

INNOVATIVE TECHNOLOGY REDUCES MERCURY EMISSIONS TO KEEP OHIO'S SEWAGE SLUDGE INCINERATORS HOT AND COSTS COOL

The Road to SSI MACT Compliance for Cincinnati and Cleveland

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ABSTRACT

Effective March 21, 2016, all Sewage Sludge Incinerators (SSIs) were required to be in compliance with the United States Environmental Protection Agency (USEPA) Maximum Achievable Control Technology (MACT) air pollutant emissions standards.

At the Northeast Ohio Regional Sewer District's (NEORS) Southerly Wastewater Treatment Center (WWTC) and the Metropolitan Sewer District of Greater Cincinnati's (MSDGC) Mill Creek Wastewater Treatment Plant (WWTP), an analysis of historical feed-sludge mercury data from approximately 2012 to present, coupled with each facility's most recent incinerator emissions tests, confirmed that additional emissions controls were required for each of the two facility's combined six fluidized bed incinerators (FBIs) (three at each facility) to consistently bring the incinerators into compliance with the new regulations, more specifically with mercury emissions limits. Without the addition of enhanced emissions controls focused on mercury removal, each facility would likely not have been able to demonstrate consistent compliance with the new rule subsequent to the associated March 2016 regulatory compliance deadline, potentially resulting in the loss of permit to incinerate sludge. This loss of permit would have resulted in NEORS and MSDGC needing to institute hauling programs to direct an average of 120+ dry tons per day (dtpd) of dewatered sludge cake from each facility to landfill. This operation was deemed by both institutions to not only be cost prohibitive, but also to be unsustainable.

Traditionally, fixed bed granular activated carbon (GAC) adsorbers have been used to reduce mercury emissions for incinerators operating existing wet scrubber emissions control systems like those at Southerly WWTC and Mill Creek WWTP. However, both NEORS and MSDGC recognized the potential of a newer proprietary mercury removal technology, known as Sorbent Polymer Composite (SPC) absorption, which as part of several successful pilot studies was demonstrating significant mercury removal in emissions from municipal SSIs. When compared to large fixed bed GAC adsorbers, the SPC absorption vessels not only offered notable capital cost savings, but also required less ancillary equipment, leading to lower overall facility operations and maintenance (O&M) costs and greater ease of retrofitting the SPC vessel systems within the existing incinerator building space.

Following careful analysis, both NEORS and MSDGC ultimately decided to install new SPC absorption vessel systems for each of their three respective FBIs. In early 2016, following installation of the new emissions controls systems, each of the SSIs underwent official SSI MACT compliance testing. This testing demonstrated that all six of the incinerators were in compliance with all regulated emissions limits, including mercury. Furthermore, all testing was complete prior to the March 21, 2016 regulatory compliance deadline, which was a significant accomplishment given the compressed time frame to analyze, design, install, and commission the

SPC vessel systems following publishing of the SPC technology pilot study results in 2014. Results and ongoing monitoring of the SPC technology's effectiveness are discussed herein.

KEYWORDS

Incineration, sewage sludge, fluidized bed, regulatory, air pollution control

INTRODUCTION

Regulatory Requirements

On March 21, 2011, the United States Environmental Protection Agency (USEPA) published *Title 40 Code of Federal Regulations (CFR) Part 60 – Standards of Performance for New Stationary Sources and Emissions Guidelines for Existing Sources: Sewage Sludge Incineration Units; Final Rule*, and thereby established more stringent air pollutant emissions standards for both pre-existing and planned future sewage sludge incinerators (SSIs) under a “model rule” (referred to herein as the SSI Maximum Achievable Control Technology (MACT) rule). In summary, the model rule stipulated that affected utilities were required to demonstrate compliance within a five year window (i.e. no later than March 21, 2016) or otherwise by an earlier date per an approved State Plan (refer to 40 CFR Part 60, §60.5245). In the State of Ohio, which did not submit a separate State Plan, March 21, 2016 was considered as the applicable final compliance deadline for all affected utilities operating SSIs.

Under the model rule, a distinction between SSIs that would be classified as “existing” versus “new” was included. This distinction was notable in that it represented a sharp difference in the level of compliance required for regulated air pollutants. In summary, an SSI classified as “new” would have stricter emissions limits when compared to an SSI classified as “existing,” and would therefore likely require additional emissions control to maintain air pollutant emissions compliance. Requirements for classifying SSIs as either “existing” or “new” were defined as follows”

- **Existing SSIs:** Multiple hearth incinerators (MHIs) and fluidized bed incinerators (FBIs) where construction commenced on or before October 14, 2010.
- **Modified SSIs:** Existing MHIs and FBIs which undergo modifications later than September 21, 2011 and meet one or both of the following two criteria:
 - The cumulative cost of changes over the life of the SSI exceeds 50 percent (50%) of the original cost of building (construction the SSI) and installing the SSI (not including land cost) updated to current dollars. A summary of what items are within the boundary of the SSI and thus used to calculate these costs was initially provided under 40 CFR Part 60, §60.4775.
 - Any physical change in the SSI or change in the method of operating the SSI that increases the amount of any air pollutant emitted for which Section 129 of the Clean Air Act or Section 111 of the Clean Water Act has established standards.Modified SSIs under the above definition will be required to meet “new” MHI or “new” FBI air pollutant emissions limits.
- **New SSIs:** MHIs and FBIs for which construction commenced after October 14, 2010.

For reference, air pollutant emissions limits set by the model rule for “existing” and “new” MHIs and FBIs are provided in Table 1.

Table 1. SSI MACT Regulated Air Pollutants and Emissions Limits for

Pollutant ¹	Units ¹	EMISSIONS LIMITS			
		“Existing” MHIs ³	“New” MHIs ⁴	“Existing” FBIs ³	“New” FBIs ⁴
Particulate Matter (PM)	mg/dscm	80		18	9.6
Hydrogen Chloride (HCl)	ppmvd	1.2	1.2	0.51	0.24
Carbon Monoxide (CO)	ppmvd	3,800	52	64	27
PCDD/PCDF, TEQ ²	ng/dscm	0.32	0.0022	0.10	0.0044
PCDD/PCDF, TMB ²	ng/dscm	5.0	0.045	1.2	0.013
Mercury (Hg)	mg/dscm	0.28	0.15	0.037	0.0010
Oxides of Nitrogen (NOx)	ppmvd	220	210	150	30
Sulfur Dioxide (SO ₂)	ppmvd	26	26	15	5.3
Cadmium (Cd)	mg/dscm	0.095	0.0024	0.0016	0.0011
Lead (Pb)	mg/dscm	0.30	0.0035	0.0074	0.00062

¹ All tested parameters corrected to 7% O₂
² Compliance with PCDD (Polychlorinated Dibenzodioxins) and PCDF (Polychlorinated Dibenzofurans) limits for TEQ (Toxic Equivalency Basis) or TMB (Toxic Mass Basis) is required, not both.
³ 40 CFR Part 60 Subpart M (‘‘Existing’’)
⁴ 40 CFR Part 60 Subpart L (‘‘New’’)

Air pollutant emissions limits set forth under the model rule, which took effect March 21, 2016 as previously noted, are enforceable by *Federal Implementation Plan (FIP) 40 CFR Part 62 Subpart LLL, RIN 2060-AR77*.

Utility Background

In the State of Ohio, several utilities operated MHIs and FBIs prior to the promulgation of the SSI MACT rule. Some of these utilities have since chosen, for a variety of reasons, to discontinue operation of their incineration facilities rather than invest in the upgrades needed to ensure compliance with the rule requirements. On the other hand, the Northeast Ohio Regional Sewer District (NEORS) and the Metropolitan Sewer District of Greater Cincinnati (MSDGC) each chose to continue operation of their existing incineration facilities at the Southerly WWTC and the Mill Creek WWTP, respectively.

The decision to continue operation of existing incinerators was made by each utility, in part, due to the alternative requirement for each to haul an average of 120+ dry tons per day (dtpd) of dewatered sludge cake to landfill, which was deemed not only to be cost prohibitive, but also to be unsustainable. As a result, NEORS and MSDGC separately initiated efforts to determine which upgrades would be required to ensure consistent compliance with the SSI MACT rule, and subsequently to implement the required upgrades. These efforts are discussed in detail herein.

A process schematic of a typical fluidized bed incinerator system, like the six total SSI systems installed at the Southerly WWTC and Mill Creek WWTP (three at each facility) is provided as Figure 1 for reference.

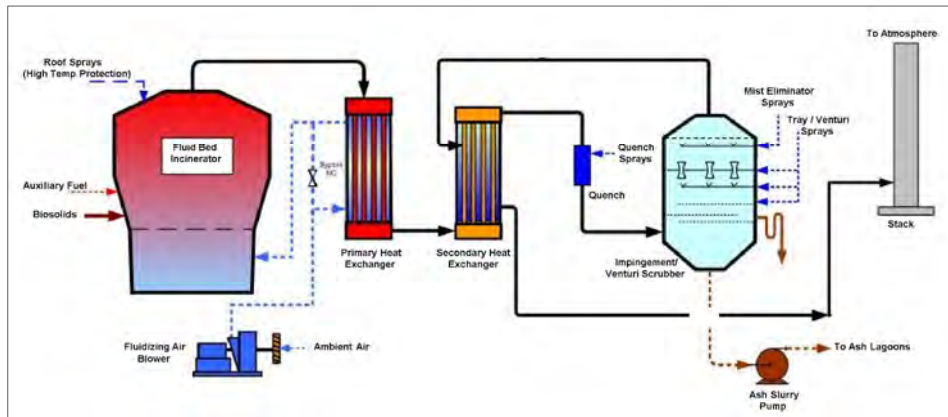


Figure 1. Typical Fluidized Bed Incineration Process Schematic

NEORSD Southerly WWTC

The Southerly WWTC serves approximately 600,000 customers within the Greater Cleveland area. The facility is the largest of NEORSD’s three wastewater treatment plants and treats an average daily flow of 125 million gallons per day (MGD) while providing complete treatment of peak flows up to 400 MGD. The facility can also partially treat up to an additional 335 MGD of storm water through primary treatment. The solids stream of the facility begins in the primary settling tanks, and the first stage and second stage secondary settling tanks. Settled sludge from the primary settling tanks is conveyed to gravity thickeners to thicken the primary sludge to 4-7% solids. Excess activated sludge from the secondary settling tanks is conveyed to gravity belt thickeners likewise to thicken the activated sludge to 5-7% total solids.

From the gravity thickeners, thickened primary sludge (TPS) is directed into one of six sludge storage tanks (SSTs) which also receive thickened excess activated sludge (TEAS) from the gravity belt thickeners. The SSTs act as sludge feedwells for the downstream centrifuges, which were commissioned in 2012 with the construction of the Southerly WWTC Renewable Energy Facility (REF). The REF is generally comprised of three main building areas: the Incinerator Building, the Biosolids Handling Building, and the Truck Loading Facility. These buildings are further subdivided into various rooms and process areas.

