.9.2013	10.9.2013	10.9.2013
Arsenic	<20.0	<20.0	<20.0	<20.0	20
Barium	50.4	42	194	160	229
Cadmium	<3.0	<3.0	<3.0	<3.0	<3.0
Chromium	<10.0	<10.0	<10.0	<10.0	<10.0
Lead	<10.0	<10.0	<10.0	<10.0	<10.0
Selenium	29.1	<20.0	24.2	26.9	31.2
Silver	<10.0	<10.0	<10.0	<10.0	<10.0
Mercury	<0.60	<0.60	<0.60	<0.60	<0.60
Nitrate as N	153	<24.4	<47.0	<27.8	<30.4
TKN	17900	3580	44100	5020	20200
Phosphorous	2600	156	3270	3200	1690

Table 43: SPLP Results for Individual Feedstocks: SVOCs (µg/L)					
SPLP Solid	Commercial Organics	Woodchips	Grass	Leaves	Co-Collected
Date	10.9.2013	10.9.2013	10.9.2013	10.9.2013	10.9.2013
Acenaphthene	<100	<100	<100	<100	<100
Anthracene	<100	<100	<100	<100	<100
Benzo(a)anthracene	<100	<100	<100	<100	<100
Benzo(a)pyrene	<100	<100	<100	<100	<100
Benzo(b)fluoranthene	<100	<100	<100	<100	<100
Benzo(g,h,i)perylene	<100	<100	<100	<100	<100
Benzo(k)fluoranthene	<100	<100	<100	<100	<100
Chrysene	<100	<100	<100	<100	<100
Dibenz(a,h)anthracene	<100	<100	<100	<100	<100
Fluoranthene	<100	<100	<100	<100	<100
Indeno(1,2,3-cd)pyrene	<100	<100	<100	<100	<100
1-Methylnaphthalene	<100	<100	<100	<100	<100
2-Methylnaphthalene	<100	<100	<100	<100	<100
Naphthalene	<100	<100	<100	<100	<100
Phenanthrene	<100	<100	<100	<100	<100
Pyrene	<100	<100	<100	<100	<100
%Moisture	77.8	39.4	68.6	45.4	50.5

Table 44: SPLP Results for Individual Feedstocks: Pesticides & Herbicides (µg/L unless otherwise noted)					
Solid SPLP	Commercial Organics	Woodchips	Grass	Leaves	Co-Collected
Date	10.9.2013	10.9.2013	10.9.2013	10.9.2013	10.9.2013
Aldrin(**reported in ng/L)**	<0.0500	<0.0500	<0.100 P12	<0.100 P12	<0.100 P12
alpha-BHC	<0.0500	<0.0500	<0.100 P12	0.107 C2, P12	<0.100 P12
beta-BHC	<0.0500	<0.0500	<0.100 P12	<0.100 P12	<0.100 P12
delta-BHC	<0.0500	<0.0500	<0.100 P12	0.206 C2, P12	<0.100 P12
amma-BHC (Lindane)	<0.0500	<0.0500	<0.100 P12	<0.100 P12	<0.100 P12
alpha-Chlordane	<0.0500	<0.0500	<0.100 P12	<0.100 P12	<0.100 P12
gamma-Chlordane	<0.0500	<0.0500	<0.100 P12	<0.100 P12	<0.100 P12
4,4'-DDD	<0.100	<0.100	<0.200 P12	<0.200 P12	<0.200 P12
4,4'-DDE	<0.100	<0.100	<0.200 P12	<0.200 P12	<0.200 P12
4,4'-DDT	<0.100	<0.100	<0.200 P12	<0.200 P12	<0.200 P12
Dieldrin	<0.100	<0.100	<0.200 P12	<0.200 P12	<0.200 P13
Endosulfan I	<0.0500	<0.0500	<0.100 P12	<0.100 P12	<0.100 P12
Endosulfan II	<0.100	<0.100	<0.200 P12	<0.200 P12	<0.200 P12
Endosulfan sulfate	<0.100	<0.100	<0.200 P12	<0.200 P12	<0.200 P12
Endrin	<0.100	<0.100	<0.200 P12	<0.200 P12	<0.200 P12
Endrin aldehyde	<0.100	<0.100	<0.200 P12	<0.200 P12	<0.200 P12
Endrin ketone	<0.100	<0.100	<0.200 P12	<0.200 P12	<0.200 P12
Heptachlor	<0.0500	<0.0500	<0.100 P12	<0.100 P12	0.107 C2, P12
Heptachlor epoxide	<0.0500	<0.0500	<0.100 P12	<0.100 P12	<0.100 P13
Methoxychlor	<0.500	<0.500	<1.00 P12	<1.00 P12	<1.00 P13
Toxaphene	<2.00	<2.00	<4.00 P12	<4.00 P12	<4.00 P13
2,4-D	<2.00	<2.00	<2.00	14.1	2.85
2,4,5-T	<2.00	<2.00	<2.00	<2.00	<2.00
2,4,5-TP (Silvex)	<2.00	<2.00	<2.00	<2.00	<2.00

Table 45: SPLP Results for Individual Feedstocks: PFCs (ng/L)					
Solid SPLP	Commercial Organics	Woodchips	Grass	Leaves	Co-Collected
Date	10.9.2013	10.9.2013	10.9.2013	10.9.2013	10.9.2013
PFBA	NQ	<0.82	9.46	4.56	3.04
PFPeA	<1.8	3.33	<1.75	<1.37	<1.14
PFHxA	<1.8	<0.82	<1.75	<1.37	<1.14
PFHpA	<1.8	<0.82	<1.75	<1.37	<1.14
PFOA	<1.8	<0.82	<1.75	<1.37	1.74
PFNA	<1.8	<0.82	<1.75	<1.37	<1.14
PFDA	<1.8	<0.82	<1.75	<1.37	<1.14
PFUnA	<1.8	<0.82	<1.75	<1.37	<1.14
PFDoA	<1.8	<0.82	<1.75	<1.37	<1.14
PFBS	<3.59	<1.64	<3.5	<2.75	<2.27
PFHxS	<3.59	<1.64	<3.5	<2.75	<2.27
PFOS	<3.59	<1.64	<3.5	<2.75	<2.27
PFOSA	<2.16	<0.984	<2.1	<2.75	<1.36
PFC % Moisture	74.9	34.1	70	48.8	54.2

Table 46: SPLP Results for Individual Feedstocks: BPA (ng/L)					
Solid SPLP	Commercial Organics	Woodchips	Grass	Leaves	Co-Collected
Date	10.9.2013	10.9.2013	10.9.2013	10.9.2013	10.9.2013
BPA	<5.49	B3.88	<3.18	<2.17	B9.11
% Moisture	82.3	30.4	68.9	43	41.1

ii. TMECC: Feedstocks 2013

Table 47: TMECC Results for Individual Feedstocks						
Solid TMECC		Commercial Waste	Woodchips	Grass	Leaves	Co-collected
Date	Units	10.9.2013	10.9.2013	10.9.2013	10.9.2013	10.9.2013
Arsenic	mg/kg	<1.0	3.6	2	2.1	3.8
Barium	mg/kg	NA	NA	NA	NA	NA
Cadmium	mg/kg	<1.0	<1.0	<1.0	<1.0	<1.0
Chromium	mg/kg	1.2	20	1.4	<1.0	3.9
Copper	mg/kg	6.7	47	15	9	24
Lead	mg/kg	<1.0	8.9	1.1	<1.0	5.5
Nickle	mg/kg	2.2	7	1.9	1.4	3.7
Selenium	mg/kg	<1.0	<1.0	<1.0	<1.0	<1.0
Mercury	mg/kg	<1.0	<1.0	<1.0	<1.0	<1.0
Molybdenum	mg/kg	<1.0	<1.0	1.3	<1.0	<1.0
Zinc	mg/kg	22	40	37	28	67
Nitrate	%	0.0039	<.0001	0.00031	0.0096	0.00016
Organic Nitrogen	%	0.48	0.24	1	0.59	0.74
Total Nitrogen	%	0.5	0.24	1.2	0.6	0.76
Phosphorous	%	0.14	0.052	0.25	0.14	0.22
Fecal Coliform	MPN/g	>2100	>1400	>2600	>1800	>1900
Total Coliform	MPN/g	>2100	>1400	>2600	>1800	>1900
E. coli	MPN/g	1200	20	>2600	>1800	>1900
Moisture	%	80.5	45.1	69.8	53.2	58.8

