

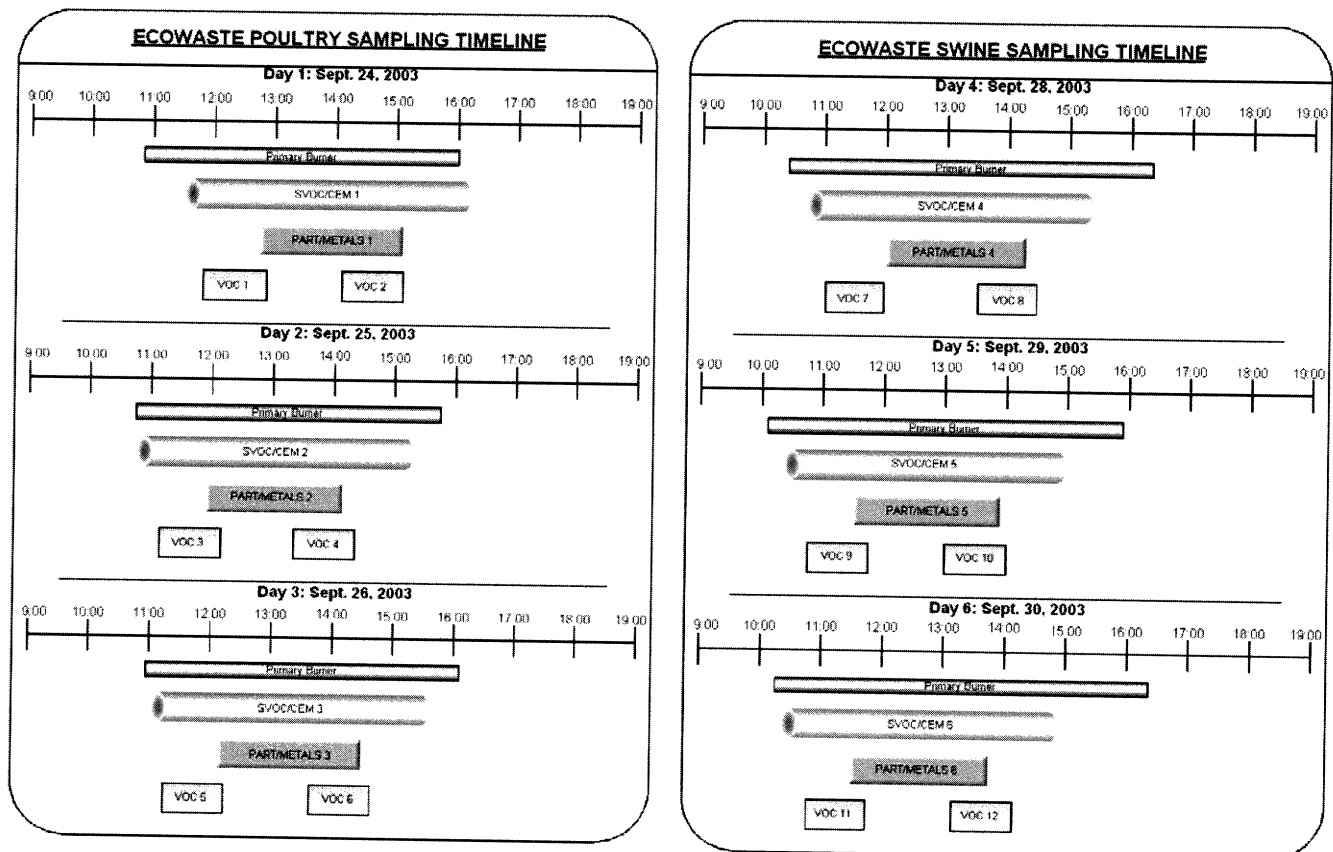
## 6. RESULTS

### 6.1. General Sampling Data

The general sampling data for the test program is presented in Table 1. This table includes the average velocity, sample volume and volumetric flow rate (dry basis, referenced to 25°C and 101.3 kPa), average stack temperature and average moisture. Average oxygen and carbon dioxide levels were determined from the flue gas samples by the procedure described in Section 3.5. The traverse data for each run and summaries are presented in Appendix I.

Eco Waste Solutions supplied an operator to oversee the incineration of the poultry and swine. The cremator is controlled by software but the operator did make some adjustments during the trials. These included frequent manual adjustments of the primary air damper and occasional changes in the primary and secondary temperature set points. The secondary temperature though was not adjusted as often as the primary. Once the secondary chamber reached temperature, the charge was loaded in the unit and the primary burner ignited. Sampling commenced once the primary reached temperature. The time between ignition of the primary and start of sampling varied from 14 to 60 minutes. Following the poultry testing, the cremator was charged with a swine load to condition the unit prior to the emission sampling. The sampling schedule is shown on Figure 7.

**Figure 7 Eco Waste Sampling Schedule**



**Table 1 Summary of General Stack Sampling Data**

Test Conditions	POULTRY			SWINE		
	EW-P1	EW-P2	EW-P3	EW-S1	EW-S2	EW-S3
<b>Crematorium Conditions</b>						
Feed (kg)	185.1	210.9	200.5	239.0	190.5	214.6
Fuel Burned (L)*	134.2	106.2	125.3	145.8	82.1	55.8
Primary Temperature	760°C to 871°C					
Secondary Temperature	On at 996°C			Off at 1038°C		
Ash Produced (kg)	6.4	6.8	5.2	6.1	5.4	6.1
Time Primary Burner On	10:52	10:45	10:55	10:20	10:07	10:15
<b>Run Conditions (SVOC/Particulate/Acid Gases/Metals)</b>						
Date (September, 2003)	24	25	26	28	29	30
Sampling Time (local)	11:41 – 16:03 12:45 – 15:05	10:55 – 15:11 11:56 – 14:11	11:10 – 15:28 12:12 – 14:28	10:50 – 15:16 12:01 – 14:16	10:31 - 14:49 11:33 - 13:50	10:29 – 14:47 11:29 – 13:47
Test Duration (min)	240 120	240 120	240 120	240 120	240 120	240 120
Isokineticity (%)	99.14 98.06	100.34 101.39	99.26 99.06	98.28 97.34	98.12 96.62	99.73 97.32
Sample Volume (m <sup>3</sup> )	4.230 2.078	4.551 2.126	4.270 2.212	3.955 2.059	4.229 2.094	4.116 2.075
<b>Stack Gas Characteristics (SVOC/Particulate/Acid Gases/Metals)</b>						
Flow Rate (m <sup>3</sup> /min)	15.2 15.0	16.1 14.9	15.3 15.9	14.3 15.0	15.3 15.4	14.7 15.2
Actual Average Velocity (m/s)	5.91 5.87	6.39 5.92	6.06 6.41	5.63 6.07	5.93 6.17	5.76 6.06
Temperature (°C)	892 910	892 895	901 927	882 913	873 919	874 910
Moisture (%)	10.14 8.98	11.38 11.11	11.17 10.64	11.28 11.24	10.71 10.29	11.50 11.40
Oxygen (%)	10.91 10.62	10.01 10.14	9.94 10.13	9.93 10.05	10.18 10.47	9.77 10.27
Carbon Dioxide (%)	7.85 8.08	8.56 8.50	8.60 8.45	8.46 8.40	8.53 8.34	8.88 8.52
Molecular Weight (lb/lb-mole)	29.69 29.72	29.77 29.77	29.77 29.76	29.75 29.75	29.77 29.75	29.81 29.77

All volumes are expressed on a dry basis referenced to 25°C and 101.325 kPa.

\* Sunoco Diesel Fuel 2, 0-0.4 % sulphur

## 6.2 Particulate, Acid Gases and Metals

The concentrations of particulate, acid gases and metals are shown in Table 2. All values in Table 2 are corrected to 11% oxygen. Note that the correction for oxygen is in the order of  $\pm 10\%$  as average oxygen levels were close to 11 percent. Analytical reports are given in Appendix II.

Particulate concentrations corrected to 11% oxygen were reasonably constant for both feed types. Concentrations ranged from 17 to 25  $\text{mg}/\text{m}^3$  for the poultry and between 14 and 18  $\text{mg}/\text{m}^3$  for the swine. The average concentration for the swine was about 5  $\text{mg}/\text{m}^3$  less than the poultry.