The Dewatering Building houses nine dewatering centrifuges, which are fed TPS/TEAS from the SSTs via one of three centrifugal pumps. Once delivered to the dewatering centrifuges, sludge is dewatered and directed to one of three sliding frame collection bins (three centrifuges per collection bin). Six piston type cake pumps (two per collection bin) direct dewatered cake to one of three 100 dtpd FBIs located in the Incinerator Building.

Each of the Southerly WWTC FBIs commenced construction prior to October 2010, and thus are considered “existing” per the SSI MACT rule. Each of the incinerator trains are identical and consist of a fluid bed reactor, primary heat exchanger (PHE) for preheating combustion air, waste heat boiler (WHB) for steam production, secondary heat exchanger (SHE) for plume suppression, ash handling equipment, and auxiliary systems including power generation. In

addition, each incinerator train was initially constructed with emissions controls sufficient to meet regulatory requirements for air pollutant emissions prior to the more stringent requirements under the SSI MACT rule. The existing emissions controls for each FBI consists of a quench and an impingement EnviroCare (ECI) VenturiPak wet scrubber with multiple fixed venturis.

MSDGC Mill Creek WWTP

The Mill Creek WWTP treats an average flow of 130 MGD and serves the City of Cincinnati and central Hamilton County, Ohio. It is the largest of MSDGC's three major wastewater treatment plants and has a firm capacity of 430 MGD through preliminary and primary treatment and 240 MGD through secondary treatment. The solids process stream for the facility begins in the primary settling basins and secondary clarifiers. Settled sludge from the primary settling basins is conveyed to gravity thickeners to thicken the primary sludge to 4-7% total solids. Waste activated sludge (WAS) from the secondary clarifiers is conveyed to thickening centrifuges, which thicken the activated sludge to 5-7% total solids.

From the gravity thickeners, thickened primary sludge (TPS) is directed into a common sludge feed header. This header also conveys the centrifuge thickened waste activated sludge (TWAS) to promote in-line blending of the combined thickened sludge (TPS/TWAS). TPS/TWAS may be transferred directly to the dewatering sludge feedwells, or first to one of twelve sludge storage tanks (former digester tanks), where TPS/TWAS is then pumped to the dewatering sludge feedwells in the Dewatering Building.

The dewatering sludge feedwells temporarily hold TPS/TWAS prior to it being pumped by one of seven progressing cavity pumps to one of six dewatering centrifuges. Centrifuge dewatered sludge cake is then directed to one of three live bottom collection bins. Six piston cake pumps, two per collection bin, direct dewatered cake to the three 96 dtpd FBIs located in the adjacent Incinerator Building.

Similar to the Southerly WWTC FBIs, the Mill Creek WWTP FBIs commenced construction prior to October 2010, and thus are considered "existing" per the SSI MACT rule. Each of the incinerator trains are also identical and consist of a fluid bed reactor, PHE, SHE, ash handling equipment and auxiliary systems. The Mill Creek WWTP incinerators are not used to generate power as are the Southerly WWTC incinerators, and thus are not equipped with WHBs. Similar to the Southerly WWTC incinerators; each of the Mill Creek WWTP incinerators was initially constructed with a quench and an impingement ECI VenturiPak wet scrubber.

Initial Compliance Evaluations

NEORS and MSDGC each separately engaged Black & Veatch in late 2013 to assess the effectiveness of existing emissions controls (i.e. ECI VenturiPak wet scrubbers) equipment for the Southerly WWTC and Mill Creek WWTP FBIs to meet the more stringent air pollutant emissions standards under the SSI MACT rule. Black & Veatch's role included coordination, review, and interpretation of historical and newly collected data in preparation for the design and implementation of enhanced emissions controls improvements.

Initial compliance evaluations for both NEORSD and MSDGC followed similar paths, and each primarily relied on the results of previous and new emissions compliance tests to assess the effectiveness of existing emissions controls to meet the SSI MACT rule’s requirements.

More specifically, in early 2014, NEORSD contracted a third party testing agency to assist in conducting Self-Evaluation Engineering Studies (i.e. unofficial emissions compliance tests) for each of the Southerly WWTC FBIs. These studies were conducted from March 25-26, 2014 and July 22, 2014, June 4-6, 2014, and June 20, 2014 for Southerly WWTC FBIs No. 3, No. 2, and No. 1, respectively. As previously noted, the goal of these studies was to compare air pollutant emissions levels for each of the incinerators against the respective SSI MACT rule’s air pollutant emissions limits.

In general, the testing methods utilized during NEORSD’s Self-Evaluation Engineering Studies and during similar efforts conducted by MSDGC (discussed later herein) were in conformance with those required per 40 CFR Part 60 Subpart M, and as summarized in Table 2.

Table 2. Required SSI MACT Resting Analytes and Methods for Existing FBIs

Analyte ¹	Averaging Methods & Sampling Duration ³	Sampling Method ³
Particulate Matter (PM)	Average of three runs Minimum 1 dscm per run	EPA Method 5, 26A, or 29
Hydrogen Chloride (HCl)	Average of three runs Minimum 1 dscm per run	EPA Method 26A
Carbon Monoxide (CO)	Average of three runs Minimum one hour duration per run	EPA Method 10, 10A, or 10B
PCDD/PCDF, TEQ ²	Average of three runs Minimum 1 dscm per run	EPA Method 23
PCDD/PCDF, TMB ²	Average of three runs Minimum 1 dscm per run	EPA Method 23
Mercury (Hg)	Average of three runs Method 29: Minimum 1 dscm per run Method 30B: As specified	EPA Method 29, 30B, or ASTM D6784-02
Oxides of Nitrogen (NOx)	Average of three runs Minimum one hour duration per run	Method 7 or 7E
Sulfur Dioxide (SO ₂)	Average of three runs Method 6: Minimum 60L per run Method 6C: Minimum one hour duration per run	Method 6, 6C, or ANSI/ASME PTC 19.10- 1981
Cadmium (Cd)	Average of three runs Minimum 1 dscm per run	EPA Method 29
Lead (Pb)	Average of three runs Minimum 1 dscm per run	EPA Method 29
Fugitive Ash Emissions	Three 1-hour observation periods	EPA Method 22
¹ All tested parameters corrected to 7% O ₂ ² Compliance with PCDD and PCDF limit for TEQ or TMB is required, not both ³ 40 CFR Part 60 Subpart M		

Similarly to NEORS, MSDGC contracted a separate third party testing agency to perform unofficial emissions compliance tests for one FBI at the Mill Creek WWTP (FBI No. 3). This testing occurred February 4-7, 2013. Note that MSDGC opted only to test a single FBI at Mill Creek WWTP given that historical, official emissions compliance test results were also available for each of the Mill Creek WWTP FBIs from their commissioning in 2010.

The following provides a summary of the initial findings of the initial compliance evaluations for NEORS and MSDGC.

NEORS Southerly WWTC

Summary emissions testing results for each of the early-2014 Self-Evaluation Engineering Studies conducted by NEORS are presented in Tables 3 through 6. Note that each table also indicates the level of compliance achieved for each pollutant per the SSI MACT rule for existing FBIs, indicated as “Percent of Allowable.” Rows, which show **bolded** text indicate those pollutants which were found to either be non-compliant (above the associated MACT limit) or which were considered approaching non-compliant (>75% of the allowable limit).

Table 3. Southerly WWTC FBI No. 1 Emissions Compliance Test Results – June 2014

Pollutant	Measured Average^{1,6}	Allowable²	Units³	Percent (%) of Allowable⁶
Particulate Matter (PM)	2.0	18	mg/dscm	11.1
Hydrogen Chloride (HCl) ⁵	-	0.51	ppmvd	-
Carbon Monoxide (CO)	24.5	64	ppmvd	38.3
PCDD/PCDF, TEQ ^{4,5}	-	0.10	ng/dscm	-
PCDD/PCDF, TMB ⁴	-	1.2	ng/dscm	-
Mercury (Hg)	0.0352	0.037	mg/dscm	95.1
Oxides of Nitrogen (NO _x)	44.2	150	ppmvd	29.5
Sulfur Dioxide (SO₂)	22.8	15	ppmvd	152.0
Cadmium (Cd)	<0.00057	0.0016	mg/dscm	<35.6
Lead (Pb)	<0.00047	0.0074	mg/dscm	<6.4

¹ Based on average of three test runs conducted in June 2014 for Southerly WWTC FBI No. 1
² SSI MACT rule air pollutant emissions limits for “existing” FBIs
³ All test parameters tested to 7% O₂
⁴ Compliance with PCDD and PCDF limit for TEQ or TMB is required, not both
⁵ HCL and PCDD/PCDF not tested for FBI No. 1 during June 2014 testing
⁶ “<” symbol indicates that the compound was not present in quantities above the Minimum Detection Limit (MDL) for at least one sample

Table 4. Southerly WWTC FBI No. 2 Emissions Compliance Test Results – June 2014

Pollutant	Measured Average ^{1,6}	Allowable ²	Units ³	Percent (%) of Allowable ⁶
Particulate Matter (PM)	1.87	18	mg/dscm	10.4
Hydrogen Chloride (HCl) ⁵	<0.151	0.51	ppmvd	<29.6
Carbon Monoxide (CO)	7.74	64	ppmvd	12.1
PCDD/PCDF, TEQ ^{4,5}	0.00047	0.10	ng/dscm	0.5
PCDD/PCDF, TMB ⁴	-	1.2	ng/dscm	-
Mercury (Hg)	0.040	0.037	mg/dscm	108.1
Oxides of Nitrogen (NOx)	103.1	150	ppmvd	68.7
Sulfur Dioxide (SO ₂)	10.7	15	ppmvd	71.3
Cadmium (Cd)	<0.0015	0.0016	mg/dscm	<93.8
Lead (Pb)	<0.00047	0.0074	mg/dscm	<6.4

¹ Based on average of three test runs conducted in June 2014 for Southerly WWTC FBI No. 2
² SSI MACT rule air pollutant emissions limits for “existing” FBIs
³ All test parameters tested to 7% O₂
⁴ Compliance with PCDD and PCDF limit for TEQ or TMB is required, not both
⁵ PCDD/PCDF TEQ tested for FBI No. 2 during June 2014 testing
⁶ “<” symbol indicates that the compound was not present in quantities above the MDL for at least one sample