VI. Comparison of select results of both Phases of this Project with SSOM Compost Site Holding Pond, Contact Water from Carver County 2008 & 2012 MPCA Funded Research and Residential Strength Septic System Effluent

Carver County conducted two previous research projects in 2008 and 2012. Each was funded by the Minnesota Pollution Control Agency (MPCA), to determine potential impacts on ground and surface water from composting source-separated organic material. The research was conducted at two separate Demonstration Sites located at the University of Minnesota Landscape Arboretum. The MPCA requested the use of lysimeters as the means to collect contact water in both of those studies. In the 2008 grant project, ten (10) lysimeters were buried at a depth of 36 inches (36") and placed under negative pressure to allow for the collection of contact water that infiltrated into surrounding loam sub-soils. They were placed underneath and surrounding the active composting piles as well as down gradient of water treatment berms to measure the effectiveness of the berm in treating contact water before it leaves the site. Samples were collected following significant rain events. Based on the data from this study the MPCA concluded that metals from contact water do not seem to be an issue. In the 2012 study, an identical test method was used with the exception of sampling contact water from piles which included source-separated organics and those containing yard waste only. Sheet flow sampling was also added at the request of the MPCA. During a natural rain event in May 2012, samples were collected at various locations on the surface of the compost site pad. The metal results of all three studies can be found in Tables 48, 49, and 50 respectively.

Table 48: 2008 SSOM Contact Water Research Utilizing Lysimeters (µg/L) ⌀

Parameter	Sample (N) Size	# Non Detect	Min	Max	Median
Arsenic	12	9	15.6	32.1	22.4
Barium	13	0	642	1,230	890
Cadmium	12	12	---	---	---
Chromium	12	10	10	28.4	---
Copper	6	4	69.5	69.7	69.6
Lead	12	12	---	---	---
Mercury	2	2	---	---	---
Molybdenum	6	5	15.9	15.9	---
Nickel	6	0	42.7	147	66.95
Selenium	13	12	40.2	40.2	---
Silver	12	12	---	---	---
Zinc	6	2	63.9	478	118.05

⌀ = *Samples not filtered prior to analysis*

Table 49: 2012 SSOM Contact Water Research Utilizing Lysimeters (µg/L) ꙮ					
Parameter	Sample (N) Size	# Non Detect	Min	Max	Median
Arsenic	5	5	---	---	---
Cadmium	5	5	---	---	---
Copper	5	2	21.6	46.5	22.4
Lead	5	5	---	---	---
Mercury	5	5	---	---	---
Molybdenum	5	5	---	---	---
Nickel	5	0	29.3	205	83
Selenium	5	4	26	26	---
Zinc	5	1	35.8	116	39.45

ꙮ *= Samples not filtered prior to analysis*

Table 50: 2012 SSOM Contact Water Research Utilizing Sheet Flow Collection Method (µg/L) ꙮ					
Parameters	Sample (N) Size	# Non Detect	Min	Max	Median
Arsenic	4	1	22	44	40.6
Cadmium	4	4	---	---	---
Copper	4	0	16.1	46.6	36.7
Lead	4	0	8.3	34.4	25.55
Mercury	4	4	---	---	---
Molybdenum	4	4	---	---	---
Nickel	4	1	28.9	54.6	45
Selenium	4	4	---	---	---
Zinc	4	0	39.8	157	106.1

ꙮ*= Samples not filtered prior to analysis*

As part of the permit requirements, the MPCA collects contact water data from source-separated organics compost facilities throughout Minnesota. The contact water is collected from holding ponds located on the site to manage contact water that is generated during rain events. For the purpose of this comparison, the MPCA provided holding pond data from SET facility in Empire Township, Full Circle Organics facility in Good Thunder and the Western Lake Superior Sanitary District (WLSSD) in Duluth.

Several states have utilized septic tank effluent as a means of comparison of environmental impact of SSO compost contact water. The MPCA funded a study to analyze effluent from eight (8) residential septic systems in the City of Becker MN. Minnesota Rules Chapter 7080 through 7083 Subsurface Sewage Treatment System Program allows for three feet (3') of various soils including sand, loams, silts and clays to treat effluent from septic tanks. A comparison of contact water concentrations from the SSMO composting facilities and effluent from septic tanks of the Becker Study can be found in Table 51.

Table 51: Maximum Concentrations for Compost Contact Water from Minnesota SSOM Facilities and Residential Strength Septic Tank Effluent (µg/L)		
Parameters	MN Organics Compost Site Holding Pond[9]	Residential Septic Tank Effluent[10]
Arsenic	15.8	Not Tested
Boron	Not Tested	13,248
Cadmium	.73	2.4
Chromium	2.0	Not Tested
Copper	15.5	80
Lead	10.38	51
Mercury	Non-Detect	Not Tested
Molybdenum	17	Not Tested
Nickel	20.49	13
Selenium	3.65	Not Tested
Silver	Non-Detect	Not Tested
Zinc	105.97	1597

During Phase I of the current research, seven (7) rainfall simulations were conducted over various compost piles and feed stocks. For the purposes of this comparison, SSO/grass yard waste compost pile and commercial organics feed stocks were utilized. This comparison allows for sources of potential contaminants. In general, the concentrations of metals were higher when grass clippings were present than with SSO only. A comparison of contact water concentrations from Phase 1 commercial organics as well as residential SSO with grass heavy yard waste can be found in Table 52.

Table 52: 2012 SSOM Contact Water Phase I Utilizing Surface Collection and Simulated Rain µg/L		
Sample ID	Commercial Organics	Residential SSOM with grass heavy yard waste
Arsenic	<10	137
Barium	96.2	447
Boron	156	1740
Cadmium	<2	7.4
Copper	39	150
Lead	<3	<3
Molybdenum	<15	37.9
Nickel	<20	120
Selenium	28.8	37.3
Silver	<10	<10
Zinc	246	1570
Mercury	<0.2	<0.6

[9] Holding Pond Data provided by MPCA permitted SSOM Composting facilities

[10] Effects of Septic Systems on Ground Water Quality, Minnesota Pollution Control Agency, May 1999.

During Phase II of the current research, rainfall simulations were conducted over three piles constructed with identical feedstocks consisting of grass, leaves, wood chips, commercial organics and residential SSO co-collected with yard waste. These piles were subjected to rainfall simulation on three separate occasions. The first simulation was conducted soon after the piles were constructed representing the day of mixing, second when the piles met PFRP (Process to Further Reduce Pathogens) and finally when the pile met the maturity requirement for finished compost. Table 53 provides the min., max. and median of all three simulations.

