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PARTICULATE REMOVAL EVALUATION OF AN ELECTROSTATIC PRECIPITATOR DUST REMOVAL SYSTEM INSTALLED ON A MULTIPLE HEARTH INCINERATOR BURNING SEWAGE SLUDGE

Final report

4-6

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TABLE 2-8. TOTAL PARTICULATE MASS CONCENTRATIONS AND MASS EMISSION RATES

		g/dscm (as measured)	g/dscm (12% O_2)	lb/hr	(lb/lb dry sludge) x 10^4
ESP	Inlet				
	Run 1	0.50	0.75	0.20	3.44
	Run 2	0.67	0.93	0.27	5.04
	Run 3	0.61	0.79	0.28	5.25
	Average	0.59	0.82	0.25	4.58
	Outlet				
	Run 1	0.017	0.11	0.017	0.29
	Run 2	0.015	0.10	0.018	0.34
	Run 3	0.0058	0.012	0.0044	0.083
	Average	0.013	0.0.74	0.013	0.24
Scrubber	Inlet				
	Run 1	0.50	0.75	7.48	128.74
	Run 2	0.67	0.93	8.59	160.26
	Run 3	0.61	0.79	10.24	192.12
	Average	0.59	0.82	8.77	160.37
	Outlet				
	Run 1	0.0042	0.013	0.12	2.07
	Run 2	0.0044	0.014	0.13	2.43
	Run 3	0.0084	0.019	0.25	4.69
	Average	0.0057	0.015	0.17	3.06

TABLE 2-13. UNCONTROLLED TRACE METAL EMISSIONS FROM THE INCINERATOR (g/dscm, as measured)

	INCINERATOR OUTLET				
	RUN 1	RUN 2	RUN 3	MEAN	SD
SULFUR	3.20E-01	4.13E-01	8.91E-01	5.41E-01	3.06E-01
CALCIUM	3.83E-02	7.55E-02	4.44E-02	5.27E-02	1.99E-02
IRON	4.50E-02	5.94E-02	4.59E-02	5.01E-02	8.03E-03
PHOSPHOROUS	2.92E-02	4.74E-02	3.70E-02	3.79E-02	9.15E-03
ALUMINUM	2.02E-02	4.15E-02	3.50E-02	3.22E-02	1.09E-02
MAGNESIUM	1.15E-02	2.16E-02	1.54E-02	1.62E-02	5.07E-03
ZINC	3.84E-03	6.27E-03	5.52E-03	5.21E-03	1.25E-03
SODIUM	3.63E-03	6.11E-03	5.42E-03	5.05E-03	1.28E-03
TITANIUM	3.57E-03	5.67E-03	4.93E-03	4.72E-03	1.07E-03
COPPER	2.72E-03	4.45E-03	3.74E-03	3.63E-03	8.70E-04
CADMIUM	1.28E-03	2.20E-03	2.01E-03	1.83E-03	4.87E-04
LEAD	1.10E-03	1.77E-03	2.39E-03	1.76E-03	6.45E-04
BARIUM	1.50E-03	1.84E-03	1.92E-03	1.75E-03	2.19E-04
TIN	4.60E-04	6.53E-04	9.10E-04	6.75E-04	2.26E-04
CHROMIUM	6.77E-04	6.14E-04	5.20E-04	6.04E-04	7.90E-05
ARSENIC	4.95E-04	7.11E-04	4.08E-04	5.38E-04	1.56E-04
MANGANESE	3.51E-04	4.42E-04	3.09E-04	3.67E-04	6.79E-05
NICKEL	1.96E-04	2.12E-04	1.87E-04	1.98E-04	1.28E-05
VANADIUM	1.39E-04	2.22E-04	1.70E-04	1.77E-04	4.22E-05
ANTIMONY	8.51E-05	1.41E-04	9.10E-05	1.06E-04	3.08E-05
SILVER	2.59E-05	5.89E-05	5.19E-05	4.56E-05	1.74E-05
COBALT	2.85E-05	4.59E-05	3.60E-05	3.68E-05	8.72E-06
SELENIUM	0.00E+00	4.69E-07	8.77E-07	4.49E-07	4.39E-07
GOLD	2.11E-07	3.68E-07	4.05E-07	3.28E-07	1.03E-07

TABLE 2-16. CONTROLLED TRACE METAL EMISSIONS FROM THE ESP
(g/dscm, as measured)