Levels for HF and HCl were also consistent. HF levels varied from 0.29 to 0.49 ppm and 0.11 to 0.16 ppm for the poultry and swine respectively. On average, HF levels for the swine were about one-third of the poultry. HCL levels were between 24 and 34 ppm for the poultry and varied from 24 to 33 ppm for the swine with both feed materials showing the same triplicate average. These results are corrected to 11% oxygen.

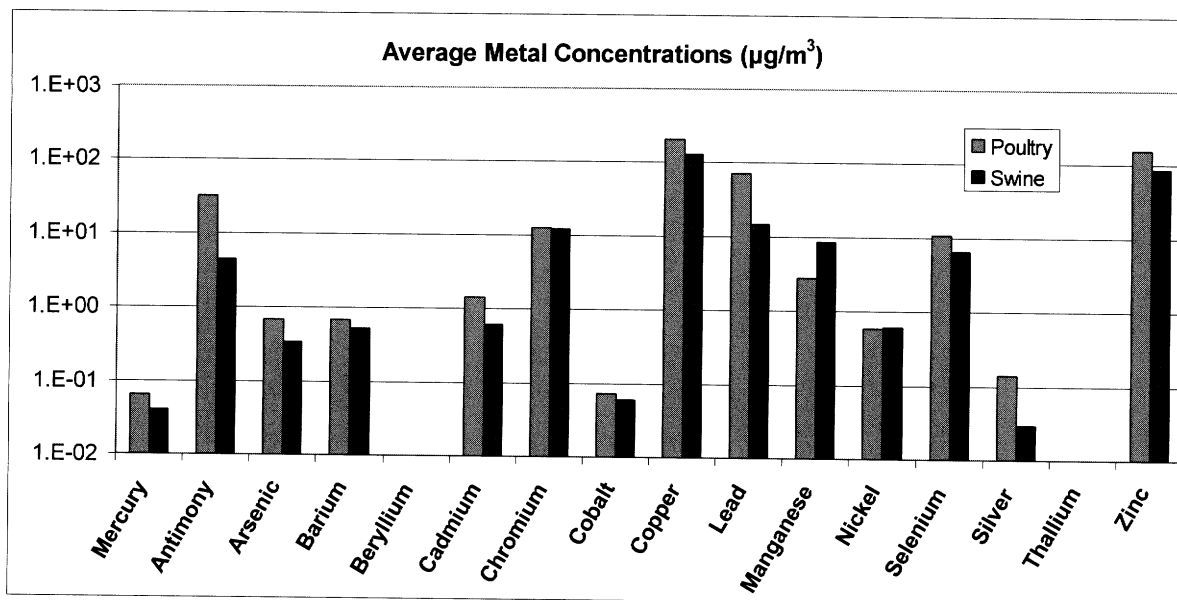
The front- and back-half fractions were combined for metals analysis. All metal concentrations in Table 2 are corrected to 11% oxygen. Two metals, beryllium and thallium were not detected in the train samples. Silver was not measured in two of the three swine tests. Mercury was detected in all runs and was less than 0.10  $\mu\text{g}/\text{m}^3$  for both feeds. Individual metal levels were consistent among the triplicates with the exception of antimony in the poultry runs and manganese in the swine. In general, metal concentrations were higher for the poultry feed. Disregarding the manganese value in the second run of the swine tests, three metals found in stainless steel, chromium, manganese and nickel displayed similar levels between both types of feed.

The average metal concentrations for the two feeds are illustrated in Figure 8. Values are plotted on a logarithmic y-axis. In descending order, copper, zinc and lead represented the most abundant of the reported metals. Copper levels for the poultry and swine and zinc concentrations in the poultry testing displayed values above 100  $\mu\text{g}/\text{m}^3$ . Three metals, antimony, chromium and lead showed levels above 10  $\mu\text{g}/\text{m}^3$  while cadmium, manganese and selenium straddled the range between 1 to 10  $\mu\text{g}/\text{m}^3$ . The remainder of the metals were below 1  $\mu\text{g}/\text{m}^3$ .

**Table 2 Summary of Particulate, Acid Gases and Metals Concentrations  
(corrected to 11% oxygen)**

Pollutant		Poultry				Swine			
		PAGM-1	PAGM -2	PAGM -3	Average	PAGM-1	PAGM -2	PAGM -3	Average
Particulate (mg/m <sup>3</sup> )		17.24	25.36	19.12	20.57	17.95	14.10	13.69	15.24
HF	(mg/m <sup>3</sup> )	0.40	0.32	0.23	0.32	0.13	0.10	0.09	0.11
	(ppm)	0.49	0.39	0.29	0.39	0.16	0.12	0.11	0.13
HCl	(mg/m <sup>3</sup> )	38.7	51.2	35.4	41.7	49.7	35.4	39.9	41.7
	(ppm)	25.9	34.3	23.7	28.0	33.4	23.7	26.8	28.0
<b>Metals (µg/m<sup>3</sup>)</b>									
Mercury		0.08	0.06	0.05	0.06	0.03	0.04	0.05	0.04
Antimony		7.88	41.11	45.71	31.57	4.87	3.90	4.49	4.42
Arsenic		0.64	0.73	0.66	0.67	0.34	0.30	0.39	0.35
Barium		0.97	0.74	0.33	0.68	0.44	0.32	0.81	0.52
Beryllium		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cadmium		1.30	1.64	1.41	1.45	1.11	0.29	0.44	0.62
Chromium		16.08	11.99	9.85	12.64	12.72	12.10	11.98	12.27
Cobalt		0.09	0.07	0.06	0.07	0.08	0.05	0.04	0.06
Copper		216.61	232.57	156.83	202.01	167.82	108.20	111.62	129.21
Lead		46.13	82.02	87.07	71.74	17.91	12.42	13.20	14.51
Manganese		3.24	2.64	2.33	2.74	2.44	20.58	2.15	8.39
Nickel		0.95	0.35	0.46	0.58	0.75	0.50	0.58	0.61
Selenium		11.68	12.42	8.60	10.90	7.13	5.48	6.78	6.47
Silver		0.13	0.15	0.13	0.14	0.09	0.00	0.00	0.03
Thallium		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Zinc		152.47	198.64	124.25	158.46	124.44	63.82	76.66	88.31

Values are expressed on a dry basis referenced to 25°C and 101.325 kPa.  
"0" denotes not detected.



**Figure 8 Average Metal Concentrations**

### 6.3 Flue Gases

The concentrations of oxygen, carbon dioxide, carbon monoxide, nitrogen oxides and sulphur dioxide are summarized in Table 3. Carbon monoxide, nitrogen oxides and sulphur dioxide are reported at 11% oxygen. The values for each run in Table 3 represent the arithmetic average of the 30 minute integrated bag samples collected during the SVOC and particulate/acid gases/metals sampling. Detailed data for all the runs is given in Appendix I.

Carbon dioxide and oxygen exhibited the same trend during each run. Oxygen levels increased towards the end of the burn while a corresponding decrease was noted for the carbon dioxide concentrations. Carbon monoxide levels were extremely low for both feed materials. The highest single CO concentration was 4 ppm for all runs with both feeds. NO and NO<sub>2</sub> concentrations were the highest at the beginning of the burn but stabilizing thereafter. The NO<sub>2</sub> fraction was the same for both feeds (15% of total NO<sub>x</sub>). SO<sub>2</sub> was detected in both feeds for each of the triplicates exhibiting a declining trend from the start of the burn to the end of sampling with consistently higher levels measured during the incineration of poultry. The same fuel was used for both feed materials.