Table 5. Southerly WWTC FBI No. 3 Emissions Compliance Test Results – March 2014

Pollutant	Measured Average ^{1,6}	Allowable ²	Units ³	Percent (%) of Allowable ⁶
Particulate Matter (PM)	2.77	18	mg/dscm	15.4
Hydrogen Chloride (HCl) ⁵	0.158	0.51	ppmvd	31.0
Carbon Monoxide (CO)	9.28	64	ppmvd	14.5
PCDD/PCDF, TEQ ^{4,5}	0.0130	0.10	ng/dscm	13.0
PCDD/PCDF, TMB ⁴	-	1.2	ng/dscm	-
Mercury (Hg)	0.0297	0.037	mg/dscm	80.3
Oxides of Nitrogen (NOx)	44.5	150	ppmvd	29.5
Sulfur Dioxide (SO₂)	34.8	15	ppmvd	232.0
Cadmium (Cd)	<0.00091	0.0016	mg/dscm	<56.9

Pollutant	Measured Average ^{1,6}	Allowable ²	Units ³	Percent (%) of Allowable ⁶
Lead (Pb)	<0.00017	0.0074	mg/dscm	<2.3

¹ Based on average of three test runs conducted in March 2014 for Southerly WWTC FBI No. 3
² SSI MACT rule air pollutant emissions limits for “existing” FBIs
³ All test parameters tested to 7% O₂
⁴ Compliance with PCDD and PCDF limit for TEQ or TMB is required, not both
⁵ PCDD/PCDF TEQ tested for FBI No. 3 during March 2014 testing
⁶ “<” symbol indicates that the compound was not present in quantities above the MDL for at least one sample

Table 6. Southerly WWTC FBI No. 3 Emissions Compliance Test Results – July 2014

Pollutant	Measured Average ^{1,6}	Allowable ²	Units ³	Percent (%) of Allowable ⁶
Particulate Matter (PM)	0.0018	18	mg/dscm	0.0
Hydrogen Chloride (HCl) ⁵	-	0.51	ppmvd	-
Carbon Monoxide (CO)	26.2	64	ppmvd	40.9
PCDD/PCDF, TEQ ^{4,5}	-	0.10	ng/dscm	-
PCDD/PCDF, TMB ⁴	-	1.2	ng/dscm	-
Mercury (Hg)	<0.034	0.037	mg/dscm	91.9
Oxides of Nitrogen (NOx)	41.2	150	ppmvd	27.5
Sulfur Dioxide (SO₂)	<19.0	15	ppmvd	<126.7
Cadmium (Cd)	<0.00033	0.0016	mg/dscm	<20.6
Lead (Pb)	<0.00142	0.0074	mg/dscm	19.2

¹ Based on average of three test runs conducted in July 2014 for Southerly WWTC FBI No. 3
² SSI MACT rule air pollutant emissions limits for “existing” FBIs
³ All test parameters tested to 7% O₂
⁴ Compliance with PCDD and PCDF limit for TEQ or TMB is required, not both
⁵ HCL and PCDD/PCDF not tested for FBI No. 3 during July 2014 testing
⁶ “<” symbol indicates that the compound was not present in quantities above the MDL for at least one sample

As shown in Tables 3 through 6, pollutants that were shown to exhibit emissions levels higher than their associated SSI MACT limits were mercury (Hg) and sulfur dioxide (SO₂). In addition, cadmium (Cd) was shown to test above the allowable limit for two of the nine test runs conducted (three per testing event), resulting in an average tested concentration of approximately 94% of the allowable limit for FBI No. 2. All other analytes measured well within the allowable limits per the SSI MACT rule, and were thus considered as being sufficiently controlled by existing air pollutant emissions controls systems.

MSDGC Mill Creek WWTP

Summary emissions testing results for the early-2013 emissions compliance testing conducted by MSDGC for Mill Creek WWTP FBI No. 3 are provided in Table 7, which displays the level of compliance achieved for each pollutant per the SSI MACT rule for existing FBIs, indicated as “Percent of Allowable.”

Table 7. Mill Creek WWTP FBI No. 3 Emissions Compliance Test Results – February 2013

Pollutant	Measured Average^{1,5}	Allowable²	Units³	Percent (%) of Allowable⁵
Particulate Matter (PM)	0.882	18	mg/dscm	4.9
Hydrogen Chloride (HCl)	0.0916	0.51	ppmvd	18.0
Carbon Monoxide (CO)	1.2	64	ppmvd	1.9
PCDD/PCDF, TEQ ⁴	0.0058	0.10	ng/dscm	5.6
PCDD/PCDF, TMB ⁴	0.0663	1.2	ng/dscm	5.5
Mercury (Hg)	0.0350	0.037	mg/dscm	94.6
Oxides of Nitrogen (NOx)	61.2	150	ppmvd	40.8
Sulfur Dioxide (SO ₂)	2.09	15	ppmvd	13.9
Cadmium (Cd)	<0.000416	0.0016	mg/dscm	<26.0
Lead (Pb)	0.000896	0.0074	mg/dscm	12.1

¹ Based on average of three test runs conducted in February 2013 for Mill Creek WWTP FBI No. 3
² SSI MACT rule air pollutant emissions limits for “existing” FBIs
³ All test parameters tested to 7% O₂
⁴ Compliance with PCDD and PCDF limit for TEQ or TMB is required, not both
⁵ “<” symbol indicates that the compound was not present in quantities above the MDL for at least one sample

As displayed upon Table 7, mercury was found to be the only tested parameter above or near respective limits per the SSI MACT rule. On average, mercury emissions during the February 2013 testing were 95% of allowable, with one test reporting mercury levels at 99.6% of allowable.

As previously indicated, in addition to the February 2013 emissions test results for Mill Creek WWTP FBI No. 3, official emissions test data from the commissioning of the Mill Creek WWTP incinerators were reviewed. These results are based on tests conducted in May, July, and September 2010 for Mill Creek WWTP incinerators No. 2, No. 3, and No. 1, respectively. Note that the 2010 emissions test results were conducted to establish compliance with a separate set of emissions standards, and as such do not include all regulated air pollutants under the SSI MACT rule; refer to Tables 8 through 10.

Table 8. Mill Creek WWTP FBI No. 1 Emissions Compliance Test Results – September 2010

Pollutant	Measured Average ^{1,6}	Allowable ²	Units ³	Percent (%) of Allowable ⁶
Particulate Matter (PM)	2.94	18	mg/dscm	16.3
Hydrogen Chloride (HCl) ⁵	-	0.51	ppmvd	-
Carbon Monoxide (CO)	2.63	64	ppmvd	4.1
PCDD/PCDF, TEQ ^{4,5}	-	0.10	ng/dscm	-
PCDD/PCDF, TMB ⁴	-	1.2	ng/dscm	-
Mercury (Hg)	0.070	0.037	mg/dscm	189.2
Oxides of Nitrogen (NOx)	17.27	150	ppmvd	11.5
Sulfur Dioxide (SO₂)	22.28	15	ppmvd	152.0
Cadmium (Cd)	<0.000078	0.0016	mg/dscm	<4.9
Lead (Pb)	0.00023	0.0074	mg/dscm	3.1

¹ Based on average of three test runs conducted in September 2010 for Mill Creek WWTP FBI No. 1
² SSI MACT rule air pollutant emissions limits for “existing” FBIs
³ All test parameters tested to 7% O₂
⁴ Compliance with PCDD and PCDF limit for TEQ or TMB is required, not both
⁵ HCL and PCDD/PCDF not tested for FBI No. 1 during September 2010 testing
⁶ “<” symbol indicates that the compound was not present in quantities above the MDL for at least one sample

Table 9. Mill Creek WWTP FBI No. 2 Emissions Compliance Test Results – May 2010

Pollutant	Measured Average ^{1,6}	Allowable ²	Units ³	Percent (%) of Allowable ⁶
Particulate Matter (PM)	1.07	18	mg/dscm	5.9
Hydrogen Chloride (HCl) ⁵	-	0.51	ppmvd	-
Carbon Monoxide (CO)	0.71	64	ppmvd	1.1
PCDD/PCDF, TEQ ^{4,5}	-	0.10	ng/dscm	-
PCDD/PCDF, TMB ⁴	-	1.2	ng/dscm	-
Mercury (Hg)	0.066	0.037	mg/dscm	178.4
Oxides of Nitrogen (NOx)	22.37	150	ppmvd	14.9
Sulfur Dioxide (SO ₂)	0.12	15	ppmvd	0.8
Cadmium (Cd)	<0.0022	0.0016	mg/dscm	<137.5
Lead (Pb)	0.00070	0.0074	mg/dscm	9.5

¹ Based on average of three test runs conducted in May 2010 for Mill Creek WWTP FBI No. 2
² SSI MACT rule air pollutant emissions limits for “existing” FBIs
³ All test parameters tested to 7% O₂
⁴ Compliance with PCDD and PCDF limit for TEQ or TMB is required, not both
⁵ HCL and PCDD/PCDF not tested for FBI No. 2 during May 2010 testing
⁶ “<” symbol indicates that the compound was not present in quantities above the MDL for at least one sample

Table 10. Mill Creek WWTP FBI No. 3 Emissions Compliance Test Results – July 2010

Pollutant	Measured Average ^{1,6}	Allowable ²	Units ³	Percent (%) of Allowable ⁶
Particulate Matter (PM)	2.48	18	mg/dscm	13.8
Hydrogen Chloride (HCl) ⁵	-	0.51	ppmvd	-
Carbon Monoxide (CO)	15.54	64	ppmvd	24.3
PCDD/PCDF, TEQ ^{4,5}	-	0.10	ng/dscm	-
PCDD/PCDF, TMB ⁴	-	1.2	ng/dscm	-
Mercury (Hg)	0.057	0.037	mg/dscm	154.1
Oxides of Nitrogen (NOx)	31.65	150	ppmvd	21.1
Sulfur Dioxide (SO₂)	13.61	15	ppmvd	90.7
Cadmium (Cd)	<0.0001354	0.0016	mg/dscm	<8.5
Lead (Pb)	0.00054	0.0074	mg/dscm	7.3

¹ Based on average of three test runs conducted in July 2010 for Mill Creek WWTP FBI No. 3
² SSI MACT rule air pollutant emissions limits for “existing” FBIs
³ All test parameters tested to 7% O₂
⁴ Compliance with PCDD and PCDF limit for TEQ or TMB is required, not both
⁵ HCL and PCDD/PCDF not tested for FBI No. 3 during July 2010 testing
⁶ “<” symbol indicates that the compound was not present in quantities above the MDL for at least one sample

As shown in Tables 7 through 10, pollutants that were shown to exhibit emissions levels higher than their associated SSI MACT limits were mercury, sulfur dioxide, and cadmium. All other analytes measured well within the allowable limits per the SSI MACT rule, and were thus considered as being sufficiently controlled by existing air pollutant emissions controls systems.

Note that elevated levels of sulfur dioxide and cadmium for various 2010 tests were at least in part attributed to process water restrictions to existing air emissions controls devices.