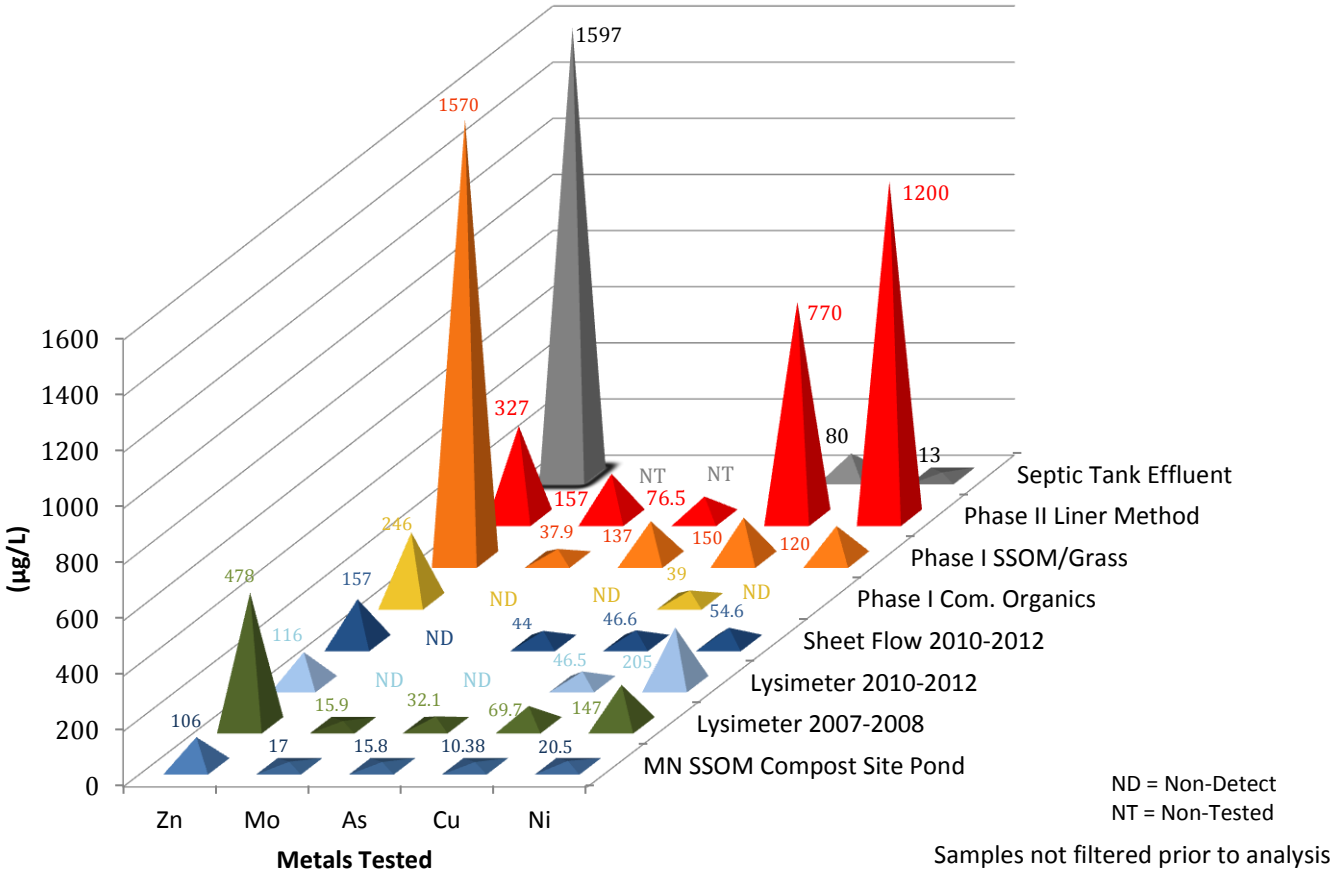
Table 53: 2013 SSOM Contact Water Phase II Utilizing MPCA designed "Liner Method" and Simulated Rain (µg/L)

Parameters	Sample (N) Size	# Non Detect	Min	Max	Median
Arsenic	9	0	5.5	76.5	30
Barium	9	0	1060	13,700	2500
Boron	9	0	680	1770	1030
Cadmium	9	0	0.5	7.6	2.6
Chromium	9	0	3.6	41.1	14.9
Copper	9	0	222	770	353
Lead	9	0	0.88	111	3.1
Mercury	9	3	0.48	2	0.49
Molybdenum	9	0	20.5	157	32.4
Nickel	9	0	220	1200	629
Selenium	9	1	3.5	8.6	4.3
Silver	9	9	---	---	---
Zinc	9	3	47.7	327	113

Median levels were not available for all contact water studied. As a result, maximum concentrations were used for the comparison found in Charts 1 and 2. When comparing the maximum metal concentration the Liner Method used in Phase II, it generated the highest concentration of metals with the exception of selenium and zinc. Phase I had the highest concentrations of both selenium and zinc. The lower maximum concentrations of metals were found in contact water from MPCA permitted SSO composting facilities holding ponds and earlier Carver County SSOM studies. The concentrations from these sources also fell within the range of residential septic tank effluent. This finding substantiates Tom Richards conclusion found in his report "Water Quality Protection, Cornell Composting Science & Engineering".[11] Richards concluded that "Although the available evidence is limited, current indications are that runoff from composting windrows has BOD and nutrient levels comparable to low strength municipal wastewater. Land treatment systems which have proven effective for these alternatives wastewaters we can expect to be effective for windrow composting facilities as well."

[11] Tom Richards "Water Quality Protection, Cornell Composting Science & Engineering

Chart 1: Comparison of Maximum Metal Concentrations of Compost Contact Water and other Effluent