**Table 3 Summary of Flue Gas Concentrations  
(CO, NO, NO<sub>2</sub>, NO<sub>x</sub> and SO<sub>2</sub> corrected to 11% oxygen)**

Run	O <sub>2</sub> (%)	CO <sub>2</sub> (%)	CO (ppm)	NO (ppm)	NO <sub>2</sub> (ppm)	NO <sub>x</sub> (ppm)	SO <sub>2</sub> (ppm)
<b>POULTRY</b>							
<b>EW-P1</b>	10.91	7.85	0.4	62.1	10.0	72.2	59.7
<b>EW-P2</b>	10.01	8.56	0.8	64.7	9.1	73.8	52.9
<b>EW-P3</b>	9.94	8.60	0.4	71.2	16.2	87.5	59.5
<b>Ave*</b>	10.29	8.34	0.5	66.0	11.8	77.8	57.3
<b>Std Dev*</b>	1.35	1.09	1.0	13.0	6.6	19.1	31.2
<b>SWINE</b>							
<b>EW-S1</b>	9.93	8.46	0.7	69.0	14.3	83.3	24.8
<b>EW-S2</b>	10.18	8.53	1.1	62.5	9.0	71.5	32.4
<b>EW-S3</b>	9.77	8.88	1.5	70.0	12.8	82.8	32.3
<b>Ave*</b>	9.96	8.62	1.1	67.1	12.0	79.2	29.9
<b>Std Dev*</b>	1.43	1.14	1.1	16.7	6.2	22.6	15.6

\* All data points for three runs

#### 6.4 Dioxins, Furans and Co-planar PCBs

PCDD/PCDF data is reported on the basis of the seventeen 2,3,7,8-substituted dioxin and furan congeners. This data is further transformed by multiplying each of the 17 congeners by their respective toxicity equivalency factor (International-TEF or I-TEF). The factors range from 1.0 for 2,3,7,8- TCDD to 0.001 for OCDD and OCDF. The sum of all the 17 factored compounds is known as the TEQ. More recently, analysis has included 12 co-planar PCB compounds. These congeners, which have dioxin-like properties have been assigned a toxicity equivalent factor (TEF) by the World Health Organization (WHO98-TEQ). In this study, only the I-TEQ emission results will be presented however, a separate table will be presented showing the levels of the co-planar PCBs without a toxicity equivalent correction. This has been done to avoid confusion between the two sets of toxicity equivalents. Analytical results of the loaded trains, field blank train, proofing and method blank samples are presented in Appendix II.

The emission summaries for the TEQ dioxins and furans are given in Table 4. The front- and back-half components of the SVOC train which correspond to the particulate and gaseous fractions respectively in the sample gas were combined for analysis. Train catches were corrected for the blank train. The blank train was around 1.1 and 0.4 pg I-TEQ/m<sup>3</sup> for the poultry and swine conditions respectively.

The levels of the 17 congeners are shown in Figure 9. In all runs, the furan TEQ outweighed the dioxins. Using triplicate averages, the 10 furan compounds represented 75 and 85% of the total train TEQ for the poultry and swine respectively. The 2,3,7,8-T4CDD congener was detected in only one of the six runs. The 2,3,4,7,8-P5CDF congener was the largest TEQ component representing 40 and 35% of the total for the poultry and swine triplicate averages respectively. Apart from the observations noted above, it was difficult to extract any other patterns of the 17 congeners as many of the congeners were not detected in both series of runs.

The average concentration between the poultry and swine series was identical however, a large variability was noted in each set of triplicates. TEQ concentrations at this site were very low. Concentrations are corrected to 11% oxygen.

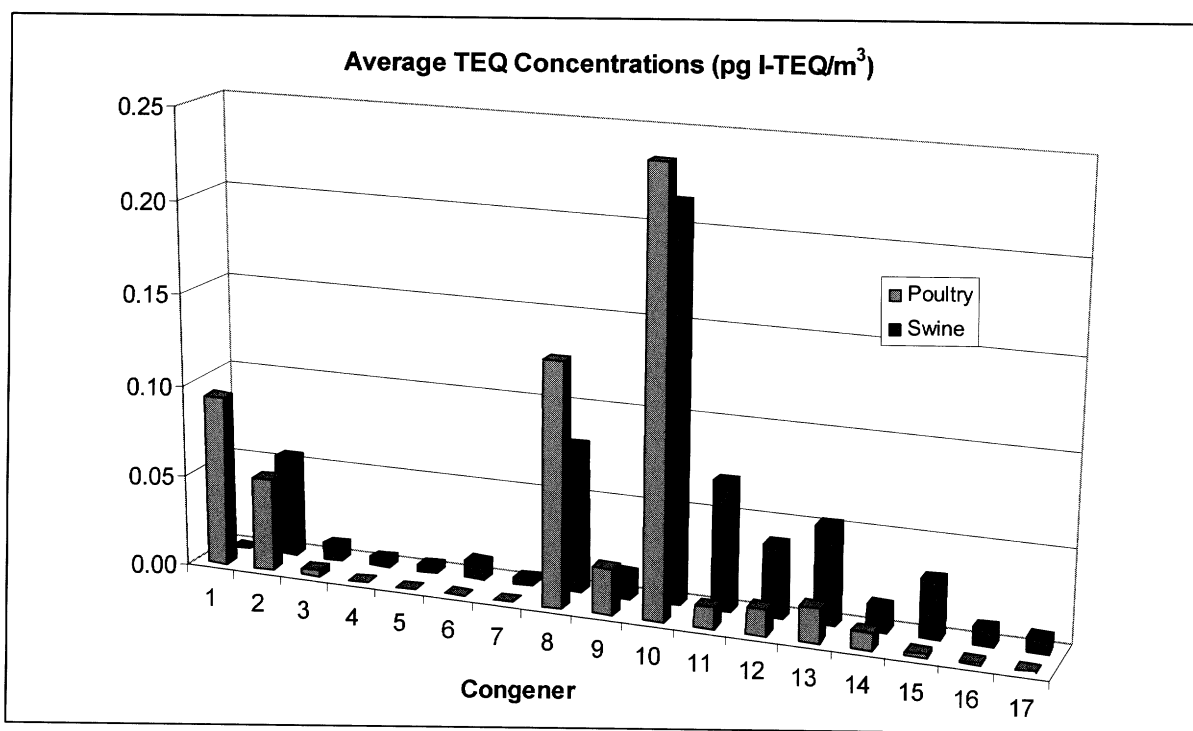


Figure 9 Average I-TEQ Concentrations

The concentrations of the 12 co-planar PCB congeners are given in Table 5. As noted earlier, the concentration values are **not corrected** for the toxicity equivalent. Train catches were corrected for the blank trains for each feed which were 200 and 160 pg/m<sup>3</sup>. Except for the PCB-81 congener, all the congeners were detected in the train samples before blank correction. Neglecting PCB-81, any not detected (ND) values reported in Table 5 are a result of the blank correction.

**Table 4 Concentrations of Dioxins and Furans  
(pg I-TEQ/m<sup>3</sup> @11% oxygen)**

Compound	POULTRY				SWINE			
	SVOC 1	SVOC 2	SVOC 3	Average	SVOC 1	SVOC 2	SVOC 3	Average
2378-T4CDD	0.000	0.280	0.000	0.093	0.000	0.000	0.000	0.000
12378-P5CDD	0.000	0.110	0.042	0.051	0.057	0.011	0.097	0.055
123478-H6CDD	0.000	0.010	0.000	0.003	0.026	0.000	0.000	0.009
123678-H6CDD	0.000	0.000	0.000	0.000	0.014	0.000	0.000	0.005
123789-H6CDD	0.000	0.000	0.000	0.000	0.011	0.000	0.000	0.004
1234678-H7CDD	0.000	0.000	0.000	0.000	0.024	0.002	0.002	0.009
OCDD	0.000	0.000	0.000	0.000	0.009	0.001	0.001	0.004
2378-T4CDF	0.005	0.395	0.000	0.133	0.184	0.026	0.030	0.080
12378-P5CDF	0.000	0.075	0.000	0.025	0.026	0.000	0.014	0.013
23478-P5CDF	0.000	0.719	0.000	0.240	0.525	0.000	0.119	0.215
123478-H6CDF	0.000	0.035	0.000	0.012	0.180	0.007	0.024	0.070
123678-H6CDF	0.000	0.043	0.000	0.014	0.105	0.013	0.000	0.039
234678-H6CDF	0.000	0.056	0.000	0.019	0.144	0.000	0.015	0.053
123789-H6CDF	0.000	0.028	0.000	0.009	0.022	0.000	0.019	0.014
1234678-H7CDF	0.000	0.007	0.000	0.002	0.085	0.009	0.001	0.031
1234789-H7CDF	0.004	0.000	0.000	0.001	0.029	0.000	0.000	0.010
OCDF	0.001	0.000	0.000	0.000	0.024	0.000	0.001	0.008
<b>Total</b>	0.009	1.757	0.042	0.603	1.462	0.068	0.324	0.618

Values are expressed on a dry basis referenced to 25° C and 101.325 kPa.

"0" denotes not detected.

Totals may not add due to rounding.

The PCB-118 congener was the largest component accounting for 60 to 63% for the poultry runs and 51 to 56% of the total for the swine. The next abundant congeners were PCB-105 and PCB-77. These three compounds accounted for 88 to 91% of the total for all six runs. Based on single run and triplicate averages, the co-planar PCB levels were higher for the swine than poultry.