Mercury Emissions Controls

Elevated levels of sulfur dioxide and cadmium observed during various testing events for the Southerly WWTC and Mill Creek WWTP FBIs were addressed via separate improvements to the existing EnviroCare VenturiPak wet scrubbers already installed for each FBI at these facilities. These improvements are not the topic of this discussion, and are thus not included herein.

Aside from elevated emissions of sulfur dioxide and cadmium, data reviewed during the initial compliance evaluations strongly pointed towards the requirement for enhanced mercury emissions controls for FBIs at both Southerly WWTC and Mill Creek WWTP. As such, the following provides a brief review of the sources of mercury in SSI applications alongside a summary of technologies considered by the project teams to address mercury emissions at Southerly WWTC and Mill Creek WWTP.

The source of mercury in SSI exhaust gasses is the solids generated within the wastewater treatment facility. Unlike most metals which typically drop out of the incineration process with the ash, and which are removed in the wet scrubber or other particulate removal technology, mercury can exist in the following three forms following incineration:

- **Particulate Mercury:** Mercury entrained with the ash and particulate matter. This fraction of the total mercury is removed in the wet scrubber and sent to the wet ash lagoon with other metals and particulates. A very small portion of the total mercury is in this form.
- **Elemental Mercury:** Mercury is volatilized by combustion. As the gaseous elemental mercury is cooled through the remaining processes, it may react with other components of the flue gas to form oxidized gaseous mercury. This form of mercury is soluble in water and can be partially removed in the wet scrubber.
- **Oxidized Gaseous Mercury:** Elemental mercury which is oxidized by exhaust gas components such as: halogens (chlorine, fluorine, and bromine); oxides of sulfur such as sulfur dioxide (SO₂) and sulfur trioxide (SO₃); and nitrogen such as nitrogen dioxide (NO₂).

In most wastewater treatment plants, only a fraction of the elemental mercury is oxidized. Therefore, a fraction of the mercury discharged from the incineration process remains in the elemental form. Although some of the oxidized mercury can be captured by wet scrubber technologies (such as the EnviroCare VenturiPak wet scrubbers installed at Southerly WWTC and Mill Creek WWTP) this form of mercury removal is very inefficient. As such, proven technologies used for mercury removal include powder activated carbon (PAC) injection for plants with dry ash systems and fixed bed granular activated (GAC) scrubbers for wet ash systems (both the Southerly WWTC and Mill Creek WWTP FBIs use wet ash systems).

PAC Injection

Figure 2 illustrates a summary process schematic for a typical PAC injection system. Typical systems include PAC storage and handling components (not shown on Figure 2), PAC injection towers, fabric filters, and spent PAC truck loading equipment. For SSI applications, PAC injection has historically been installed upstream of the wet scrubber and used as the primary means for removing both ash and mercury. For such installations, dry ash handling is used. Because the Southerly WWTC and Mill Creek WWTP FBIs currently operate with a wet ash handling system to direct ash slurry to lagoons, use of a PAC injection system train would require the system to be installed downstream of the existing wet scrubber and after the SHE to minimize impact on current ash handling practices. As such, the existing SHE would be re-used to re-heat the exhaust gases above dew point temperatures before entering the fabric filter. The fabric filter bags are expected to form a PAC layer on the surface of each bag essential for gas-solid contact with the carbon for mercury adsorption. The PAC would need to be fed to the exhaust gases on a continuous basis to maintain this layer for proper mercury adsorption. Note that PAC injection is typically capable of achieving a mercury reduction of ~85%.

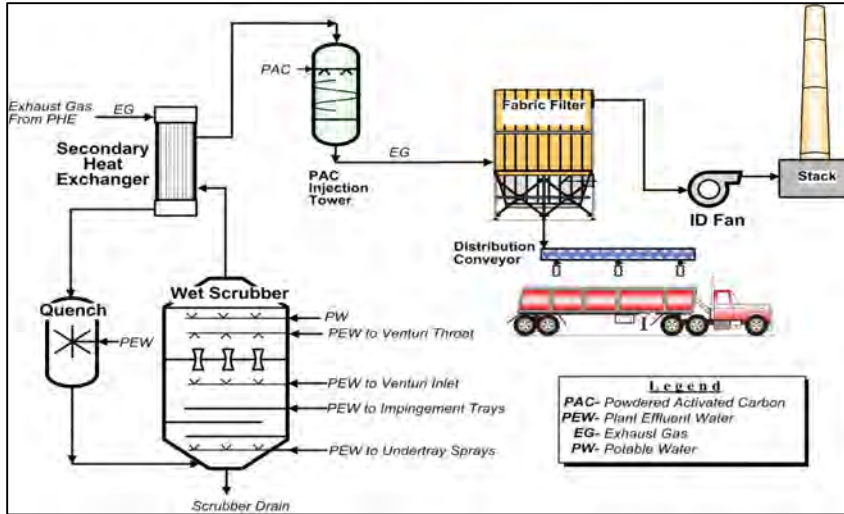


Figure 2. Typical PAC Injection System Schematic

Note that, in lieu of the dry ash load-out arrangement displayed on Figure 2, for FBIs which operate energy recovery facilities (and which are thus equipped with WHBs) it would theoretically be possible to direct ash collected from fabric filters to existing WHB ash slurry mix tanks. This would likely require modifications / partial re-design of existing ash slurry systems.

Given the notable considerations for PAC injection such as: 1) space requirements (each fabric filter is expected to have dimensions of approximately 45 ft. x 15 ft. x 50 ft. (L x W x H)); 2) typical applicability of a PAC injection system for SSIs operating dry ash systems; and 3) relative cost (including higher continuous power demand and chemical usage), this technology was not further considered by the project teams for Southerly WWTC and Mill Creek WWTP.

Fixed Bed GAC Media Filters

Figure 3 illustrates a summary process schematic for a typical fixed bed GAC media filter system. Typical systems are comprised of a demister and a multiple-celled, fixed-bed GAC media filter. The demister is intended to remove water droplets from the exhaust gases prior to entering the GAC media filter (scrubber). This droplet removal allows the mercury in the SSI exhaust gases to be effectively adsorbed to the GAC media. Once the adsorption capacity of the media is exhausted, it is removed and replaced. Each media filter is typically designed for one to two years of operation before media replacement is required. In addition, each scrubber system would be provided with a start-up skid including an electrical heater and blower (not shown on Figure 3) to warm-up the media filter prior to system start-up. Note that GAC media filter technology is typically capable of achieving mercury reduction greater than 95%.

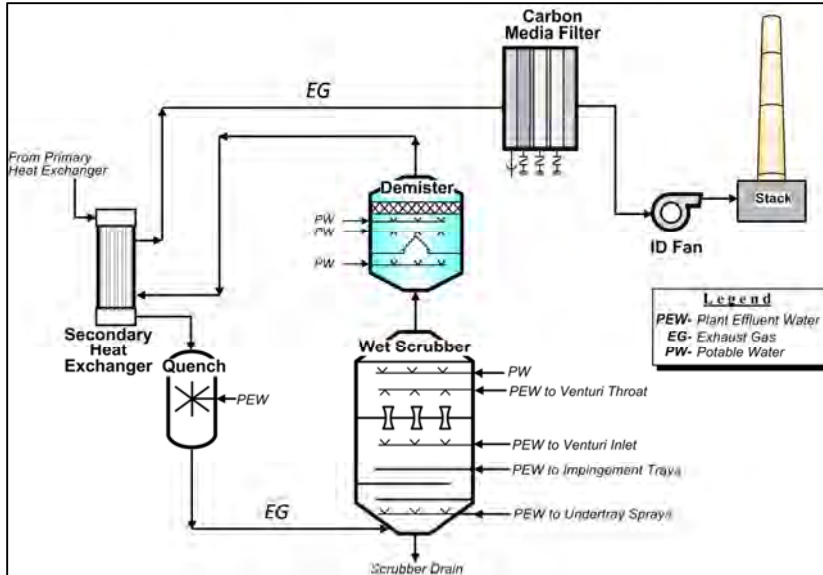


Figure 3. Typical GAC System Schematic

A benefit of the fixed bed GAC media technology is its ability to achieve superior mercury removal efficiencies when compared to other options discussed herein. A potential future change in regulations (requiring greater than 90% mercury removal) could be supported by the GAC system. As a result, GAC system manufacturers currently operating in the municipal SSI market (Carbon Process & Plant Engineering (CPPE) and Air Pollution Control Technologies, Inc. (APC)) are typically willing to provide performance guarantees designed to meet mercury limits for FBIs classified as “existing” and “new” per the SSI MACT rule

Downsides to the GAC media technology include space requirements (each tower is expected to have dimensions of approximately 12 ft. in diameter and up to 40 ft. high); these dimensions would likely require that such systems be installed in standalone building for existing installations). Another notable downside for this technology is its relative cost compared to other options, as discussed herein.

Sorbent Polymer Composite (SPC) Media Technology

Near to the beginning of evaluation efforts conducted by the project teams for Southerly WWTC and Mill Creek WWTP, an alternative to the PAC and GAC systems was identified. Previously unproven in the municipal SSI market, this alternative was a proprietary system offered by EnviroCare International (ECI) and W.L. Gore utilizing Sorbent Polymer Composite (SPC) media. At the onset of the evaluation efforts, this technology had undergone two pilot tests in SSI applications, and was being evaluated by a number of other utilities also operating SSIs.

The SPC media technology can be retrofitted as part of existing EnviroCare wet scrubbers or may be provided as a standalone unit. The system utilizes a proprietary media bed comprised of SPC media modules, which have the capability of capturing both the ionized and elemental forms of mercury from SSI exhaust gases. In contrast to GAC media scrubbers, the sorbent media modules are tolerant of water saturated gas streams and do not require a separate demister or a re-heating step upstream. It is important to note that the SPC’s mercury removal efficiency is a function of media bed depth provided with each installation, or the number of sequential

layers of SPC media modules provided. Similar to GAC media scrubbers, the sorbent media modules need to be replaced on an average bi-annual basis depending on inlet mercury loading and volume of the media bed. To measure performance of the sorbent bed over time, periodic media or gas grab samples are required; samples are analyzed to determine remaining life of the media bed.

Figure 4 illustrates a summary process schematic for an installation of the SPC media technology installed as a retrofit to an existing wet scrubber (with SPC media modules located downstream of the existing fixed venturi section).