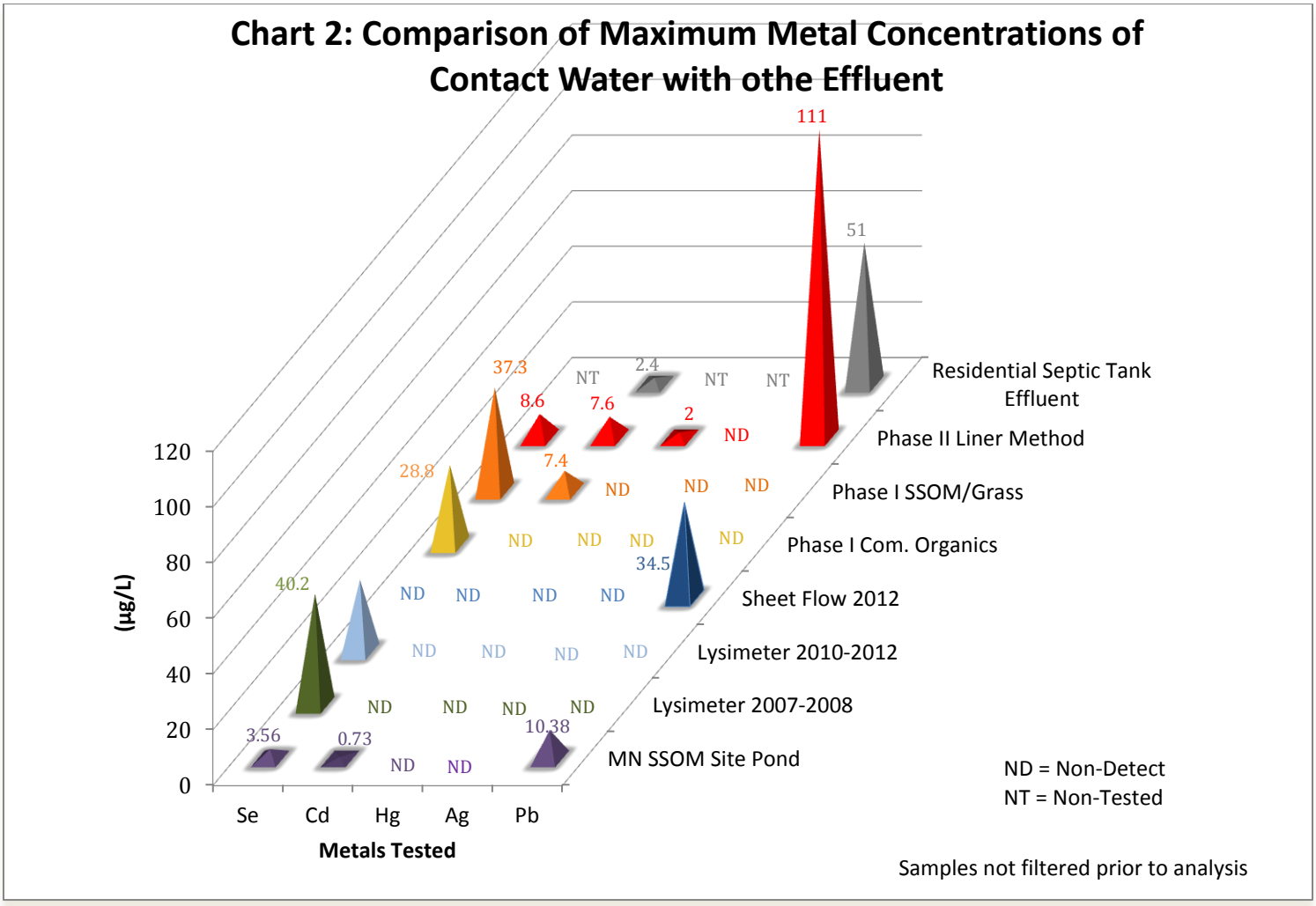
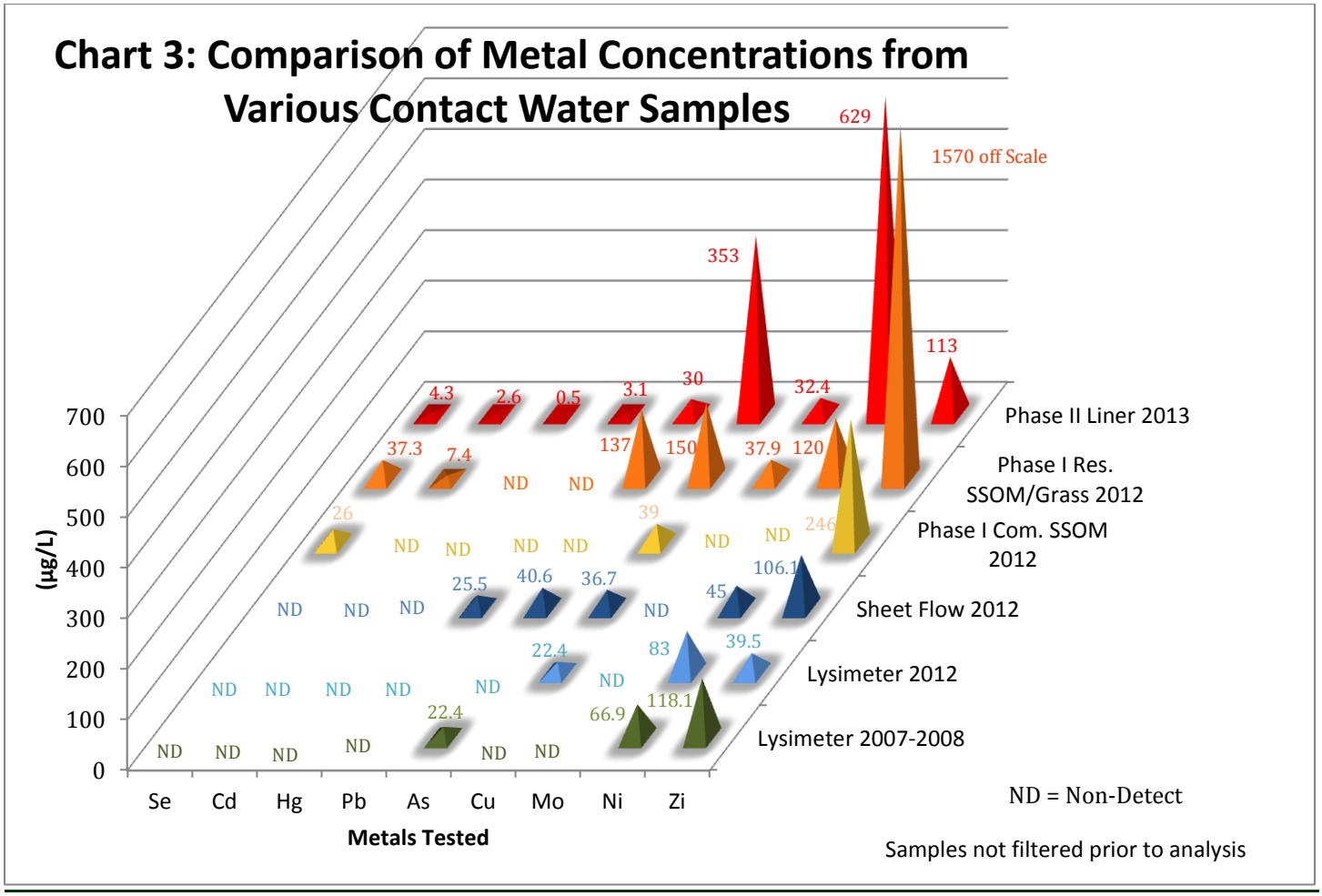


Chart 3 provides a comparison of the median concentrations for the contact water collected during the 2008 and 2012 and Phase II with Phase I results which represents single data points.

When comparing the metals levels, Phase I and II generally had the highest concentrations. Phase II test method resulted in the highest concentrations of nickel, copper and mercury. Phase I residential grass/SSO had the highest median concentrations for zinc, molybdenum, arsenic, cadmium, and selenium. In Phase I commercial organics without yard waste, levels were below detectable levels for cadmium, mercury, lead, arsenic, molybdenum and nickel. In addition, the levels found in commercial organics for Selenium, Copper and Zinc were lower than Phase I and Phase II when yard waste was present.

The 2008 and 2012 contact water results were below Phase I and II concentrations for all metals tested.



Metal concentrations from solid feedstock samples collected can be found in Chart 4. It should be noted that the feedstock samples were not included in the composted piles tested as part of Phase I or II of this study. As a result, they cannot be directly compared to contact water samples.

Copper, nickel and zinc were detected in all feedstocks. Molybdenum was detected in only the grass feedstock which also had detectable levels of arsenic and lead. Grass clippings co-collected with organics had the highest level of zinc. Woodchips were found to have the highest levels of copper, nickel and lead.

Commercial organics feedstock was below detection limits for mercury, lead, arsenic, selenium, molybdenum and Cadmium. Commercial organics also had the lowest levels of copper and zinc.