**Table 5 Concentrations of Co-planar PCBs**  
**(pg/m<sup>3</sup> @11% oxygen)**  
**(Toxic Equivalent Factor not applied)**

Compound / (IUPAC Number)	WHO98 TEF	POULTRY				SWINE			
		SVOC 1	SVOC2	SVOC 3	Average	SVOC 1	SVOC2	SVOC 3	Average
Non-ortho Polychlorinated Biphenyls (PCBs)									
3,3',4,4'-tetraCB (77)	0.0001	10.75	6.75	7.36	8.29	9.38	11.53	9.88	10.26
3,4,4',5-tetraCB (81)	0.0001	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3,3',4,4'5-pentaCB (126)	0.1	0.00	0.00	0.00	0.00	0.48	0.39	0.39	0.42
3,3',4,4',5,5'-hexaCB (169)	0.01	0.16	0.04	0.00	0.07	0.00	0.02	0.00	0.01
Mono-ortho Polychlorinated Biphenyls (PCBs)									
2,3,3',4,4'-pentaCB (105)	0.0001	16.94	10.05	10.85	12.61	21.04	23.78	29.07	24.63
2,3,4,4',5-pentaCB (114)	0.0005	3.02	1.94	1.82	2.26	0.62	2.16	2.18	1.65
2,3',4,4',5-pentaCB (118)	0.0001	58.03	39.05	39.75	45.61	41.00	59.70	62.54	54.42
2',3,4,4',5-pentaCB (123)	0.0001	6.63	3.42	3.89	4.65	3.92	4.89	6.38	5.06
2,3,3',4,4',5-hexaCB (156)	0.0005	0.00	0.00	0.00	0.00	2.21	1.94	2.87	2.34
2,3,3',4,4',5'-hexaCB (157)	0.0005	0.54	0.46	0.21	0.40	0.41	0.00	0.93	0.45
2,3',4,4',5,5'-hexaCB (167)	0.00001	0.00	0.00	0.00	0.00	0.89	1.18	1.36	1.14
2,3,3',4,4',5,5'-heptaCB (189)	0.0001	0.00	0.00	0.00	0.00	0.09	0.33	0.17	0.20
Total		96.08	61.70	63.89	73.89	80.05	105.93	115.77	100.58

Values are expressed on a dry basis referenced to 25° C and 101.325 kPa.

"0" denotes not detected.

Totals may not add due to rounding.

IUPCA-International Union of Pure and Applied Chemistry

## 6.5 Chlorobenzenes and Pentachlorophenol

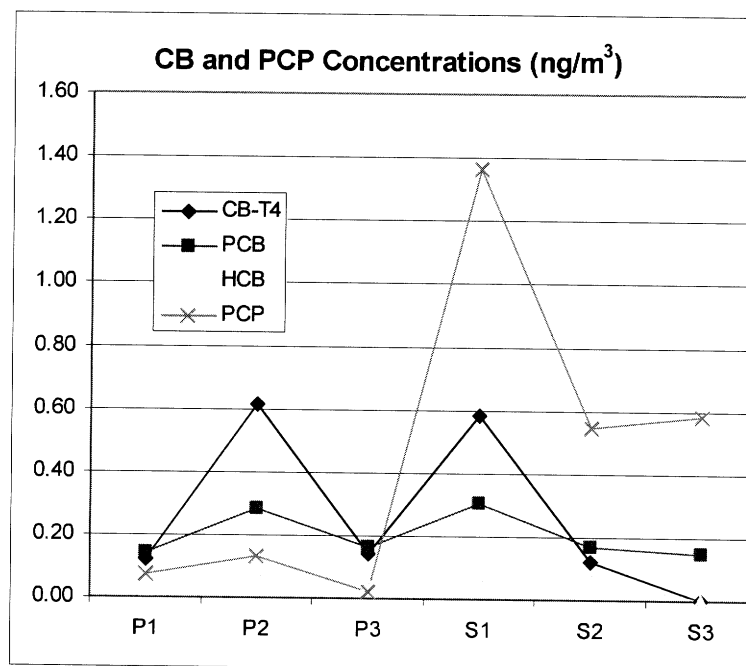
The analysis of the SVOC train samples also included chlorobenzenes (CBs) and pentachlorophenol (PCP). Chlorobenzene compounds included 1,2,3,5-tetrachlorobenzene, 1,2,4,5-tetrachlorobenzene, 1,2,3,4-tetrachlorobenzene, pentachlorobenzene and hexachlorobenzene. The reported train catches were corrected for the blank train levels. Blank train levels for hexachlorobenzene for both poultry and swine and for PCP in the poultry runs were relatively high. Concentrations for the five selected chlorobenzenes and pentachlorophenol (PCP) are summarized in Table 6 and illustrated in Figure 10. Analytical results of the loaded trains, blank train, proofing and control samples are presented in Appendix II.

Both train fractions were combined for the analysis of the selected chlorobenzenes. The tetrachlorobenzenes represented the largest component of the reported chlorobenzenes. Total CBs ranged between 0.15 and 0.97 ng/m<sup>3</sup>. Hexachlorobenzene concentrations were considerably lower due to the relatively high blank train correction. Total average CB concentrations between the poultry and swine conditions are similar however a large variability was noted among the single runs. Triplicate variability is due to the very low levels detected in the train samples. The PCP average was significantly higher for the swine test series. Chlorobenzene and pentachlorophenol concentrations are not corrected to 11% oxygen.

**Table 6 Concentrations of Chlorobenzenes and Pentachlorophenol (ng/m<sup>3</sup>)**

Compound	POULTRY				SWINE			
	SVOC 1	SVOC 2	SVOC 3	Average	SVOC 1	SVOC 2	SVOC 3	Average
1,2,3,5-Tetrachlorobenzene	0.000	0.220	0.000	0.073	0.253	0.000	0.000	0.084
1,2,4,5-Tetrachlorobenzene	0.000	0.176	0.000	0.059	0.177	0.000	0.000	0.059
1,2,3,4-Tetrachlorobenzene	0.118	0.220	0.141	0.159	0.152	0.118	0.000	0.090
Pentachlorobenzene	0.142	0.286	0.164	0.197	0.303	0.166	0.146	0.205
Hexachlorobenzene	0.024	0.066	0.047	0.045	0.076	0.071	0.000	0.049
<b>Total selected CBs</b>	<b>0.284</b>	<b>0.967</b>	<b>0.351</b>	<b>0.534</b>	<b>0.961</b>	<b>0.355</b>	<b>0.146</b>	<b>0.487</b>
Pentachlorophenol	0.071	0.132	0.023	0.075	1.365	0.544	0.583	0.831

Values are expressed on a dry basis referenced to 25° C and 101.325 kPa.  
 "0" denotes not detected.



**Figure 10 Chlorobenzene and Pentachlorophenol Concentrations**

## 6.6 Polycyclic Aromatic Hydrocarbons (PAHs)

PAH concentrations are summarized in Table 7. As mentioned previously, the front- and back-halves of the sampling train were combined for analysis. Train catches were corrected for the PAHs detected in the blank train. Most of the lighter fractions of the PAHs were found in the blank trains however the total found in the blank train was insignificant. PAH analytical results of the loaded trains, blank train, proofing and control samples are presented in Appendix II.

Retene, a compound associated with wood combustion and indeno(1,2,3-cd)fluoranthene were added to the PAH list. Naphthalene was analyzed but not reported in the emissions. Eleven of the compounds were not detected in any of the runs for both test conditions. Fluorene, phenanthrene, anthracene, fluoranthene, pyrene and retene were the most abundant compounds. On average, these six compounds represented 86 and 84% of the total PAHs for the poultry and swine conditions respectively. Some trace amounts of PAHs heavier than retene were detected in either one or both test conditions but these amounts were insignificant. The totals for all runs ranged from 16 to 31 ng/m<sup>3</sup> (average 22 and 24 ng/m<sup>3</sup> for poultry and swine respectively). These concentrations are not corrected to 11% oxygen. On a total average basis, little difference was apparent between the two feeds. A plot of the detected PAHs above 1 ng/m<sup>3</sup> is shown in Figure 11.