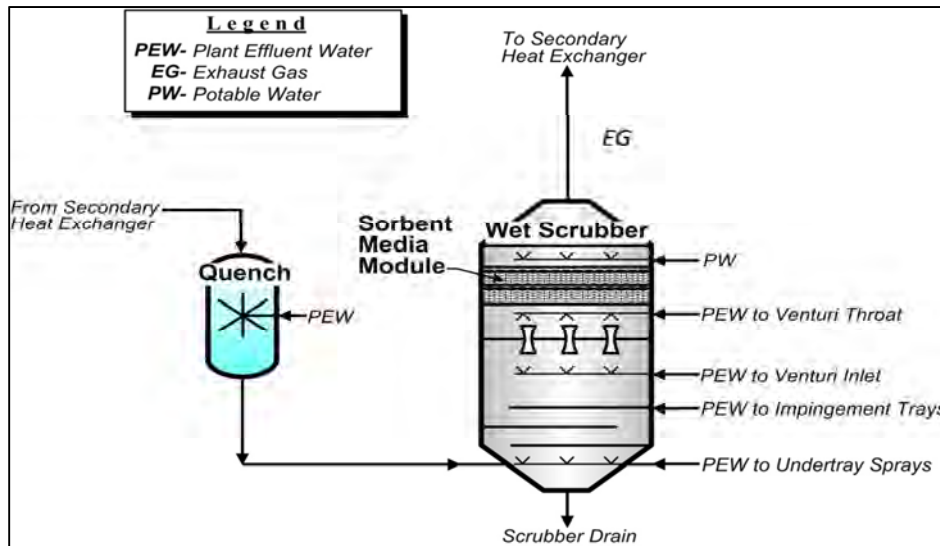


Figure 4. Typical SPC Integrated Into Wet Scrubber Schematic

An alternate approach to the integrated SPC media module arrangement (Figure 4) is to locate the SPC media modules within a standalone vessel downstream of the wet scrubber. This option allows for greater flexibility in terms of locating the system and designing for access requirements.

With the standalone configuration, the SPC media modules would be arranged within the standalone vessel in layers to prevent exhaust gas bypassing or “short circuiting,” and to allow each layer of modules to be sampled or removed from the vessel without disturbing or removing other layers. In addition, each vessel would be equipped with a demister (mist eliminator) section and appropriate spray lances downstream (above) the SPC media modules for intermittent wash-down.

SPC TECHNOLOGY EVALUATION AND TECHNOLOGY COMPARISON

While it was recognized that the SPC media technology would result in notably less equipment and modifications when compared to GAC and PAC systems, thus resulting in notably lower capital cost, it was also understood that the technology had not been proven in a full scale SSI application prior to the evaluation efforts described herein. As a result, a detailed evaluation was performed by the project teams for Southerly WWTC and Mill Creek WWTP to determine the applicability of the technology for FBIs at these facilities. Note that the evaluations conducted

for both facilities were similar in nature, and ultimately yielded similar conclusions. As a result, for the purposes of this discussion, only specific details associated with the NEORSD evaluation are provided.

In order to assess the level of compliance offered by the SPC technology in relation to Southerly WWTC's FBIs specifically, the project team conducted a review of the Self-Evaluation Engineering Study emissions testing results previously presented herein and of an extensive set of historical inlet biosolids mercury concentrations provided by NEORSD. This process resulted in an estimation of emissions compliance failure probability with the use of the SPC technology:

- 124 data points representing inlet-biosolids mercury concentrations (collected by NEORSD) were compiled. Of these, 23 were taken by NEORSD as background test data during test runs for each of the Self-Evaluation Engineering Studies for FBIs No. 1, No. 2, and No. 3 (refer to Tables 3 through 6).
- A comparison of the reported mercury emissions test results, biosolids feed rates, and stack discharge flow rates during each study, and of the inlet biosolids mercury concentrations provided by NEORSD during testing, was performed as a calibration for a mercury emissions model developed by the project team. It was determined that the existing Southerly WWTC ECI VenturiPak wet scrubbers are capable of capturing approximately 25% of the total mercury (i.e. the mercury is contained in the ash slurry effluent). As previously referenced, note that the wet scrubber efficiency in terms of mercury capture will vary depending on the form of mercury present in the exhaust gases, as only ionized forms can be effectively removed by water. Note also that mercury concentrations can vary seasonably and with the weather, or depending on the type and quantity of influent industrial discharge.
- Utilizing the calibrated mercury emissions model, the project team evaluated various mercury removal efficiencies across individual layers of SPC media modules to determine the total mercury removal efficiency required to ensure compliance with the SSI MACT rule.

SPC Compliance Analysis Results

Inlet biosolids mercury concentrations generated from the analysis of grab samples collected by NEORSD were compiled and sorted chronologically from January 2011 to June 2014 (latest data available during the evaluation). Note that this period begins after the point at which dental amalgam traps were required for dental facilities (starting in 2010), meaning that the mercury removal benefits resultant from this change are captured within the data set. Overall results are presented in Figure 5.

Note that the average inlet mercury concentration observed over the January 2011 to June 2014 period was ~0.57 mg Hg / kg biosolids, while the maximum was ~0.99 mg Hg / kg biosolids. Note also that the standard deviation of the data set was calculated as ~0.14 mg Hg / kg biosolids. This data indicates that Southerly WWTP FBI inlet mercury concentrations are highly variable and unpredictable, as is typical for municipal wastewater treatment facilities.

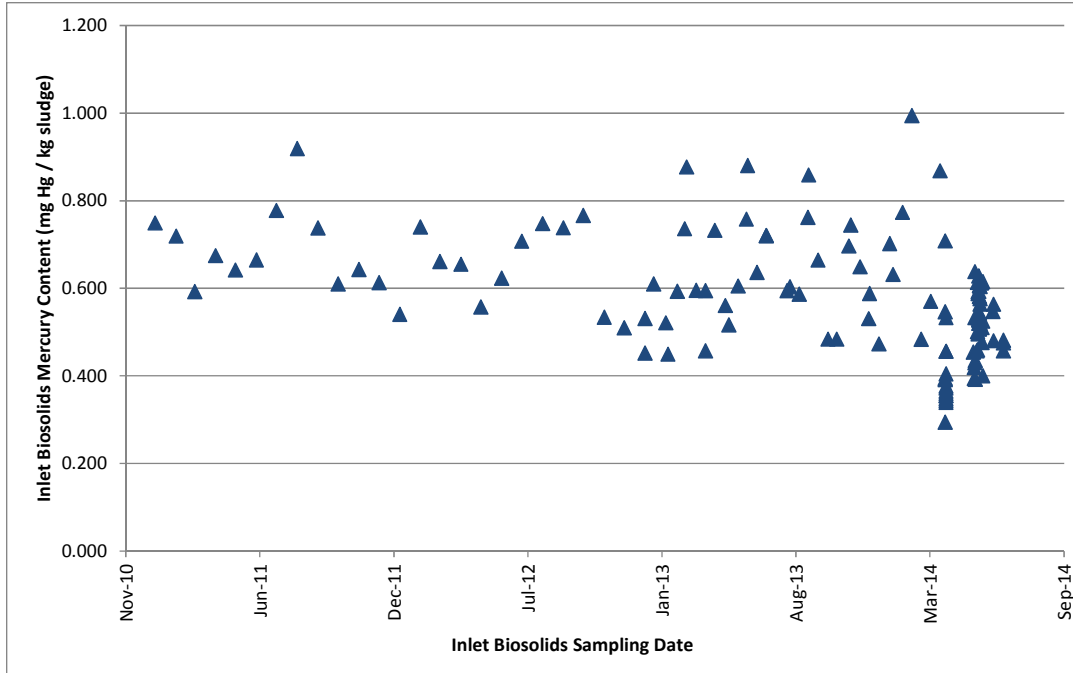


Figure 5. Inlet Biosolids Mercury Concentrations – January 2011 through June 2014

Utilizing the inlet biosolids mercury concentrations presented in Figure 5, in addition to the operations data collected by NEORSD during each of the Self-Evaluation Engineering Studies, a model calibration of predicted incinerator exhaust gas mercury concentrations (mg / dscm corrected to 7% O₂) was performed. This calibration, performed over 23 inlet-biosolids mercury concentrations taken during the studies, indicated that the existing Southerly WWTC ECI VenturiPak wet scrubbers are capable of capturing approximately 25% of the total mercury in the incinerator-exhaust-gas stream.

Assuming 25% total mercury reduction across the existing wet scrubbers, the calibrated model was then extended to the additional 101 inlet-biosolids mercury concentration data points provided to the project team by NEORSD. Assuming no additional mercury removal equipment is provided for Southerly WWTC’s FBIs, exhaust gas mercury concentrations downstream of the wet scrubbers were predicted for each historical inlet concentration. The results of this analysis are presented in Figure 6.

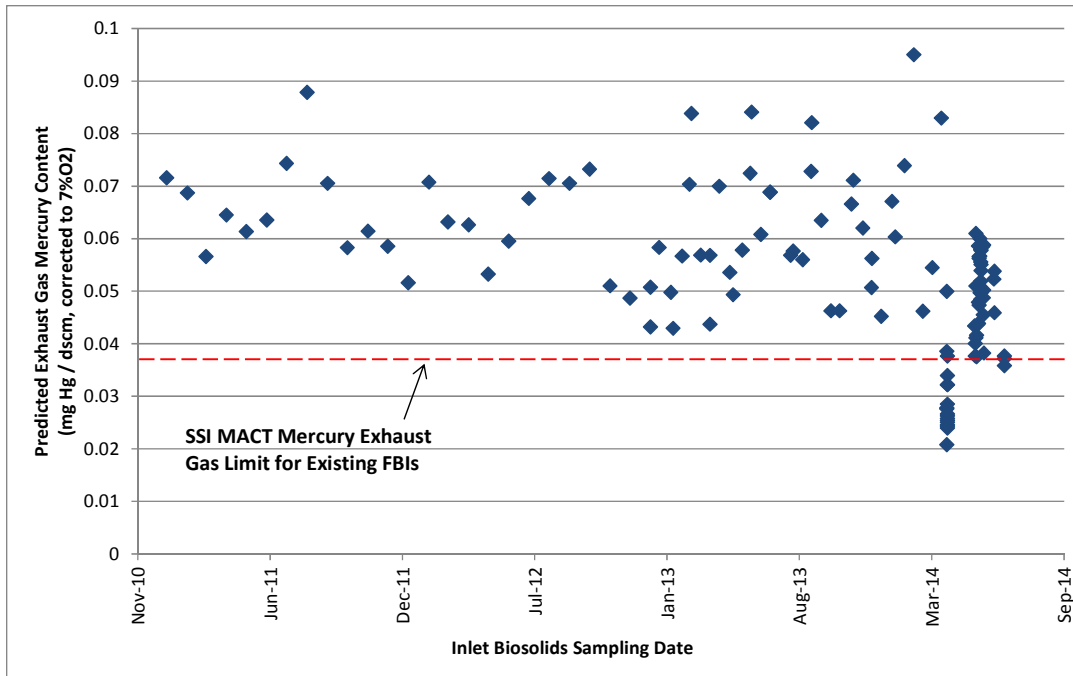


Figure 6. Estimated Mercury Exhaust Gas Content with Existing Emissions Controls

From Figures 5 and 6, note that the highest concentration of data collected over the January 2011 to June 2014 period was generated from late March 2014 to early June 2014. Also, note that inlet mercury loadings over this time were generally lower than those documented elsewhere within the historical data set. As a result, while the Self-Evaluation Engineering Study emissions test results documented exhaust gas mercury emissions below or only slightly higher than the applicable SSI MACT limit for existing FBIs, the mercury emissions model generally predicted higher mercury emissions values for the remaining data points. In short, this helped reinforce the need for enhanced mercury emissions controls at Southerly WWTC.