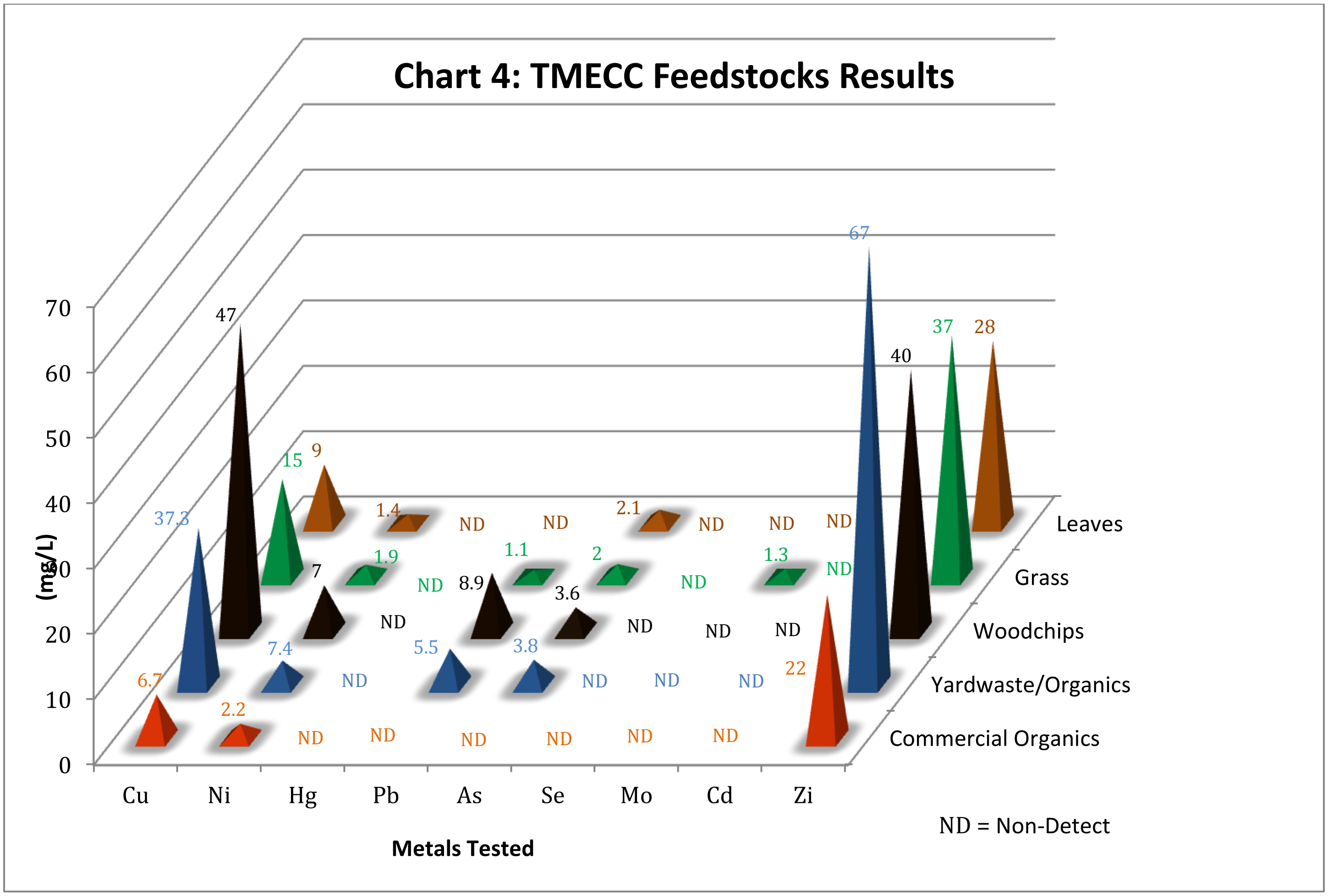


Chart 4: TMECC Feedstocks Results
(mg/L)
0
10
20
30
40
50
60
70
Cu
Ni
Hg
Pb
As
Se
Mo
Cd
Zi
Metals Tested
Leaves
Grass
Woodchips
Yardwaste/Organics
Commercial Organics
ND = Non-Detect
47
37.3
6.7
2.2
15
9
7
7.4
1.4
1.9
ND
8.9
5.5
3.8
1.1
2
2.1
3.6
1.3
22
67
40
37
28

VII. Study Summary & Conclusions

The Minnesota Pollution Control Agency's 2013 Waste Characterization Study found that organic materials account for up to 41% of what Minnesotan's throw away, yet only 3.5% is currently being diverted.[12] Expanding capacity for processing source-separated organic (SSO) material has the potential to divert additional 1.4 million tons of waste in Minnesota annually. Organics composting capacity will need to expand in Minnesota in order to achieve the Minnesota Pollution Control Agency's (MPCA) goal of 15% by 2020 set in the 2010-2030 Metropolitan Solid Waste Management Plan.

Concurrent with the policy related discussions calling for additional SSO processing capacity, the MPCA initiated an amendment process for the permitting of SSO composting facilities. As the rules amendment process continued, the MPCA requested additional research to obtain a more comprehensive understanding of environmental impacts of co-composting SSO and yard waste. In May 2012, the MPCA issued a Request for Proposal outlining the specific details the Agency required as part of the research to assist in the process. Specifically the MPCA required the use of a rain simulator to mitigate draught conditions and lysimeters as the approved sampling method.

The objective outlined in the RFP was to provide additional data to supplement previous research and help provide additional data to answer the following questions:

1. Is there a need for a pad in the curing area or will a drivable surface over certain soil types and depth to the water table be enough to protect the water table below a facility?
2. What is the chemical composition of contact water from various areas (i.e. the mixing, active [both under windrows and in between the windrows], and curing area) of the compost facility?
3. Is there infiltration into the soil in the areas that have a pad vs. those that don't have a pad? Is there a difference in infiltration rates?

In 2012, Carver County applied for a MPCA grant to expand on previous organics composting research conducted at University of Minnesota Landscape Arboretum demonstration sites. This research is summarized in the July 9, 2008 report "Commingling Residential Organics with Yard Waste" and the November 27, 2012 report "Continuation & Expansion of the Commercial & Residential Co-Collection Organics Composting Project". These reports can be found at www.mncompostingcouncil.org/research.

The Project Team lead by Marcus Zbinden of Carver County Environmental Services consisted of Anne Ludvik- Specialized Environmental Technologies, Thomas Halbach - University of Minnesota Dep. Soil,

[12] 2013 MPCA Minnesota Statewide Waste Characterization Study, http://www.pca.state.mn.us/index.php/waste/waste-and-cleanup/waste-management/solid-waste/integrated-solid-waste-management/minnesota-msw-composition-study/index.html

Water and Climate, Mark Zumwinkle - Minnesota Department of Agriculture, Kellie Kish-Carver County Environmental Services and Ginny Black – MPCA/Black Gold Recycling, LLC. (Ms. Black retired from MPCA in 2013). The Team began work with the MPCA in September 2012. As required by the MPCA, lysimeters were used to collect contact water that infiltrated through the compacted gravel pad and on site loam soils. This sampling plan also included the collection of contact water collected from the surface of the pad that was generated by the use of a rainfall simulator placed over the center of the piles. This segment of the project is referred to as **Phase I**.

Midway through the process the MPCA assigned new technical staff to the project. Following the staffing change, the MPCA completely modified the sampling plan. MPCA staff redesigned a contact water collection system to incorporated compacted gravel over a drainage layer of sand covering a 40 mil landfill liner. The project team opposed the changes siting concerns that the new sampling method was unable to provide data on the following focus areas identified by the MPCA in the research grant Request for Proposal:

- Is there a need for a pad in the curing area or will a drivable surface over certain sol types and depths to water table be enough to protect the water table below the facility
- Is there infiltration into soils in areas that have a pad vs. those that do not have a pad? Is there a difference in infiltration rates?

This sampling system was referred to as the "Liner Method" was utilized in **Phase II** of this project.

The following sections discuss Phase I and II results as well as the study's conclusions and recommendations. Dave Benke, the MPCA Division Director for the Resource Management & Assistance Division submitted a letter and evaluation of the Technical Report on December 22, 2014 which he requested to be included as part of this Report. The review includes MPCA thoughts regarding the project results and method limitations, many of which have been included in the report. The MPCA letter as well as the Project Team's response is attached as Appendix F.