**Table 7 Concentrations of PAHs (ng/m<sup>3</sup>)**

Compound	POULTRY				SWINE			
	SVOC 1	SVOC 2	SVOC 3	Average	SVOC 1	SVOC 2	SVOC 3	Average
Acenaphthylene	0.21	0.15	0.16	0.18	0.86	0.17	0.00	0.34
Acenaphthene	0.00	0.00	0.19	0.06	1.95	0.59	0.39	0.98
Fluorene	0.59	1.38	0.59	0.85	5.08	2.20	0.22	2.50
2-Methyl-Fluorene	0.78	0.99	1.08	0.95	1.31	0.87	0.78	0.99
Phenanthrene	12.48	6.33	6.46	8.42	10.06	8.23	8.07	8.79
Anthracene	1.37	1.65	0.84	1.29	2.60	2.44	2.24	2.43
Fluoranthene	4.56	1.25	1.38	2.40	1.62	1.70	1.48	1.60
Pyrene	2.39	1.78	1.76	1.97	2.15	2.62	2.38	2.38
Retene	4.28	5.47	3.23	4.33	3.82	0.61	2.48	2.30
Benzo(a)Fluorene	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Benzo(b)Fluorene	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1-Methyl-Pyrene	0.14	0.20	0.21	0.18	0.00	0.00	0.17	0.06
Benzo(g,h,i)Fluoranthene	0.19	0.13	0.09	0.14	0.48	0.35	0.46	0.43
Benzo(a)Anthracene	0.12	0.00	0.00	0.04	0.00	0.00	0.24	0.08
Triphenylene	0.33	0.00	0.12	0.15	0.38	0.33	0.56	0.42
Chrysene	1.09	0.04	0.02	0.38	0.48	0.38	0.58	0.48
7-Methyl-Benzo(a)Anthracene	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Benzo(b)Fluoranthene	0.92	0.00	0.00	0.31	0.00	0.00	0.00	0.00
Benzo(k)Fluoranthene	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Benzo(e)Pyrene	0.64	0.00	0.00	0.21	0.00	0.00	0.00	0.00
Benzo(a)Pyrene	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Perylene	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3-Methyl-Cholanthrene	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Indeno(1,2,3-cd)Fluoranthene	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Indeno(1,2,3-cd)Pyrene	0.90	0.00	0.00	0.30	0.00	0.00	0.00	0.00
Dibenzo(a,h)Anthracene	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Benzo(b)Chrysene	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Benzo(g,h,i)Perylene	0.50	0.00	0.00	0.17	0.00	0.00	0.00	0.00
Anthanthrene	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
<b>Total</b>	31.49	19.38	16.14	22.34	30.80	20.50	20.04	23.78

Values are expressed on a dry basis referenced to 25°C and 101.325 kPa.  
 "0" denotes not detected.

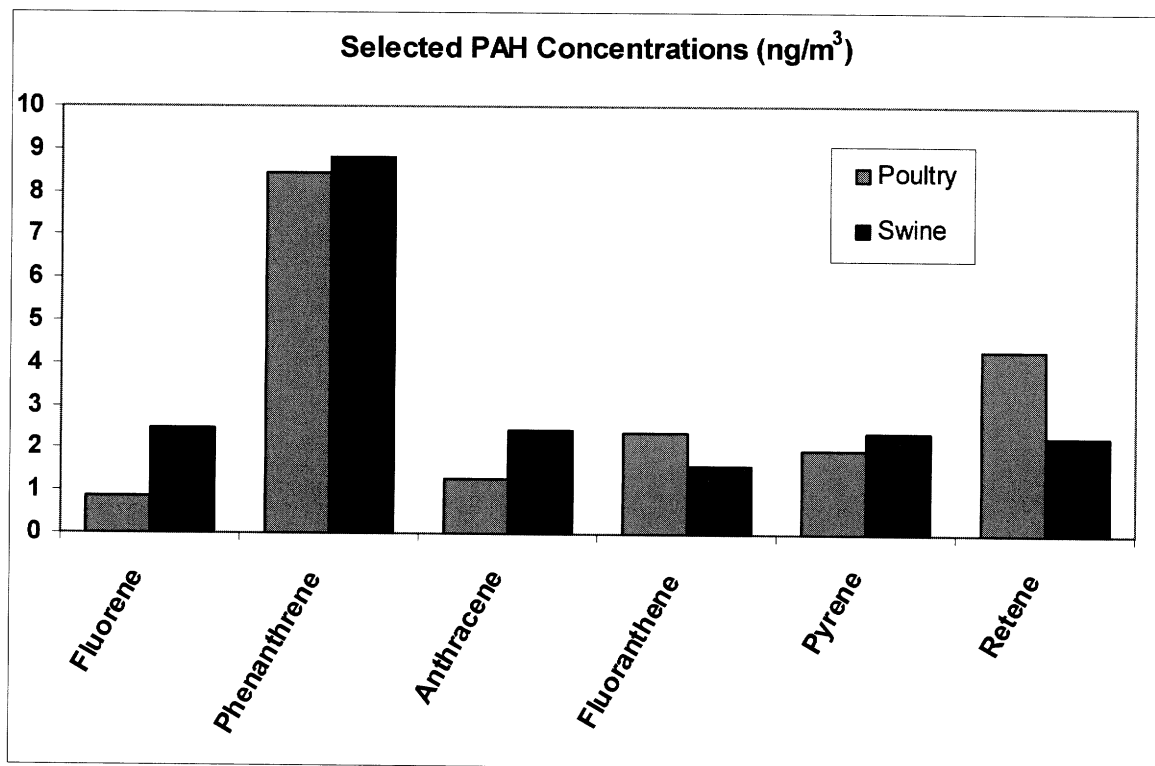


Figure 11 Selected PAH Concentrations

## 6.7 Volatile Organic Compounds (VOCs)

The full VOC target list contains 150 compounds, however this list was pared down for reporting purposes as many of the species are of lesser interest. Normally the list is reduced to include BTEX (benzene, ethylbenzene, toluene and xylenes) and halogenated hydrocarbons. Benzene and some halogenated hydrocarbons such as vinyl chloride, 1,3-butadiene, dichloromethane, tri and tetrachloroethene, 1,1,1-trichloroethane, 1,2-dichloroethane and hexachlorobutadiene are classified as CEPA-toxic substances. Naphthalene, a PAH compound, was also included since it is not reliably determined using the modified Method 5 type train. The full list of VOC concentrations is given in Appendix II.

The emission data for VOCs of interest is summarized in Table 8. Two canister samples were collected during each SVOC run. VOC concentrations are not corrected to 11% oxygen. The average of these two canisters is reported in Table 8.

**Table 8 Concentrations of Selected VOCs ( $\mu\text{g}/\text{m}^3$ )**

Compound	POULTRY				SWINE			
	SVOC 1	SVOC 2	SVOC 3	Overall Average	SVOC 1	SVOC 2	SVOC 3	Overall Average
Chloromethane	0.18	0.37	0.81	0.45	1.11	0.98	0.43	0.84
Chloroethane	0.00	0.10	0.18	0.08	0.38	0.10	0.17	0.22
Dichloromethane	0.30	0.55	0.58	0.46	0.50	0.57	0.75	0.59
Benzene	4.78	6.38	7.83	6.14	5.59	7.68	9.28	7.29
Toluene	1.54	1.56	2.35	1.75	1.43	3.06	2.43	2.29
Chlorobenzene	0.06	0.11	0.08	0.08	0.09	0.07	0.10	0.08
Ethylbenzene	0.14	0.13	0.47	0.22	0.33	0.27	0.19	0.27
m,p-Xylene	0.38	0.40	0.95	0.53	0.69	0.85	0.58	0.72
o-Xylene	0.11	0.09	0.33	0.16	0.30	0.18	0.13	0.21
Naphthalene	0.25	1.99	4.22	1.89	29.38	0.49	0.36	11.29
<b>Total Above</b>	<b>7.73</b>	<b>11.67</b>	<b>17.80</b>	<b>11.77</b>	<b>39.80</b>	<b>14.22</b>	<b>14.42</b>	<b>23.81</b>
<b>All VOCs</b>	<b>30.9</b>	<b>45.7</b>	<b>61.9</b>	<b>46.2</b>	<b>118.9</b>	<b>56.9</b>	<b>49.8</b>	<b>75.2</b>

*Values are expressed on a dry basis referenced to 25°C and 101.325 kPa.*

The level of VOCs was very low at this source. The VOCs reported in Table 8 account for 21 to 35% of the total VOCs for all the test runs. Eight CEPA-toxic compounds, vinyl chloride, 1,3-butadiene, 1,2-dichloroethane, 1,1,1-trichloroethane, tri and tetra chloroethene, carbon tetrachloride and hexachlorobutadiene were not detected.