Based on discussions with the SPC technology provider (ECI) during the evaluation, a conservative assumption of guaranteed mercury removal efficiency across an individual layer of SPC media modules is approximately 25%. Note that the evaluation recognized that there was still some uncertainty regarding the effect of varying inlet mercury loadings on the removal efficiency achieved by the SPC media (i.e. whether higher or lower inlet mercury loadings increase or decrease removal efficiency) given that limited inlet versus outlet mercury emissions data is available. Of particular interest was the ability of the SPC media to handle inlet “spikes” in mercury loadings. However, for the purposes of the evaluation, the mercury emissions model assumes a 25% mercury-removal-efficiency guarantee across an individual layer of SPC media modules independent of inlet mercury loading. Using this approach, various predictive plots were generated assuming varying layers of SPC media modules and associated level of mercury removal. For a single layer of SPC media modules, approximately 65% of the data points were projected to be above the “existing” FBI MACT limit of 0.037 mg Hg / dscm exhaust gas (corrected to 7% O₂). For two layers of SPC media modules, approximately 20% of the data points were projected to be above the “existing” FBI MACT limit of 0.037 mg Hg / dscm

exhaust gas (corrected to 7% O₂). For three layers of SPC media modules, only two data points (~1.6%) were projected to be above the “existing” FBI MACT limit of 0.037 mg Hg / dscm exhaust gas (corrected to 7% O₂). Note, however, that a number of other data points were also close to this limit. Lastly, a plot was generated for four layers of SPC media modules. Under this scenario, as shown on Figure 7, no data points were projected to be above the existing FBI MACT limit of 0.037 mg Hg / dscm exhaust gas (corrected to 7% O₂).

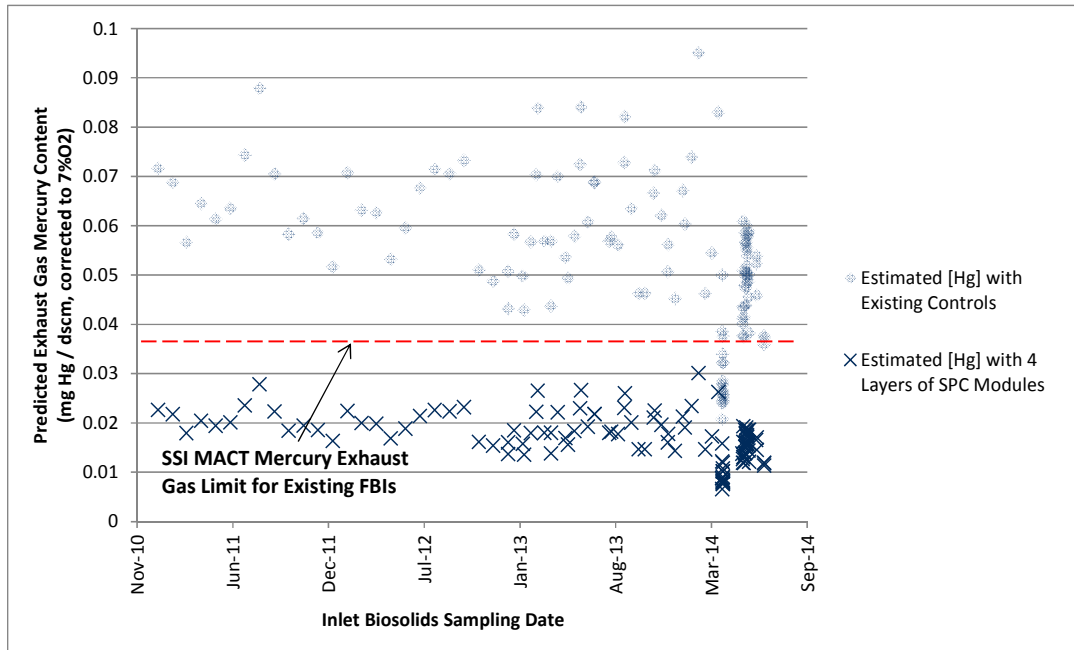


Figure 7. Estimated Mercury Exhaust Gas Content with Four SPC Media Layers

Considering the results of this evaluation, the project team concluded that the SPC media technology was a viable option for providing adequate control of mercury emissions in exhaust gas to meet the SSI MACT standard for existing FBIs at Southerly WWTC, as long as an appropriate number of layers of SPC media modules are provided and maintained. Note that a similar conclusion was generated for the FBIs at the Mill Creek WWTP.

Comparison of Mercury Removal Technologies

From the discussion above, two alternative mercury removal technologies (GAC media and SPC media) were identified as viable for providing the required enhanced mercury emissions controls to bring the Southerly WWTC FBIs and Mill Creek WWTP FBIs into compliance with the applicable SSI MACT standard for FBIs classified as “existing.” Table 11 provides a summary comparison of these two technologies.

Table 11. Summary Comparison of Applicable Mercury Removal Technologies

GAC MEDIA FILTERS	SPC MEDIA TECHNOLOGY
Mercury Removal Efficiency	
Expected mercury-removal efficiencies of 95% or higher.	Sufficient mercury-removal efficiency for ECI to guarantee emissions of less than <0.037 mg/dscm for typical Southerly WWTC and Mill Creek WWTP FBI inlet biosolids mercury loadings.
Regulatory	
<ul style="list-style-type: none"> ▪ Able to meet both “existing” and “new” SSI MACT mercury standards for FBIs. ▪ GAC system also capable of providing performance guarantees for PCDDs/PCDFs¹. 	<ul style="list-style-type: none"> ▪ Able to meet “existing” SSI MACT mercury standards for FBIs for typical inlet mercury loadings; GAC technology would need to be employed to meet “new” FBI MACT limits. ▪ Performance guarantees currently not provided for removal of PCDDs/PCDFs¹.
Equipment	
<ul style="list-style-type: none"> ▪ Equipment located downstream of wet scrubber. ▪ Mercury captured on carbon media. ▪ Requires exhaust gas conditioning upstream of fixed bed GAC media filter to remove large water droplets and re-heat the gases to temperature above gas dew point. Water droplet removal is achieved by a demister and re-heating through existing secondary heat exchanger. ▪ Requires upsized fluidizing air blowers or ID fans to accommodate additional pressure drop. ▪ Cannot be feasibly located within existing REF. 	<ul style="list-style-type: none"> ▪ Equipment integrated within existing wet scrubber or alternatively downstream of wet scrubber as a standalone vessel. ▪ No additional upstream gas conditioning is required. ▪ Downstream demister (mist eliminator) system required for periodic wash-down with standalone vessel configuration. ▪ Equipment can be located within existing REF.
Consumables	
GAC scrubbers would be sized for change out bi-annually with ~30 tons of media.	SPC media-module-life guarantees are for 18 months.
Cost	
<ul style="list-style-type: none"> ▪ ~\$11M total equipment cost to meet SSI MACT mercury and PCDD/PCDF standards for “new” FBIs (3 units, 1 per FBI)². ▪ <\$8M total equipment cost to meet SSI MACT mercury and PCDD/PCDF standards for “existing” FBIs (3 units, 1 per FBI)³. ▪ ~\$175K per GAC media bed replacement. 	<ul style="list-style-type: none"> ▪ ~\$1.5M equipment cost (3 units, 1 per FBI)⁴. ▪ ~\$10K replacement cost per SPC media module (9 modules per layer; ~\$90K total replacement cost per layer).

SPC Media Technology Recommendation

In total, both the GAC and SPC systems were found to be able to provide mercury removal efficiencies required to meet the SSI MACT limits for mercury emissions from FBIs classified as existing. Based on the information presented in Table 11 and summarized earlier in this document, it was ultimately recommended by the project teams for Southerly WWTC and Mill Creek WWTP that the SPC media technology be installed. The following presents additional information regarding this recommendation:

- **Reduced system complexity.** The GAC media technology system requires gas-conditioning steps, including upstream demister and exhaust gas reheat equipment, in addition to ancillary equipment, such as GAC media filter start-up heater skids. Furthermore, installation of new ID fans (in the case of Mill Creek WWTP) or upgrades to the existing ID fans (in the case of Southerly WWTC) were determined to be required to address additional pressure losses presented by the new system. In comparison, the SPC media technology only requires standalone SPC media module containment vessels located downstream of the existing wet scrubbers. This is due to low-pressure drop across each layer of SPC media modules (1/8 to 1/3 in. w.c.).
- **Reduced space requirements.** The SPC media technology can be housed entirely within the existing building space. Given the notably large footprints of the GAC system media filters, they cannot be feasibly installed within the existing building and would need to be housed within a new superstructure addition adjacent to the incinerator buildings for Southerly WWTC and Mill Creek WWTP.
- **Enhanced future mercury-removal efficiency.** While the SPC media technology does not provide mercury removal performance up to that provided by the GAC media technology (i.e. greater than 95% percent mercury removal, meeting existing and new SSI MACT requirements), the proposed layout allows for additional layers of SPC media to be installed to achieve greater mercury removal efficiency in the future. Note that with ECI's 2014 pilot at Asheville, NC, a five-layer arrangement of SPC media modules has resulted in greater than 90% mercury-removal efficiency. Based on these results, ECI preliminarily offered a 70% performance guarantee for mercury removal across a five-layer system.
- **Cost savings.** The SPC media technology appears to be about a quarter of the equipment cost required for the GAC media technology (not including installation, building modifications, new superstructure, ductwork, or ancillary equipment and controls).

RESULTS

SPC Media Technology Installation and Testing

Based on the information presented herein, and in considering the recommendation of the project teams, both NEORSD and MSDGC ultimately chose to install the SPC media technology for each of their respective three FBIs at Southerly WWTC and Mill Creek WWTP.

In-line with the findings of SPC technology evaluations conducted by the project teams, NEORSD chose to install a three layer standalone SPC media vessel for each FBI, with space to house an additional two layers of SPC media modules in the future, if required. MSDGC on the other hand chose to install a five-layer standalone SPC media vessel for each FBI, with space to house an additional two layers of modules. Note that MSDGC's decision to install an initial five layers of modules was based on elevated mercury loadings seen throughout the MSDGC service area, including at other wastewater treatment facilities, which may in the future direct dewatered sludge cake to Mill Creek WWTP for disposal.