A. Phase I Overview

The sampling plan called for saturating various compost and feedstock piles utilizing an eight foot (8') USDA Prude-Style rainfall simulator with the intention of collecting contact water infiltrating piles and running horizontally off the pad. In addition, contact water was collected through the use of lysimeters after the water came in contact with the compost and feedstock piles and infiltrated through the gravel pad into loam sub-soils beneath the pad. Sampling began in September 2012 with eight (8) separate rainfall simulations conducted over the following materials and surfaces: empty gravel pad, commercial organics (food waste, compostable plastics and non-recyclable paper from commercial accounts), grass heavy organics compost pile (active pile composting residential organics co-collected with grass), grass heavy yard waste compost pile (active pile compositing grass clippings without organics), native soil (control off the pad), leaf heavy co-collected organics pile (active pile composting residential organics co-collected with leaves), and leaf feedstock pile (newly collected fall leaf feedstock pile).

Contact water was gathered from the surface of the pad in the course of all eight (8) rainfall simulations. During simulations conducted over the modified windrows, contact water infiltrated the center of windrow and traveled to the compacted gravel pad where it moved horizontally down slope through the toe of the windrow. No contact water was collected in the lysimeter under the piles. Surface samples from rainfall simulation events were analyzed for heavy metals; perfluorinated compounds (PFCs), pesticides, herbicides, pathogens and nutrients. Test America analyzed aqueous PFC samples and all other parameters were analyzed by Pace Analytical.

Samples were taken of the incoming feedstocks and analyzed for pesticide and herbicide concentrations by Columbia Food Laboratories in Oregon.

B. Phase I Results Summary

The volume and intensity of simulated rain influenced the amount of water available for infiltration through the windrow and pad. In Phase I, the standard test area in the center of the modified compost piles were subjected to rainfall ranging from 6.8-18.3 inches of rain in a 3.5 hour period of time. Simulated rain was applied to the compost until surface water was generated for the purposes of collection and analysis. Due to the ability of compost to hold water, these extreme simulated rain need to be applied to collect samples. However, these excessive levels of precipitation altered water holding capacity, natural movement of contact water through pile, and microbial action.

Contact water was not found in lysimeters under windrows following the rainfall simulations suggesting there is no vertical movement of water through the windrow into the pad and into the sub-soils beneath compost piles. This result is consistent with findings from the previous research conducted as part of the 2008 and 2012 MPCA grant projects.

Of the 503 metals analyzed, commercial organics did not exceed drinking water Health Risk Limit (HRL) standards set by the Minnesota Department of Health (MDH). Metals were only detected when yard waste was present with exception of mercury and silver which were not found above detection limits for any samples.

Total Kjeldahl Nitrogen (TKN) and phosphorus do not have HRLs or a range of surface water limits for comprehensive comparison of results. Results for nitrate were all below the MDH HRL value of 10 mg/L. TKN values range from 27.3 mg/L (feedstock leaves) to 1,470 mg/L (grass heavy yard waste). The range for phosphorus is 18.5 mg/L (commercial organics) to 71.3 mg/L (grass heavy yard waste).

In contact water samples fecal coliform was too numerous to count (TNTC) for residential organics that were leaf heavy and for leaf feedstock and in the native soil of the pad.
However, total coliform was found to be less than 1 CFU/100mL for commercial organics and the facility pad. This would suggest that fecal coliform is being brought to the facility in yard waste potentially by pet waste inadvertently added to the yard waste carts. Commercial organics appears not to be a source of fecal coliform.

Of the 67 semi-volatile organic compounds (SVOCs) tested, all were non-detect except for one sample in the residential grass heavy organics showing phenols at 159 µg/L. This concentration is within the surface water limits (123 - 4,428 µg/L). There is no MDH HRL for phenols.

Samples were analyzed for 29 pesticides and herbicides. All pesticides were non-detect at the reporting limits. Only one of the herbicides analyzed, 2,4-dichlorophenoxyacetic acid (2,4-D), was detected. It was found in three different samples that all contained yard waste. 2, 4-D levels exceeded MDH HRL (.07 µg/L) in residential grass and leaf heavy organics as well as grass heavy yard waste. Feedstock leaves and cafeteria organics did not show the presence of herbicides.

C. Phase II "Liner Method" Overview

In December 2012, the MPCA underwent staffing changes resulting in new technical staff being assigned to this research project. Following the staffing transition, MPCA Technical Staff required a complete change in sampling method citing concerns with potential limitations of lysimeters. Specifically staff noted the following potential limitations with the use of lysimeters:

- Collecting sufficient sample volumes may be difficult
- Do not allow for the determination of total volume of contact water generated
- Time necessary to extract samples from lysimeters may exceed sample holding times
- Sampler may add or subtract chemical constituents by leaching or absorption

The determination to eliminate lysimeters contradicts the MPCA's position on their use in monitoring plans for programs such as the land treatment of landfill leachate.

Throughout winter and spring, the Project Team worked with MPCA Technical Staff to revise the project design. The new method incorporated a MPCA revised procedure referred to as a "Liner Method" which called for utilizing three small test cells using one foot compacted aggregate over a drainage layer of sand and 40-mil high-density polyethylene (HDPE) landfill liner.

The Project Team had concerns replacing established lysimeters methods with the unproven "Liner Method" citing concerns over the ability to collect accurate volume measurements and perform valid chemical and biological analyses. Specific concerns included: the elimination of native soils as part of the experimental design, pile size not representative of operating site and uncertainty of an unproven sample collection method.

Despite the Project Team concerns with the Liner Method the MPCA required its use for the purposes of completing this grant project. Phase II rainfall simulations began in July 2013. Three compost piles consisting of approximately thirteen cubic yards (13 yd^3) were placed on each test cell. The mixture of each pile was identical and included: commercial organics, grass clippings, co-collected organics and yard waste, leaves, and woodchips. From the month of July through October, rainfall simulations were conducted over each test cell on three separate occasions. Samples were collected representing three stages of composting including:

- Day 1 when feedstocks were mixed and piles constructed,
- Day 38 during active composting once piles were turned five times and the PFRP requirement was met, and
- Day 72 at the end of active composting when Solivta test indicated pile maturity.

The Liner Method test cells were designed with the intention of collecting contact water running off the pile onto the surface of the pad or water infiltrating compost and running horizontally off the pad. In addition, contact water was to be collected that had run through the compost pile and infiltrated through the gravel of the test cell. Contact water from the surface was collected from only the first rainfall simulation after piles were constructed. No other simulations performed on test cells produced surface contact water run-off. All rain simulations on test cells produced contact water that was collected from sub-surface collection sumps.

Following each rain simulation, the contact water collected twenty-four (24) hours after each rainfall simulation in the sub-surface sumps. Contact water samples were collected and analyzed for heavy metals, PFC, pesticides, pathogens and nutrients.

Solid samples of both actively composting materials and feedstocks were also collected. The Project Team used two methods of analysis: synthetic precipitate leaching potential (SLPL), which included an acid pre-treatment; and the test method for evaluating composting and compost (TMECC) which does not use sample preparation. TMECC provides detailed protocols for the composting industry to verify the physical, chemical, and biological conditions of composting feedstocks, material in process and compost products at the point of sale. TMECC parameters included: pH, TKN, total P, 503 metals, mercury, coliform, E. coli, total phenols, SVOC, pesticides, herbicides, PFC, and BPA.

D. Phase II Results Summary

The volume and intensity of simulated rain influenced the amount of water available for infiltration through the compost pile and gravel surface of “Liner Method” test cells. In Phase II, the standard test areas over the center of the undersized compost piles were subjected to two 6.8 -8.4 inch in a 3.5 hour rain simulation event. In addition, natural rain events also added moisture when piles were not covered or when the tarps covering the pile failed. In total the amount of precipitation far exceeded a typical rain fall in Minnesota. This excessive level of precipitation applied to the piles altered the ability to reach PFRP quickly, water holding capacity, natural movement of contact water through the pile, and microbial action.