Except for the first SVOC run with the swine feed, benzene was the largest component of the VOCs ranging from 43 to 71 % of the selected compounds. Naphthalene and dodecane levels in the first swine run were substantially higher than the other five SVOC runs. These two compounds contributed 64% of the total reported VOCs for the first canister collected in the first swine run. Total VOC levels for the individual canisters ranged from 25 to 87  $\mu\text{g}/\text{m}^3$  and 45 to 187  $\mu\text{g}/\text{m}^3$  for the poultry and swine runs respectively.

In four out of the six pairs of canisters, lower levels were measured in the second canister collected for each run on a total VOC basis. The overall average for the swine runs was higher than the poultry testing but most of this difference was attributable to the naphthalene and dodecane in the first canister of the first swine run. Note that the VOC levels from this source are negligible. Using a benzene basis, the overall average mass/volume concentrations of 46 and 75  $\mu\text{g}/\text{m}^3$  are equivalent to 15 and 24 parts per billion (ppb) on a volume/volume basis for the poultry and swine test conditions respectively.

## 6.8 Estimated Emission Rates

The annual emission rates for the particulate, acid gases, metals and organics are given in Table 9. These values should be regarded as estimates as the emission results from a one-week period are extended to an entire year.

**Table 9 Estimated Annual Emission Rates**

BASIS: 100 charges per year 8 hours per charge Stack flow rate - average used for each test condition		
Pollutant	POULTRY	SWINE
<b>Particulate, Acid Gases and Metals</b>		
Particulate (kg/year)	16.32	11.80
HCl (kg/year)	33.1	32.3
HF (g/year)	253	82.4
<b>Metals (g/year)</b>		
Mercury	0.05	0.03
Antimony	25.3	3.42
Arsenic	0.53	0.27
Barium	0.53	0.40
Beryllium	0.00	0.00
Cadmium	1.15	0.48
Chromium	9.96	9.48
Cobalt	0.06	0.05
Copper	160	100
Lead	57.1	11.2
Manganese	2.16	6.39
Nickel	0.46	0.47
Selenium	8.62	5.00
Silver	0.11	0.02
Thallium	0.00	0.00
Zinc	125	68.5
<b>Organics</b>		
PCDD/PCDF ( $\mu\text{g I-TEQ/year}$ )	0.49	0.49
Coplanar PCBs ( $\mu\text{g/year}$ )	58.0	80.0
TCB (3 isomers) (mg/year)	0.22	0.17
PCB (mg/year)	0.15	0.15
HCB (mg/year)	0.03	0.04
PCP (mg/year)	0.06	0.60
PAHs (mg/year)	16.5	17.1
VOCs (g/year)	34.1	54.1

*Uncorrected concentrations at reference conditions used to calculate emission rates.*

## 6.9 Dispersion Modelling

The Ontario Ministry of the Environment (MOE) Regulation 346 dispersion model was applied to estimate the maximum Point-of-Impingement (POI) concentrations for each of the test conditions. The average temperature and exit velocity for each of the test conditions were used in the dispersion model.

The POI concentrations for each of the pollutants are given in Table 10. The input parameters and outputs are shown in Table 10. The higher of the stability classes was picked for predicting the maximum ground level concentrations. In this case, the "D" stability class yielded the higher concentration. In both test conditions, the single source maximum ground level concentration was located 142 metres from the source.

**Table 10 Single Source Maximum Ground Level Concentrations**

Reg 348 Input and Output Parameters	Poultry	Swine	Half Hour POI Limits* (µg/m³)
Height (m)	9.14	9.14	
Emission Rate (g/s)	1	1	
Exit velocity (m/s)	5.95	6.08	
Diameter (m)	0.4593	0.4593	
Temp (K)	1159	1185	
Max Concentration (µg/m3 per g/s)	571	571	
Stability Class	D	D	
Distance (m)	142	142	
Particulate and Acid Gases (µg/m³)			
Particulate	3.2E+0	2.3E+0	100
HCl	6.6E+0	6.4E+0	100
HF	5.0E-2	1.6E-2	4.3
Metals (µg/m³)			
Mercury	9.9E-6	6.2E-6	5
Antimony	5.0E-3	6.8E-4	75
Arsenic	1.1E-4	5.3E-5	1
Barium	1.1E-4	8.0E-5	30
Beryllium	0.0E+0	0.0E+0	0.03
Cadmium	2.3E-4	9.5E-5	5
Chromium	2.0E-3	1.9E-3	5
Cobalt	1.1E-5	9.2E-6	0.3
Copper	3.2E-2	2.0E-2	100
Lead	1.1E-2	2.2E-3	6
Manganese	4.3E-4	1.3E-3	7.5
Nickel	9.1E-5	9.4E-5	5
Selenium	1.7E-3	9.9E-4	20
Silver	2.2E-5	4.6E-6	3
Thallium	0.0E+0	0.0E+0	
Zinc	2.5E-2	1.4E-2	100
Organics (µg/m³)			
Dioxins and Furans (pg TEQ/m³)	9.7E-5	9.8E-5	15
Co-planar PCBs	1.2E-8	1.6E-8	Not available
Selected Chlorobenzenes	1.37E-10	1.22E-10	Not available
Pentachlorophenol	7.8E-8	6.9E-8	60
Polycyclic Aromatic Hydrocarbons			
Benzo(a)pyrene	0.0E+0	0.0E+0	0.0033
Volatile Organic Compounds			
Vinyl Chloride	0.0E-5	0.0E-0	3
Napthalene	2.8E-4	1.6E-3	36

\*Ontario Ministry of the Environment, March 1999, half-hour limits

The maximum ground level concentrations for each of the reported pollutants for both test conditions are substantially below the POI limits in Regulation 346. Note that the maximum ground level concentrations for some VOCs such as toluene, trichlorobenzene and xylenes were not calculated as these compounds have high POI limits. The predicted POI values should only be used as a guide for the impact of this source. The predicted impact for the animal cremator will depend on the capacity of the unit, meteorological conditions, surrounding terrain and receptor points.

## **7. SUMMARY**

The results presented in this report are representative of the feed and operating conditions during the test program. No problems were encountered with the collection of the samples for the target pollutants. The provision of an Eco Waste operator during the test program ensured a smooth and uninterrupted operation. None of the predicted maximum ground level concentrations exceeded the Ontario POI limits.

# **APPENDIX I**

## **Sampling Schedule**

## **Flue Gas Monitoring Data**

## **SVOC Traverse Data**

## **Particulate /Acid Gases/Metals Traverse Data**

## **APPENDIX II**

### **Particulate, Anions and Metals Analysis**

### **Dioxin, Furan, Co-planar PCB, CB, PCP and PAH Analytical Reports**

### **VOC Analytical Data**

# ATTACHMENT 3

## CHARACTERIZATION OF EMISSIONS FROM THE ECO WASTE SOLUTIONS THERMAL WASTE OXIDIZER, BURLINGTON ONTARIO

**401-1113 Jade Court • Thunder Bay, ON P7B 6M7 • Tel: 807-346-1668 • Fax: 807-345-0284**  
**E-mail: [info@wolfdenresources.com](mailto:info@wolfdenresources.com) • Web: [www.wolfdenresources.com](http://www.wolfdenresources.com)**

---

# Characterization of Emissions From the Eco Waste Solutions Thermal Waste Oxidizer Burlington, Ontario

Dominic Cianciarelli  
Christopher House

Report ERMD 2002-03

February 2003

Emissions Research and Measurement Division  
Environmental Technology Advancement Directorate

---



Environment  
Canada

Environnement  
Canada

Environmental  
Technology  
Centre



Centre de  
Technologie  
Environnementale

## DISCLAIMER

---

This report has not undergone detailed technical review by the Environmental Technology Advancement Directorate and the content does not necessarily reflect the views and policies of Environment Canada. Mention of trade names or commercial products does not constitute endorsement for use.

This unedited version is undergoing a limited distribution to transfer the information to people working in related studies. This distribution is not intended to signify publication and if the report is referenced, the author should cite it as an unpublished report of the directorate indicated below.