	ESP OUTLET				
	RUN 1	RUN 2	RUN 3	MEAN	SD
SULFUR	3.55E-02	8.03E-02	2.93E-01	1.36E-01	1.37E-01
CALCIUM	5.42E-03	5.59E-03	5.24E-03	5.42E-03	1.74E-04
ALUMINUM	1.98E-03	2.31E-03	2.30E-03	2.19E-03	1.88E-04
IRON	8.11E-04	1.56E-04	1.38E-04	3.68E-04	3.84E-04
MAGNESIUM	1.76E-04	8.11E-05	1.60E-04	1.39E-04	5.10E-05
BARIUM	1.08E-04	1.32E-04	1.03E-04	1.14E-04	1.54E-05
PHOSPHOROUS	1.23E-04	8.35E-05	1.17E-04	1.08E-04	2.13E-05
NICKEL	4.13E-05	3.69E-05	6.83E-06	2.83E-05	1.88E-05
LEAD	2.98E-05	2.31E-05	2.31E-05	2.54E-05	3.89E-06
CHROMIUM	4.58E-05	7.27E-06	1.19E-05	2.16E-05	2.10E-05
ARSENIC	1.11E-05	3.39E-05	7.16E-06	1.74E-05	1.45E-05
TITANIUM	1.39E-05	8.59E-06	2.01E-05	1.42E-05	5.77E-06
SELENIUM	3.34E-05	1.61E-06	1.85E-06	1.23E-05	1.83E-05
SODIUM	5.84E-06	1.98E-06	2.11E-05	9.65E-06	1.01E-05
ZINC	1.00E-05	3.23E-06	4.61E-06	5.96E-06	3.60E-06
COBALT	1.00E-05	4.88E-06	1.95E-06	5.61E-06	4.07E-06
MANGANESE	1.26E-05	8.50E-07	4.54E-07	4.64E-06	6.91E-06
TIN	9.50E-07	6.73E-07	9.50E-06	3.71E-06	5.02E-06
COPPER	3.01E-06	1.07E-06	5.99E-06	3.36E-06	2.48E-06
VANADIUM	5.17E-06	2.72E-06	5.32E-07	2.81E-06	2.32E-06
CADMIUM	5.65E-06	1.34E-06	5.89E-07	2.53E-06	2.73E-06
ANTIMONY	8.99E-07	4.01E-07	3.43E-07	5.48E-07	3.06E-07
SILVER	8.33E-08	0.00E+00	2.53E-07	1.12E-07	1.29E-07
GOLD	0.00E+00	0.00E+00	1.09E-07	3.62E-08	6.27E-08

TABLE 2-1. MEAN INCINERATOR OPERATING PARAMETERS DURING ESP TESTS

Parameter	Run 1	Run 2	Run 3	Average
Sludge Feed Rate (lb/hr)				
Wet Cake	3,750	3,460	3,460	3,557
Dry Cake	581	536	533	550
Residue at 600°C	180	172	171	174
Sludge Composition (wt. %)				
Moisture	84.5	84.5	84.6	84.5
Volatile Matter	69.0	68.0	68.0	68.3
Dry Solids	15.5	15.5	15.4	15.5
Percent O_2[a] (Dry Vol. %)	15.1	14.5	14.0	14.5
Auxiliary Fuels				
Fuel Gas (cu ft/hr)	5,060	3,900	3,400	4,120
Fuel Oil (gal/hr)	11.0	16.0	14.0	13.7

[a]Mean excess oxygen in incinerator emissions.

Table 2-2. ICAP Analyses of the Sludge Feed Samples

	METALS CONTENT OF SLUDGE FEED PPM				
METAL	RUN 1	RUN 2	RUN 3	AVERAGE	REL STD
ALUMINUM	3.01E+04	3.93E+04	4.94E+04	3.96E+04	24.43
ANTIMONY	1.50E+02	1.35E+02	7.51E+01	1.20E+02	33.10
ARSENIC	7.04E+02	6.85E+02	7.98E+02	7.29E+02	8.32
BARIUM	2.62E+03	2.33E+03	2.37E+03	2.44E+03	6.30
CADMIUM	2.88E+02	2.14E+02	1.95E+02	2.33E+02	21.18
CALCIUM	5.20E+04	6.59E+04	7.89E+04	6.56E+04	20.47
CHROMIUM	7.41E+02	7.28E+02	8.61E+02	7.77E+02	9.41
COBALT	6.25E+01	5.54E+01	5.47E+01	5.76E+01	7.51
COPPER	5.25E+03	5.07E+03	5.67E+03	5.33E+03	5.79
GOLD	0.00E+00	9.81E-01	0.00E+00	3.27E-01	173.21
IRON	5.52E+04	5.86E+04	6.70E+04	6.03E+04	10.10
LEAD	9.40E+02	1.02E+03	1.01E+03	9.92E+02	4.61
MAGNESIUM	2.23E+04	2.46E+04	2.40E+04	2.37E+04	5.03
MANGANESE	4.01E+02	4.39E+02	4.90E+02	4.43E+02	10.02
NICKEL	3.27E+02	2.44E+02	1.95E+03	8.40E+02	114.38
PHOSPHOROUS	5.53E+04	5.42E+04	5.14E+04	5.36E+04	3.77
SELENIUM	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00
SILVER	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00
SODIUM	7.57E+03	7.68E+03	8.30E+03	7.85E+03	5.05
SULFUR	1.86E+04	2.06E+04	1.94E+04	1.95E+04	5.24
TIN	4.67E+02	4.18E+02	4.39E+02	4.41E+02	5.60
TITANIUM	7.12E+03	6.43E+03	7.66E+03	7.07E+03	8.73
VANADIUM	1.95E+02	2.06E+02	2.35E+02	2.12E+02	9.90
ZINC	6.57E+03	7.44E+03	7.64E+03	7.22E+03	7.94
TOTAL:	2.67E+05	2.96E+05	3.28E+05	2.97E+05	10.26