According to volumes measured and recorded from the sumps of the Phase II Liner Method, between 37%-55% of water applied by the rainfall simulator infiltrated through compost pile into the aggregate surface and drainage layer of sand and was collected in the sump. This was a major deviation from pervious findings using the compacted Class V gravel pad at the Arboretum Organics Composting Demonstration Sites which represents a typical pad construction. In the 2008 and 2012 Carver County research funded by the MPCA as well as in Phase I of the current study, no vertical infiltration was

observed through the pad under compost piles. This is a significant finding as it relates to potential impacts on groundwater resources under more typical operational conditions.

The 503 metals from Phase II rainfall simulations displayed a wide range of results. Metals that did not exceed MHD HRL standards for drinking water for all three rounds include: chromium, copper, selenium, sliver and zinc. Cadmium, lead and mercury had median values less than the MDH HRL but some values exceed the standard. Over half of the results for arsenic, barium, boron and molybdenum exceeded drinking water standards. All of the nickel results exceed MDH HRLs. These results were from un-filtered samples. Municipal water samples are filtered samples in Minnesota.
Results for nitrogen are divided into nitrate (NO_3-), nitrite (NO_2-) and TKN (organic N). Nitrate results range from 1-32.6 mg/L; nitrite ranged from 0.49-28.6 mg/L; TKN ranges from 111-572 mg/L for sub-surface contact water. One third of nitrate levels were above the MDH HRL. Over half of the results for nitrite were above the MDH HRL. There is no MDH HRL or surface water limit for comparing TKN values. Phosphorus results ranged from 0.48-1.8 mg/L. Bacteria were present in samples collected during all three phases of rainfall simulations.

There are few standards for comparing solids and oxygen demands in waters of Minnesota. Total dissolved solids (TDS) results ranged from 3,440-27,400 mg/L and exceeded the surface water limit of 500 mg/L. Total suspended solids (TSS) results ranged from 18.2-164 and there for no Minnesota limits for this parameter. Carbonaceous oxygen demand (cBOD) results ranged from 1,280-21,000 mg/L but there is not a MDH HRL or surface water limit for cBOD. Biological oxygen demand (BOD) results ranged from non-detect <15,600 mg/L. While there is no MDH HRL for BOD, surface water limits are 7 mg/L and only one data point fell below this limit in the third rainfall simulation. Chemical oxygen demand (COD) results ranged from 2,190-303,000 mg/L with no corresponding MDH HRL for this parameter.

Phenols results ranged from <500-4,610 µg/L. While there are no drinking water limits for phenols, surface water limits range from 123-4,428 µg/L. Only one data point from one rainfall simulation event showed results for SVOCs. The single result was for 882 µg/L 2-methylphenol (o-Cresol) and came from the surface water collection sump from the rainfall simulation which was deemed and outlier.

Analysis of 21 samples for pesticides resulted in four (4) samples with pesticides identified in sub-surface contact water. The remaining seventeen (17) samples were negative for pesticides. Pesticides present in the sub-surface contact water were: alpha-BHC, delta-BHC, gamma-BHC (Lindane) and alpha-Chlordane. Lindane is a pesticide that has been taken out of most uses since 2006. Lindane is a persistent pesticide and breaks down slowly in water and extremely slow in soil. Lindane results range from non-detect <0.0500- .363 µg/L. Alpha-BHC results ranged from non-detect <0.0500-0.0836 µg/L and delta-BHC was present from non-detect <0.0500-.316 µg/L. MDH HRL for Lindane is 0.200 µg/L, which was exceeded in two cases of contact water samples. Lindane (<0.0500-0.363 µg/L) has surface water standards that range from 0.0087-2 µg/L. Alpha-Chlordane was present in contact water ranging from non-detect <0.0500-.403 µg/L and has surface was limits ranging from 0.073- 2,400 µg/L.

Analysis for three herbicides showed 2,4-D present in sub-surface contact water. Ranges for 2,4-D were <2.00-33.3 µg/L with a median of 4.23 µg/L. There are no MDH HRL or surface water limit for 2,4-D.

Seven of thirteen samples tested for Perfluorinated Chemicals (PFCs) returned results above laboratory reporting limits. PFNA, PFDA, PFUnA, PFBoA, PFHxS and PFOS did not have results above reporting limits. PFBA results were non-quantifiable due to matrix issues with contact water. PFPeA, PFHxA, PFHpA, and PFOSA results ranged from <12.9-301 ng/L and do not have MDH HRLs or surface water limits. PFOA results ranged from <11.3-34 ng/L which is below the MDH HRL at 300 ng/L. PFBS results ranged between 38.4-326.4 ng/L and are below the HRL value of 7,000 ng/L.

VIII. Study Conclusions and Recommendations

The relevance of the contact water data from both Phase I and Phase II of this study, when drawing comparisons to actual contact water generated at a source-separated organics material compost site, is problematic. Through the course of sampling, the Project Team and the MPCA discovered several limitations with both the use of the rainfall simulator as well as the MPCA designed Liner Method used in Phase II. The fundamental limitations of the sampling method uncovered during the course of the study include:

1) **"Liner Method" Permeability**: Permeability and compaction of Liner Method pads used in Phase II were not representative of a working compost sites. The method by which Phase II pads were constructed had many flaws. First, the gravel came up to the edge of the berm covered by the landfill liner on an angle creating a situation that the depth of gravel was minimal. As a result, any contact water generated at the edge of the pad had a direct path to the subsurface sump. The second issue was the high permeability of the center of pads of the test cells. An independent analysis from Braun Intertec determined the pads used as part of Liner Method were determined to have moderately rapid permeability $3.41x10^{-3}$ cm/sec or 4.84 (in/hr) infiltration and did not shed water while the working pad at the Arboretum Demonstration site used as part of Phase I of the study had a much lower permeability of $1.34x10^{-4}$ (cm/sec) or .19 (in/hr). Braun Intertec determined the Liner Method's pads were 25 times more permeable than the working pad at the demonstration site. An evaluation done by American Engineering Testing (AET), Inc., found in Appendix G, concludes that a hard-packed surface of Class 5 or 6 having a permeability $3x10^{-4}$ cm/sec (.43 inch/hr), such as the pad used in Phase I of the project, would minimize migration of material and contact water into the subsurface and therefore meet the definition of "Impervious Surface" as defined by the MPCA storm water permit. AET went on to say that hard-packed Class 5 surface found at the Arboretum Organics Composting Demonstration Site would be an adequate impervious surface that retards infiltration and promotes natural attenuation for SSO compost operations. Based on their analysis, AET determined the it would be inappropriate to draw conclusions on compost site pad permeability based on the results of Phase II of this study utilizing the MPCA designed Liner Method.
2) **Pile Size:** In Phase I and to a greater degree in Phase II, the compost piles had to be shortened in length and lowered in height to accommodate the capabilities and safety of the Purdue-style rainfall simulator used for this study. The pile size and shape created a situation where the test

piles were no longer representative of a pile found at an operating SSO compost facility. The piles of compost in Phase 1 were 44 times smaller in volume than a typical commercial SSO pile while the piles in Phase II were 77 times smaller in volume. The applicability of contact water volume and chemistry data from considerably undersized piles is highly questionable since the typical commercial SSO piles would have the ability to absorb and hold greater volumes of precipitation prior to becoming saturated.

3) **Concentration of Contact Water**: Run-on & run-off from the pad or additional falling participation was not incorporated into the sampling method. Simulated rain fell only on the pile and not on the surrounding pad as would occur during a natural rain event at working compost facility. This resulted in artificially high contaminant concentration.

4) **Water Holding Capacity**: Test piles in Phase II were near or above the water holding capacity at pile creation prior to the addition of simulated rain. This significantly reduces the windrows ability to hold additional water from the rain simulation events.