Any comments concerning its content should be directed to:

Environment Canada  
Emissions Research and Measurement Division  
Environmental Technology Advancement Directorate  
Environmental Technology Centre  
Ottawa, Ontario  
K1A 0H3

## TABLE OF CONTENTS

DISCLAIMER .....	i
LIST OF FIGURES .....	iii
LIST OF TABLES .....	iv
ACKNOWLEDGEMENTS .....	v
1. INTRODUCTION .....	1
2. SAMPLING SITE AND LOCATION .....	2
3. SAMPLING METHODS .....	2
3.1 General .....	2
3.2 Particulate/Acid Gases/Metals Train Description .....	3
3.3 SVOC Train Description .....	4
3.3.1 Glassware Cleaning and Proofing .....	5
3.3.2 Sample Recovery .....	5
3.4 Volatile Organic Compounds (VOCs) .....	6
3.5 Flue Gases .....	7
4. QUALITY ASSURANCE/QUALITY CONTROL (QA/QC) .....	8
5. ANALYTICAL METHODS .....	8
5.1 Particulate and Metals .....	8
5.2 Semi-volatile Organic Compounds .....	8
5.3 Volatile Organic Compounds .....	10
6. RESULTS .....	11
6.1 General Sampling Data .....	11
6.2 Particulate/Acid Gases/Metals .....	13
6.3 Flue Gases .....	15
6.4 Dioxins and Furans .....	15
6.5 Chlorobenzenes and Octachlorostyrene .....	18
6.6 Polycyclic Aromatic Hydrocarbons (PAHs) .....	19
6.7 Volatile Organic Compounds (VOCs) .....	21
6.8 Estimated Emission Rates .....	22
7. SUMMARY .....	24

APPENDIX I  
APPENDIX II

## LIST OF FIGURES

---

Figure	Page
1	Sampling Location – Eco Waste Solutions Oxidizer.....2
2	Particulate/Acid Gases/Metals Sampling Train .....3
3	Dioxin, Furan, PAH, CB and OCS Sampling Train .....4
4	Recovery Procedure for the Dioxins, Furans, PAHs, CBs and OCS .....6
5	Volatile Organic Compounds Sampling Train .....7
6	Flue Gas Monitoring System .....7
7	Eco Waste Sampling Schedule .....11
8	Average Metal Concentrations .....13
9	Distribution of TEQ Congeners .....16
10	Chlorobenzene Concentrations .....18
11	Selected PAH Concentrations.....19
12	Summary of Emission Results .....24

## LIST OF TABLES

---

Table		Page
1	Summary of General Stack Sampling Data .....	12
2	Summary of Particulate, Acid Gases and Metals Concentrations .....	14
3	Summary of Flue Gas Concentrations .....	15
4	Concentrations of Dioxins and Furans.....	17
5	Concentrations of Chlorobenzenes and Octachlorostyrene .....	18
6	Concentrations of PAHs .....	20
7	Concentrations of Selected VOCs .....	21
8	Effect of Averaging Method on Uncorrected Concentrations .....	22
9	Estimated Annual Emission Rates .....	23

## ACKNOWLEDGEMENTS

---

The Emissions Research and Measurement Division would like to express their appreciation to Jean Lucas and the operating staff of Eco Waste Solutions for their cooperation and assistance during the test program at the thermal waste oxidizer. Special thanks are extended to the Analysis and Ambient Air Quality Division at the Environmental Technology Centre for performing the dioxin, furan, PAH, chlorobenzenes, octachlorostyrene and volatile organic compounds analyses. Philip Analytical Services Inc. of Burlington, Ontario performed the metals analysis.

## 1. INTRODUCTION

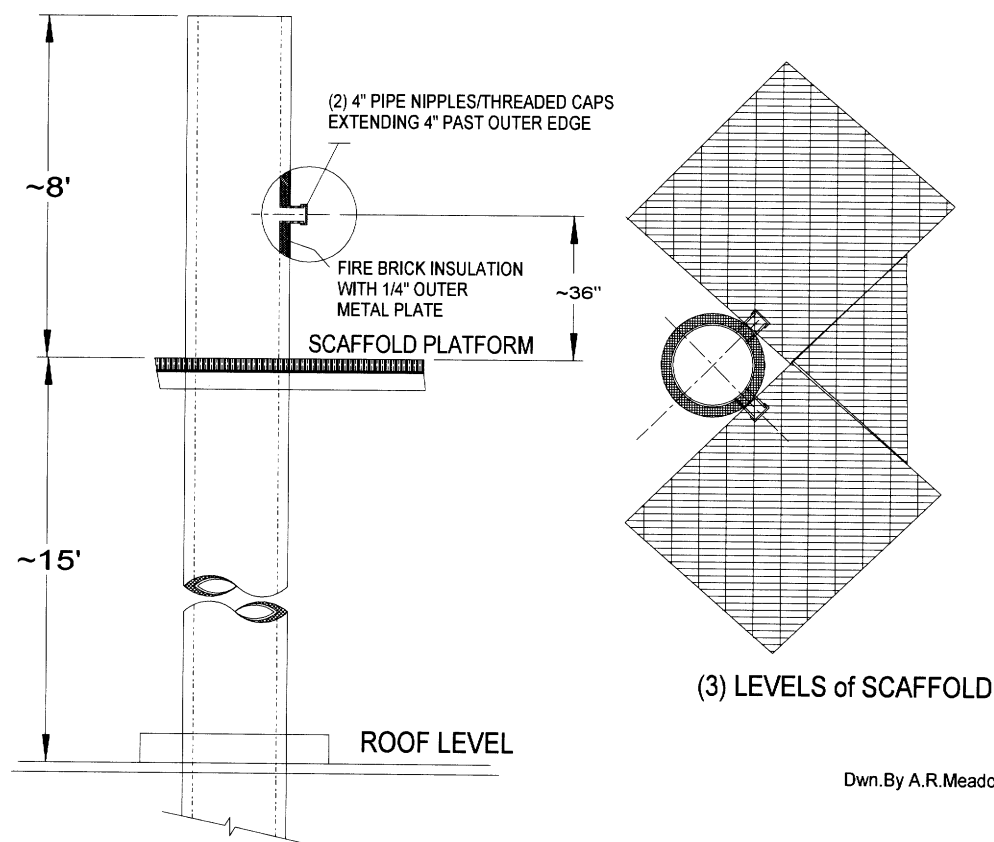
In cooperation with the National Office of Pollution Prevention, the Emissions Research and Measurement Division (ERMD) conducted characterization of the Eco Waste Oxidizer manufactured by Eco Waste Solutions of Burlington, Ontario. The Eco Waste Oxidizer uses a two-step thermal oxidation process. In the first step, municipal solid waste is burned in the dual primary chambers under starved oxygen conditions and relatively low temperatures (500 to 650°C) in order to preserve metal and glass for later recycling. Each of the two primary chambers in this oxidizer has a capacity of two tonnes of waste. Once the waste starts burning, the process becomes self-fuelling until the volume is reduced by over 90 percent. In the second step, smoke and gases from the two parallel primary chambers are treated in the afterburner or secondary chamber at an operating temperature of 1000°C and a minimum of 2 seconds residence time to ensure complete oxidation of the combustion products.

The Eco Waste Oxidizer is configured to treat the flue gases from the afterburner in a water quench system followed by a packed tower scrubber to remove acid gases and metals. However, the scrubber system was bypassed in this study. The main purpose of this study was to characterize the emissions from a well-operated incinerator without control technology.

The Emissions Research and Measurement Division (ERMD) conducted source testing at this facility for various target compounds. These pollutants included particulate, metals, acid gases, dioxins and furans (PCDDs/PCDFs), polycyclic aromatic hydrocarbons (PAHs), selected chlorobenzenes (CBs), octachlorostyrene (OCS), volatile organic compounds (VOCs) and flue gases (CO<sub>2</sub>, O<sub>2</sub>, CO, SO<sub>2</sub> and NO<sub>x</sub>). The semi-volatile and volatile organic compounds included Track 1 and CEPA toxic compounds.

## 2. SAMPLING SITE AND LOCATION

Sampling was conducted on the stack exhaust located above the roof of the Eco Waste facility. Samples were extracted from the two existing ports. The sampling location is illustrated in Figure 1. Sampling was conducted from two 4-inch ports positioned approximately 36 inches above the temporary platform and 15 feet above the roof. The stack sampling location met the "eight and two" criteria.