Pictures of the final NEORSD and MSDGC SPC vessel installations are provided as Figure 8.



Figure 8. Typical SPC Vessel Installation (Southerly WWTC Left, Mill Creek WWTP Right)

Official Emissions Testing Results

Official SSI MACT rule air pollutant emissions compliance testing was conducted by both NEORS and MSDGC in late 2015 through early 2016. Final results for testing are provided in Table 12 for Southerly WWTC FBIs No. 1, 2, and 3, and in Table 13 for Mill Creek WWTP FBIs No. 1, 2, and 3, respectively. Note that each table presents the results as a representation of compliance achieved for each pollutant per the SSI MACT rule for existing FBIs, indicated as “Percent of Allowable.”

Table 12. Southerly WWTC FBI No. 1, 2, and 3 Official Compliance Testing – Dec 2015 through Feb 2016

Pollutant	Units	Allowable ^{2,3}	PERCENT (%) OF ALLOWABLE ^{1,3,5}		
			FBI No. 1	FBI No. 2	FBI No. 3
Particulate Matter (PM)	mg/dscm	18	6%	6%	5%
Hydrogen Chloride (HCl)	ppmvd	0.51	<5%	<35%	<18%
Carbon Monoxide (CO)	ppmvd	64	<2%	<4%	<2%
PCDD/PCDF, TEQ ⁴	ng/dscm	0.10	4%	5%	18%
PCDD/PCDF, TMB ⁴	ng/dscm	1.2	7%	<1%	<1%
Mercury (Hg)	mg/dscm	0.037	38%	8%	18%
Oxides of Nitrogen (NOx)	ppmvd	150	53%	68%	40%
Sulfur Dioxide (SO ₂)	ppmvd	15	<54%	<39%	<57%
Cadmium (Cd)	mg/dscm	0.0016	<11%	<16%	<19%
Lead (Pb)	mg/dscm	0.0074	4%	10%	4%

Pollutant	Units	Allowable ^{2,3}	PERCENT (%) OF ALLOWABLE ^{1,3,5}		
			FBI No. 1	FBI No. 2	FBI No. 3
¹ Results based on average of three test runs conducted for respective FBIs					
² SSI MACT rule air pollutant emissions limits for “existing” FBIs					
³ All test parameters tested to 7% O ₂					
⁴ Compliance with PCDD and PCDF limit for TEQ or TMB is required, not both					
⁵ “<” symbol indicates that the compound was not present in quantities above the Minimum Detection Limit (MDL) of the analytical method for at least one sample fraction					

Table 13. Mill Creek WWTP FBI No. 1, 2, and 3 Official Compliance Testing – Dec 2015 through Feb 2016

Pollutant	Units	Allowable ^{2,3}	PERCENT (%) OF ALLOWABLE ^{1,3,5}		
			FBI No. 1	FBI No. 2	FBI No. 3
Particulate Matter (PM)	mg/dscm	18	11%	7%	8%
Hydrogen Chloride (HCl)	ppmvd	0.51	<6%	<4%	<5%
Carbon Monoxide (CO)	ppmvd	64	4%	11%	<1%
PCDD/PCDF, TEQ ⁴	ng/dscm	0.10	2%	9%	4%
PCDD/PCDF, TMB ⁴	ng/dscm	1.2	2%	20%	7%
Mercury (Hg)	mg/dscm	0.037	3%	7%	33%
Oxides of Nitrogen (NO _x)	ppmvd	150	24%	27%	12%
Sulfur Dioxide (SO ₂)	ppmvd	15	<1%	1%	<1%
Cadmium (Cd)	mg/dscm	0.0016	<4%	<5%	<9%
Lead (Pb)	mg/dscm	0.0074	35%	23%	8%
¹ Results based on average of three test runs conducted for respective FBIs					
² SSI MACT rule air pollutant emissions limits for “existing” FBIs					
³ All test parameters tested to 7% O ₂					
⁴ Compliance with PCDD and PCDF limit for TEQ or TMB is required, not both					
⁵ “<” symbol indicates that the compound was not present in quantities above the Minimum Detection Limit (MDL) of the analytical method for at least one sample fraction					

Notable in the results presented within Tables 12 and 13 is that one incinerator each for Southerly WWTC and Mill Creek WWTP exhibited reduced mercury capture (i.e. Southerly WWTC FBI No. 1 and Mill Creek WWTP FBI No. 3) when compared to testing results for the other incinerators at each facility, respectively. Additional data collected by MSDGC during official compliance testing offers some explanation as to this variation as discussed following Table 15. In summary, MSDGC opted to perform additional testing for the concentration of mercury and sulfur dioxide within gasses inlet to each SPC vessel. The primary purpose for this testing was to ensure performance guarantees provided by the SPC technology provider were

met (i.e. evaluate air pollutant removal efficiencies across the SPC vessels). Sulfur dioxide was tested in addition to mercury given that pilot information provided by ECI indicated some level of sulfur dioxide removal across the SPC media modules.

Comparison of inlet versus outlet mercury and sulfur dioxide exhaust gas concentrations are provided in Table 14 for each of the Mill Creek WWTP FBIs.

Table 14. Mill Creek WWTP FBI SPC Vessel Performance Evaluation

Pollutant	Units	FBI No. 1 ^{1,2,3}			FBI No. 2 ^{1,2,3}			FBI No. 3 ^{1,2,3}		
		Inlet	Outlet	Percent (%) Removal	Inlet	Outlet	Percent (%) Removal	Inlet	Outlet	Percent (%) Removal
Mercury (Hg)	mg/dscm	0.0340	0.0009	97.4	0.0499	0.0027	94.6	0.0312	0.012	61.5
Sulfur Dioxide (SO ₂)	ppmvd	<0.91	<0.2	78.0	1.32	0.104	92.1	1.91	<0.1	>94.9

¹ Results based on average of three test runs conducted for respective FBIs
² All test parameters tested to 7% O₂
³ “<” symbol indicates that the compound was not present in quantities above the Minimum Detection Limit (MDL) of the analytical method for at least one sample fraction

As shown in Table 14, inlet mercury levels to the SPC vessels for each Mill Creek WWTP FBI were consistent, ranging from 0.0312 to 0.0499 mg/dscm (corrected to 7% O₂). However, while resultant mercury removal efficiencies across the SPC vessels for FBI No. 1 and No. 2 were also consistent, the mercury removal percentage across the SPC vessel for FBI No. 3 was much lower. This can at least in part be attributed to a “break in” period required by the SPC technology manufacturer for the SPC media. In summary, the manufacturer states that a month (or so) is required for the SPC media to settle in on a long-term removal efficiency. As a result, test results for Mill Creek WWTP FBIs No. 1 and No. 2, which were collected for systems that had been in operation for less than two weeks, demonstrate higher mercury-removal efficiencies within the SPC media “break in” period. On the other hand, test results for Mill Creek WWTP FBI No. 3, which were collected after the system had been online for over a month, demonstrate lower mercury-removal efficiencies after the “break in” period. Figure 9, provided by ECI, provides pilot data that indicate anticipated long-term mercury removal across the SPC media. Note that towards the beginning of the SPC media life cycle, removal efficiencies hover around 95%, while after the “break in” period, efficiencies drop to a somewhat consistent ~80% level.

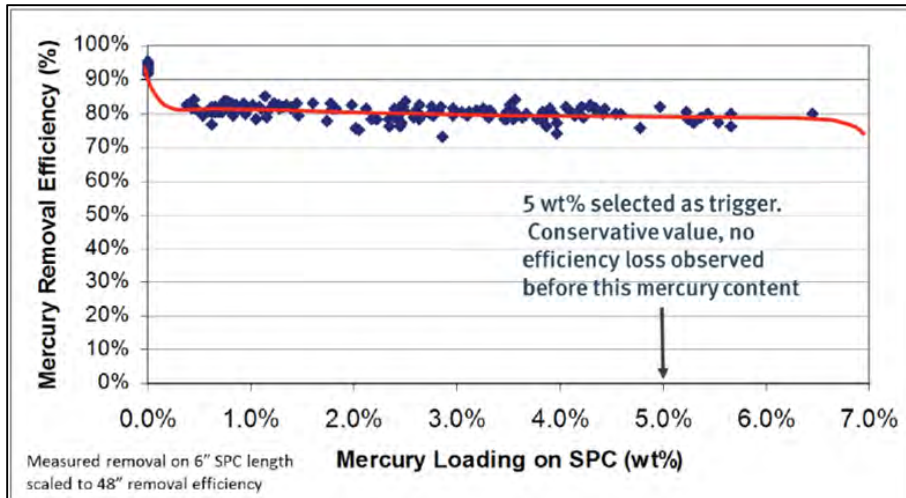


Figure 9. ECI Published Data for SPC Media Long Term Mercury Removal Efficiency

Sulfur Dioxide Removal

SPC vessel inlet versus outlet sulfur dioxide concentrations for each of the Mill Creek WWTP FBIs, as displayed on Table 14, point towards significant, but somewhat variable, sulfur dioxide removal across the SPC media. Based on discussions with ECI, this is due to the presence of a sulfur dioxide oxidation catalyst within the SPC media, which converts sulfur dioxide to sulfuric acid (H_2SO_4). In effect, the acid is collected on the surface of the SPC media, requiring periodic washdown of the SPC media. For installations at Southerly WWTC and Mill Creek WWTP, this was accomplished through use of an automatic spray wash-down system set to approximately 2 minutes of spray each hour.

It is anticipated that additional data for sulfur dioxide removal across the SPC vessels will be collected over time by ECI.

DISCUSSION

Long Term SPC Media Performance

As shown in Figure 9, ECI has conservatively recommended that individual SPC media modules be replaced after reaching a mercury concentration of approximately 5% by weight. Given that exhaust gas mercury loadings to the SPC vessel are not continuously monitored, it became apparent that periodic sampling and monitoring of the SPC media would be required in order to better determine proper media change-out frequency. This periodic monitoring was also required as part of Site Specific Monitoring Plans developed for Southerly WWTC and Mill Creek WWTP in conformance with the requirements of the SSI MACT rule.

Long-term SPC-media monitoring was thus structured in such a way as to allow sampling of SPC media modules on an approximate quarterly basis. This monitoring involves the following:

- Visual inspection of SPC vessel and media modules
- Rotation of SPC media modules per ECI's recommendation (to ensure equal mercury capture across modules)
- Location (physically within the SPC vessel) of each SPC media module and operational time of each system tracked
- Physical sample of SPC media to determine mercury concentration by weight

- Gas phase carbon trap (EPA Method 30B) samples taken to determine mercury removal across SPC media modules

Results of the most recent sampling/testing for Southerly WWTC and Mill Creek WWTP are provided in the following sections.