5) **Native Soil Attenuation:** Soils have the ability to attenuate contaminants in water such as metals and the microbial activity in soils breakdown organics contaminants. This is accomplished by the processes of filtration, ion exchange, chelation, and fixation. Native sub-soils were incorporated in to Phase I of the study but were removed by MPCA Technical Staff in Phase II when the decision was made to utilize Liner Method. This method replaced native soils with a one foot (1') drainage layer of sand below the porous gravel pad. Since subsurface soils were removed any conclusions drawn from data collected by the Liner Method regarding potential ground water contamination are questionable.

6) **Non Typical Rain Events:** Independent review of the test method by AET concluded the amount of simulated rain water that was applied represented an extreme event and significantly and artificially inflated the amount of contact water likely to be observed under a more typical, realistic rainfall scenario.

7) **Sample Size:** The sample size of both Phase I and Phase II were too small to be statistically significant.

The Minnesota Pollution Control Agency (MPCA) agrees with the Project Team's findings that there were substantial deficiencies with the test method and sampling protocol. Specifically the Agency acknowledges that there were significant limitations with, but not limited to: liner design, pad construction, rainfall simulator, the use of non-filtered water samples and simulation events as well as representative pile height.

This conclusion was confirmed by AET who conducted an independent evaluation of the MPCA Liner Method and made the following conclusion: "The applicability of contact water data from the Liner Method rain simulation to actual contact water generated at a SSO compost facility is highly questionable as compost piles generally are not saturated, would not have free flowing water moving

vertically through the compost pile, and would not have a hydraulic head build up at the base of the compost pile."

The MPCA surmised that many of the limitations were due to the use of the Purdue-style Rainfall Simulator. Specifically they drew the following conclusions:

- The rainfall simulator was designed to apply water over a small area on flat ground. Use of the simulator mandated a smaller-than-representative compost pile height approximately four feet (4') versus twelve feet (12') and pad dimensions. This severely limited the pile's ability to hold the quantity of water applied.
- Given that the Purdue-style Rainfall Simulator was designed to apply water to flat ground and the pile was not flat, the distribution of the water over the pile was very uneven (0.45 inches at the edge and 12.7 inches in the center) this resulted in the center of the pile wetted to beyond saturation with the edges significantly less wet.
- Applying a quantity of water representative of a 24 hour rain event in 3 ½ hour period further exacerbated the beyond-saturated conditions at the center of the pile.

The MPCA determined that these circumstances led to conditions that were far from representative of a natural rain event or normal composting operations. The Project Team agrees with the MPCA that the way in which the Purdue-style Rainfall Simulator was used provided non-representative results. However, the Project Team maintains the primary reason for the uneven distribution of rain was the MPCA insistence on measuring the simulated rain outside the standard test area of the equipment. As a result, the center of the pile received a significantly larger quantity of water while the outside edges received negligible drift.

In general, the manner in which the rainfall simulator was used compromised the validity of the data and, therefore should not be used to measure environmental impacts to both ground and surface water.

The biological data collected from the Liner Method revealed high bacterial loading throughout all three stages tested. This finding was counter to typical compost operations. As a result, Dr. Michael Sadowsky, Director of the BioTechnology Institute of the University of Minnesota was asked to conduct an independent review of the Liner Method and corresponding biological results. Dr. Sadowsky concluded that any bacteria seen post active composting was almost certainly due to growth of contaminating bacteria in the collection system (the sump) which has temperatures more conducive for microbial growth 25-37°C. He also concluded that the growth seen in Liner Method collection sump is made even more conducive to microbial growth as leachate entering the sump would be rich in organic matter (N, P, and S) that would help facilitate microbial growth.

Based on these issues, Dr. Sadowsky found that the Liner Method is not useful for measuring bacterial loading of the compost pile following a normal composting cycle. He suggested the use of random grab sampling and coring to selective depths using a sterile auger to accurately measure bacterial loading of compost pile following a normal compost cycle.

In addition to the defects with the test method, reservations were also raised with the MPCA requested use of drinking water standards (MDH HRLs) as a basis for comparing contact water results. According to AET, drinking water standards are based on water that has been filtered, removing the suspended solids. It is important to note that the contact water samples collected for this research as well as both the 2008 and 2012 Carver County studies were not filtered prior to analysis.
As a result they should be considered "total" contaminants measurements which include contaminants that are contained in suspended solids as well as dissolved in water. It is misleading to compare unfiltered water sample data collected for this project to drinking water standards derived from filtered water. The appropriate practice for characterization of compost contact water when comparing to drinking water standards is to filter the water samples prior to analysis in order to obtain a more representative chemical characterization.

In order to provide an appropriate and meaningful evaluation of the metals data, AET plotted the contaminant concentrations and the total suspended solid (TSS) concentrations for metals reported to exceed the drinking water standards. These metals include: arsenic, barium, boron, cadmium, lead, mercury and nickel. They then conducted linear regression statistical analysis of the data to determine the correlation between the metal concentration and the TSS concentration and the likely metal concentration in the water if the suspended solids were removed, filtered, as is standard practice prior to laboratory analysis. The statistical analysis demonstrates that if samples had been filtered prior to analysis, the metals concentrations in the samples would have been less than drinking water standards in all cases with the exception of nickel. There were two "outliers" for nickel identified by AET that influenced statistical analysis. They recommended reviewing the original data to determine if there is an explanation for the anomaly. Excluding the two outlier data points, AET's linear regression statistical analysis demonstrated that nickel concentrations in the samples would be less than drinking water standards based on filtered samples. AET's April 10, 2014 report is attached as Appendix G.

Due to the limitations found in Phase I and the experimental Phase II "Liner Method" design, the Project Team has no confidence in this study's results. There is no conclusive evidence from this research to adequately comment on the stated objectives in the grant to support the decision-making process in regards engineering requirements to source-separated organics compost facilities. In short, this study was not capable of determining the appropriate pad design, optimal vertical distance to water table or measure the ability of native soil to attenuation both biological and chemical contaminants.

The MPCA stated that due to the project limitations it cannot be stated equivocally that compost contact water is benign or that it presents a pronounced risk to human health or the environment.

This study relied on untried experimental methods with conditions not found at a SSO composting facility. Test methods could be improved in future studies by simulating real-life scenarios, including piles sizes that represent actual composting operations and pads that are properly compacted with a representative permeability.

The MPCA contends that future research would benefit from a more expansive literature review and that this review would provide some context to compare the methods, design and results of this report

and provide guidance for future work. The Project Team agrees with the MPCA's recommendation for a more expansive literature review and further analysis of previous Carver County research as well as actual contact water collected at permitted SSOM compost facility holding ponds.

As a final point, the Project Team shares MPCA's desire that further research continue in an effort to provide additional information on the true environmental impacts of contact water generated from composting source separated organics.

To assistance in this process the Project Team makes the following recommendations for further investigation:

1. Incorporate a working compost pad which includes native soils into sampling plan.
2. Use MPCA approved sheet flow sampling methods during a natural rain event to collect contact water samples.
3. Use random sampling and coring to selective depths using a sterile auger to accurately measure bacterial loading of compost pile during a normal compost cycle.
4. When making comparisons to drinking water standards (MDH HRLs), use only filtered samples.
5. Investigate other types of compost such as yard waste only. This will help confirm the assertion that composting co-collected source separated organics with yard waste poses no additional risk to the environment than composting yard waste alone.
6. Avoid the use of a rain simulator in a manner which produces artificially high concentrations of contaminants in the contact water.
7. In view of the fact that septic systems effluent concentrations fall within the range of properly collected contact water data, a thorough evaluation of native soil attenuation on both forms of discharge would provide a better understanding of potential environmental impacts of SSO composting.