Relative standard deviation = $\frac{\text{std. dev.}}{\text{mean}} \times 100$

TABLE 2-5. FLUE GAS FLOW RATES

Location	dscmm	acmm
Incinerator Outlet[a]		
Run 1	116.17	309.74
Run 2	100.10	259.34
Run 3	130.58	317.85
Average	115.62	295.64
Scrubber Inlet[a]		
Run 1	113.22	301.87
Run 2	97.05	251.43
Run 3	127.08	309.33
Average	112.45	287.54
Scrubber Outlet[b]		
Run 1	223.43	256.93
Run 2	231.08	267.60
Run 3	222.63	263.61
Average	225.71	262.71
Slipstream to ESP		
Run 1	2.95	7.86
Run 2	3.05	7.91
Run 3	3.49	8.51
Average	3.17	8.09
ESP Outlet		
Run 1	7.70	10.61
Run 2	8.92	12.50
Run 3	5.70	8.38
Average	7.44	10.50
Scrubber Outlet/Incinerator Outlet		
Run 1	1.92	.83
Run 2	2.31	1.03
Run 3	1.70	.83
Average	1.98	.90
Slipstream to ESP/Incinerator Outlet		
Run 1	.025	.025
Run 2	.031	.031
Run 3	.027	.027
Average	.028	.028

[a]Calculated from scrubber outlet flow measurements and oxygen balance across scrubbers.
[b]Includes shaft cooling air.

TABLE 2-21. CONTROLLED TRACE METALS EMISSIONS FROM THE SCRUBBER (g/dscm, as measured)

	SCRUBBER OUTLET				
	RUN 1	RUN 2	RUN 3	MEAN	SD
CALCIUM	3.01E-03	2.97E-03	2.04E-02	8.81E-03	1.01E-02
ALUMINUM	3.03E-03	2.19E-03	1.25E-02	5.90E-03	5.70E-03
SULFUR	4.02E-03	5.85E-03	1.20E-03	3.69E-03	2.34E-03
IRON	9.15E-04	2.86E-03	1.27E-04	1.30E-03	1.40E-03
SODIUM	3.68E-04	5.86E-04	6.10E-06	3.20E-04	2.93E-04
ZINC	2.87E-04	3.91E-04	8.58E-05	2.55E-04	1.55E-04
COPPER	1.76E-04	3.09E-04	1.11E-04	1.99E-04	1.01E-04
LEAD	5.32E-05	3.48E-04	1.55E-04	1.85E-04	1.50E-04
PHOSPHOROUS	2.61E-04	6.06E-05	2.26E-04	1.83E-04	1.07E-04
CHROMIUM	9.84E-05	4.42E-04	5.54E-07	1.80E-04	2.32E-04
TIN	2.06E-04	2.49E-04	5.09E-05	1.69E-04	1.04E-04
CADMIUM	1.28E-04	1.99E-04	1.01E-04	1.43E-04	5.05E-05
BARIUM	9.19E-05	7.20E-05	2.05E-04	1.23E-04	7.16E-05
MAGNESIUM	9.97E-05	1.21E-04	1.14E-04	1.11E-04	1.06E-05
SELENIUM	2.53E-07	2.78E-04	9.91E-07	9.32E-05	1.60E-04
TITANIUM	1.72E-04	5.99E-05	3.02E-05	8.74E-05	7.48E-05
NICKEL	5.03E-06	2.08E-04	3.02E-07	7.11E-05	1.19E-04
MANGANESE	1.39E-05	5.11E-05	4.93E-11	2.17E-05	2.64E-05
ARSENIC	1.52E-05	1.01E-05	2.35E-05	1.63E-05	6.76E-06
VANADIUM	3.39E-06	1.97E-05	3.52E-06	8.86E-06	9.37E-06
ANTIMONY	2.87E-06	2.65E-06	5.93E-06	3.82E-06	1.83E-06
SILVER	1.34E-06	1.07E-06	2.86E-06	1.76E-06	9.67E-07
COBALT	8.04E-07	2.44E-06	1.57E-07	1.13E-06	1.18E-06
GOLD	0.00E+00	6.33E-08	0.00E+00	2.11E-08	3.66E-08