NEORSD Southerly WWTC

Table 15 provides pertinent information as to the operation of each Southerly WWTC FBI and respective SPC vessel since commissioning in 2015.

Table 15. Southerly WWTC SPC Vessel Operational Information

	FBI No. 1	FBI No. 2	FBI No. 3
SPC Vessel Installation Date	12/03/15	11/16/15	12/31/15
Startup Date	12/20/15	11/20/15	1/7/16
Dry Tons of Sludge Fired	14,901.3	7,868.4	8,497.5
Hour of Operation	5,293.6	3,000.5	2,819.9
Average Feed Rate (ton/hour)	2.81	2.62	3.01

As shown on Table 15, FBI No. 1 has been in operation for the longest of the three Southerly WWTC FBIs since commissioning of the SPC vessels in early 2016. As a result, it would be anticipated that the SPC media contained within this incinerator’s SPC vessel would exhibit the highest levels of mercury concentration by weight. This is correlated via the information presented in Table 16 below.

Summary results for ECI’s inspection and sampling of the Southerly WWTC SPC vessels, which occurred October 18-19, 2016, are provided below. Physical media sampling was not conducted for the SPC vessel for FBI No. 2 due to that incinerator being in-service during the inspection period.

Each of the Southerly WWTC SPC vessels was initially installed with three layers of SPC media modules. The first layer (“Layer 1”) within each SPC media module is the layer through which inlet gasses pass first, and is located at the bottom of each SPC vessel. Table 16 indicates the remaining mercury adsorption capacity of each layer of SPC media modules, as determined by ECI during the October 18-19, 2016 sampling.

Each module was assumed capable of adsorbing up to 1.5 pounds prior (5% by weight) before requiring replacement. Through physical sampling of the SPC media and performance of testing to determine mercury content, remaining mercury adsorption capacity was determined.

Table 16. Southerly WWTC SPC Vessel Remaining SPC Media Mercury Adsorption Capacity

	FBI No. 1	FBI No. 2	FBI No. 3
Layer 1 Remaining Capacity	90%	Not Tested	92%
Layer 2 Remaining Capacity	93%	Not Tested	95%
Layer 3 Remaining Capacity	95%	Not Tested	95%

Based on the findings presented in Table 16, which represent ~10 months of operation for each of the Southerly WWTC SPC vessels, ECI has indicated that the SPC media modules appear to be operating as expected in terms of mercury capture. ECI has indicated that an estimate of

remaining life of the SPC media modules will be made following the next quarterly sampling/testing event.

Unfortunately, during the October 18-19, 2016 sampling by ECI, it was discovered by ECI that EPA Method 30B (carbon trap sampling) to determine mercury removal across each layer of SPC media modules will not be effective for the SPC vessels at Southerly WWTC. This is due to a high negative pressure across the SPC vessels, which are installed immediately upstream of induced draft (ID) fans in the incinerator process train. As a result, the carbon contained within the standard Method 30B sample tubes was disrupted in most of the traps, and in some cases, the carbon was completely evacuated from the tube into the SPC vessel. For this reason, no data is currently available for mercury removal across each layer of SPC media modules for the October sampling event. ECI has indicated that modifications to the sampling methodology will be made, and sampling performed in coordination with NEORSD in the near term. Data will be appended to this document as it becomes available.

Mill Creek WWTP

Table 17 provides pertinent information as to the operation of each Mill Creek WWTP FBI and respective SPC vessel since commissioning in 2015.

Table 17. Mill Creek WWTP SPC Vessel Operational Information

	FBI No. 1	FBI No. 2	FBI No. 3
SPC Vessel Installation Date	02/23/16	01/19/16	12/22/15
Startup Date	On Standby	01/29/16	12/26/15
Dry Tons of Sludge Fired	0	7,524	8,510
Hour of Operation	0	3,473	4,207
Average Feed Rate (ton/hour)	0	2.17	2.02

As shown on Table 17, FBIs No. 2 and No. 3 has been in near continuous operation since commissioning of the SPC vessels in early 2016, while FBI No. 1 has been in standby for the same period. As a result, it would be anticipated that the SPC media contained within these incinerator’s associated SPC vessels would exhibit similar mercury concentrations. This is correlated via the information presented in Table 19 below.

Summary results for ECI’s inspection and sampling of the Mill Creek WWTP SPC vessels, which occurred July 26 through 28, 2016, are provided below. Physical media sampling was not conducted for the SPC vessel for FBI No. 1 due to that incinerator not having been in operation since commissioning in early 2016.

Each of the Mill Creek WWTP SPC vessels was initially installed with five layers of SPC media modules. The first layer (“Layer 1”) within each SPC media module is the layer through which inlet gasses pass first, and is located at the bottom of each SPC vessel. Table 18 indicates the remaining mercury adsorption capacity of each layer of SPC media modules, as determined by ECI during the July 26 through 28, 2016 sampling.

Similarly to the approach for Southerly WWTC, each module was assumed capable of adsorbing up to 1.5 pounds prior (5% by weight) before requiring replacement. Through physical sampling

of the SPC media and performance of testing to determine mercury content, remaining mercury adsorption capacity was determined.

Table 18. Mill Creek WWTP SPC Vessel Remaining SPC Media Mercury Adsorption Capacity

	FBI No. 1	FBI No. 2	FBI No. 3
Layer 1 Remaining Capacity	100%	96%	99%
Layer 2 Remaining Capacity	100%	98%	98%
Layer 3 Remaining Capacity	100%	98%	99%
Layer 4 Remaining Capacity	100%	99%	99%
Layer 5 Remaining Capacity	100%	99%	99%

Based on the findings presented in Table 18, which represent ~6-7 months of operation for the SPC vessels for Mill Creek WWTP FBIs No. 2 and No. 3, ECI has indicated that the SPC media modules appear to be operating as expected in terms of mercury capture. ECI has indicated that an estimate as to the remaining life of the SPC media modules will be made following the next quarterly sampling/testing event.

In addition to the physical media sampling performed for each of the Mill Creek WWTP SPC vessels, ECI was able to perform EPA Method 30B sampling upstream and downstream of each layer of SPC media modules for Mill Creek WWTP FBIs No. 2 and No. 3. Results for this sampling are provided upon Figure 10, provided by ECI to MSDGC, below.

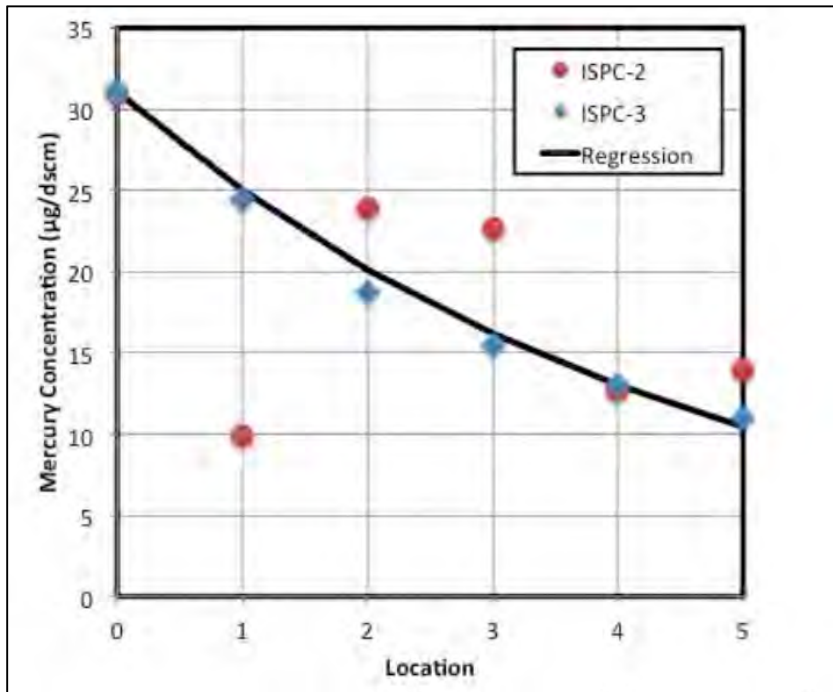


Figure 10. SPC Media Module Inlet/Outlet Mercury Concentrations

Per information provided by ECI, the solid black line shown on Figure 10 represents the anticipated mercury removal efficiency across five layers of SPC media modules, and generally depicts a 20% mercury reduction across each layer of modules with a total mercury mass reduction of 66% across all five layers.

From Figure 10, it is clear that the EPA Method 30B sampling for FBI No. 3's SPC vessel revealed mercury reduction across each layer of SPC media modules along the expected trend, with a total mercury reduction observed at approximately 65%. In reviewing data from official emissions compliance tests presented previously herein, note that Mill Creek FBI No. 3 previously tested at approximately 61% mercury removal across the SPC vessel. The findings of the subsequent EPA Method 30B sampling appear to confirm that, following the break-in period for the SPC media, approximately 60-70% mercury removal can be expected across five layers of SPC media modules.

While sampling for SPC vessel for FBI No. 3 aligned well with anticipated results, data for FBI No. 2's SPC vessel did not appear to correlate very well at all. Based on discussions with ECI, it is unclear why this is. Another iteration of EPA Method 30B is planned in the short term to further evaluate this. Data will be appended to this document as it becomes available.

CONCLUSION

The new SPC vessels at the Southerly WWTC and Mill Creek WWTP have now been in operation for about a year. The information presented herein has demonstrated that the decision by NEORSD and MSDGC to install this technology has, to-date, been a good one in terms of achieving compliance with the SSI MACT rule requirements. In addition, in comparison to the GAC technology, it is anticipated that the chosen approach resulted in at least \$15M - \$20M in capital savings for both NEORSD and MSDGC.

Since completion of the SPC vessel installations at Southerly WWTC and Mill Creek WWTP, several other facilities have installed the technology. Installations include facilities in New York, North Carolina, Virginia, and Washington State. In addition, a number of other utilities are currently in evaluation stages to determine the applicability of the technology for their MHI or FBI systems.

Long-term monitoring of the SPC technology's performance will be critical in determining the long-term effectiveness, longevity of SPC media modules and associated change out frequency, and any unforeseen operational issues that could arise over time. For now, all information appears to point toward a technology that is capable of providing the required SSI exhaust-gas mercury-removal efficiencies required to comply with the SSI MACT rule for FBIs classified as "existing" and MHIs classified as "existing" or "new."

REFERENCES

"New Mercury and SO₂ Control Technology by EnviroCare and W.L. Gore." Envirocare International | Engineered Solutions for Pollution Control. EnviroCare International, n.d. Web. 12 Jan. 2017.