**Figure 1 Sampling Location – Eco Waste Solutions Oxidizer**

## 3. SAMPLING METHODS

### 3.1 General

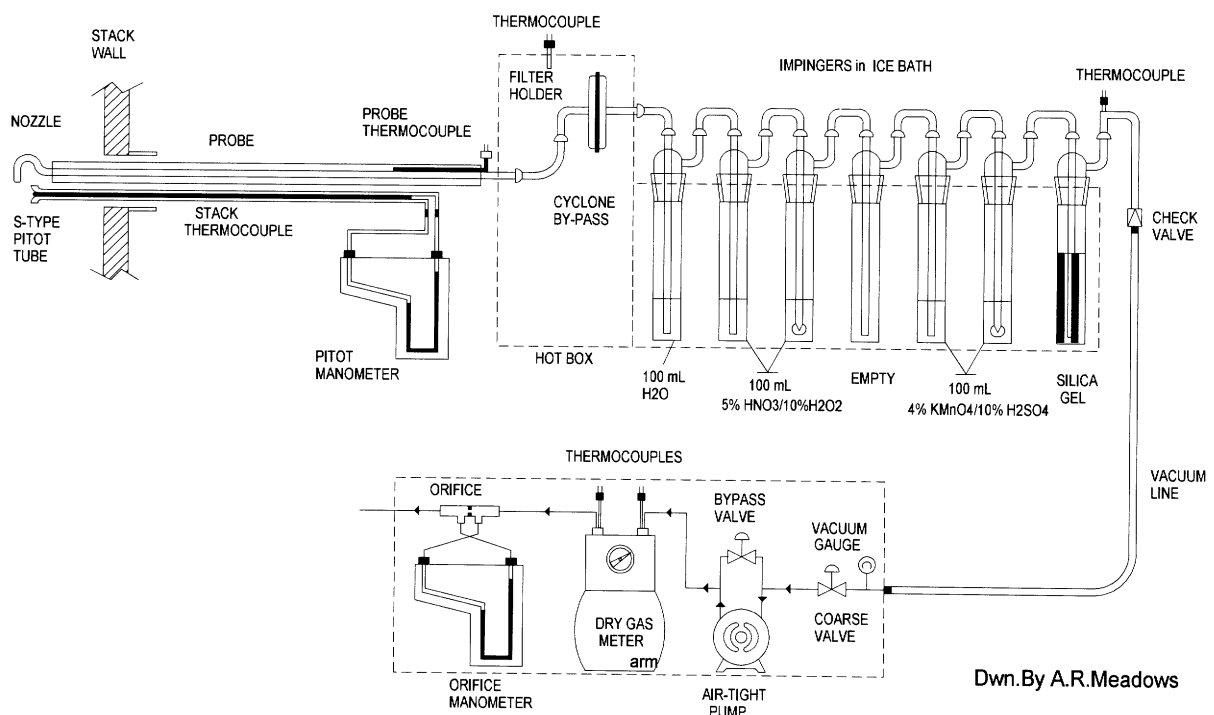
The Method 5 train formed the basis of the manual methods used to collect particulate, acid gases, metals and semi-volatile organics during the sampling phase. The train consisted of a probe, heated filter enclosure, leak-free vacuum line, vacuum gauge, flow control valves, vacuum pump and a dry gas and orifice meter. Stack gas and orifice pressures were measured with an inclined manometer and micromanometer. Temperatures were measured in the hot box,

impinger train outlet and at the inlet and outlet of the dry gas meter. In the case of the SVOCs, the temperature was also monitored at the Amberlite XAD-2 inlet. All trains were assembled in the ERMD mobile lab.

Leak-checks were conducted at the beginning and at the end of each run or whenever a train joint was opened. Sampling was conducted from two traverses at isokinetic sampling rates with readings recorded every five minutes. Sampling duration for the particulate/metals and organic runs was 2 and 4 hours respectively.

### 3.2 Particulate/Acid Gases/Metals Train Description

EPA Method 29, "Determination of Metal Emissions from Stationary Sources", was used to determine particulate and metal emissions. Particulate emissions were collected in the probe and on the heated filter. The condensation and collection of the gaseous fraction was accomplished using seven impingers connected in series. The first impinger was filled with 100 mL deionized water to trap acid gases, followed by two impingers containing 100 mL of an acidic solution of hydrogen peroxide (5%  $\text{HNO}_3$ /10%  $\text{H}_2\text{O}_2$ ), followed by an empty impinger, followed by two impingers containing 100 mL each of an acidic solution of potassium permanganate (4%  $\text{KMnO}_4$ /10%  $\text{H}_2\text{SO}_4$ ) and finally followed by a silica gel impinger. A schematic of the sampling train is shown in Figure 2.



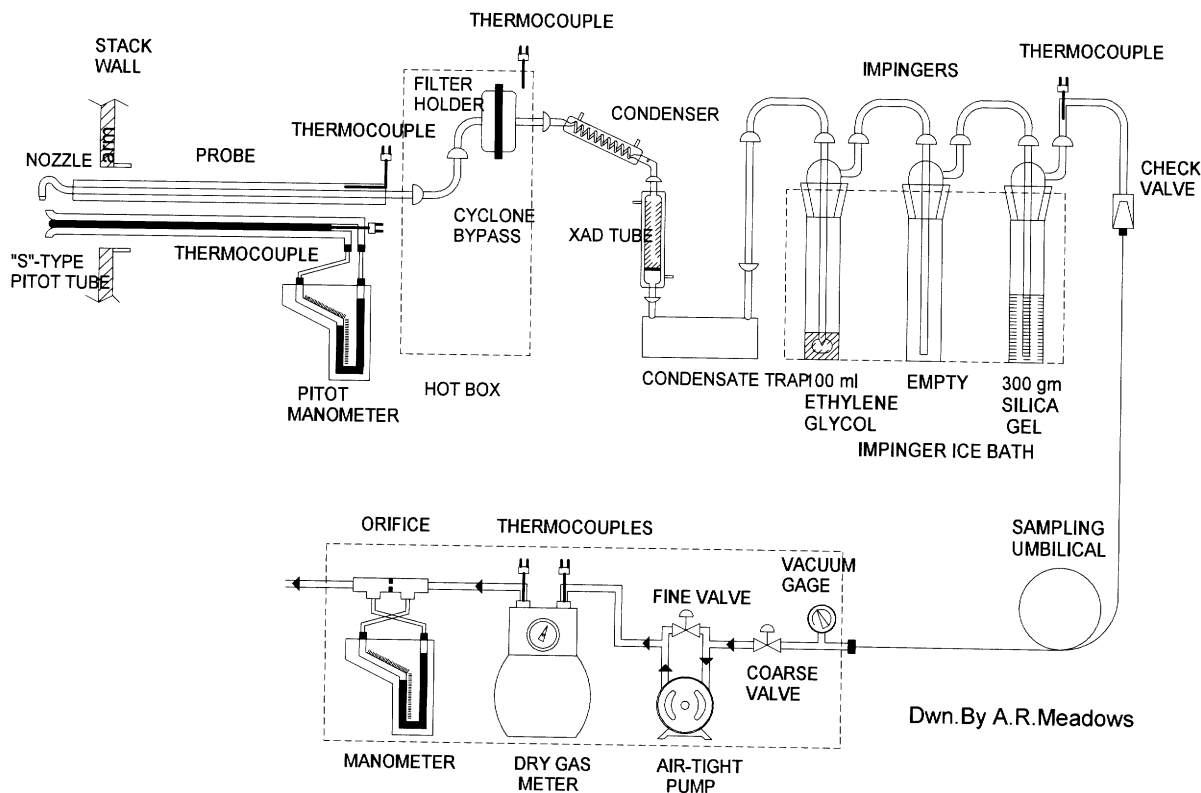
**Figure 2 Particulate/Acid Gases/Metals Sampling Train**

The glassware was pre-cleaned following the meticulous procedure detailed in the method. Eight samples from each test were obtained from the recovery procedure and submitted for analysis. These samples include the particulate filter, aliquots of the first impinger water, rinses of the front- and back-half glassware with various portions of acetone, nitric acid, acidified potassium permanganate and hydrochloric acid that are detailed in the method. As well, aliquots of the reagents used in the sampling train and in the recovery procedure were submitted for blank analysis.

Glass bottles with Teflon-lined caps were used for storage of acidified  $\text{KMnO}_4$  containing samples and blanks. No metal components were used in this method. In its place, Teflon probe fittings and filter supports and quartz nozzles and probes were utilized to avoid contamination of the train and samples.

### 3.3 SVOC Train Description

The Environment Canada Report EPS 1/RM/2 *"Reference Method for Source Testing: Measurement of Releases of Semi-volatile Organic Compounds from Stationary Sources"* was used to determine the emissions of dioxins, furans, polycyclic aromatic hydrocarbons, chlorobenzenes and octachlorostyrene from the stack. A schematic of the sampling train is shown in Figure 3.



**Figure 3 Dioxin, Furan, PAH, CB and OCS Sampling Train**

This method is the most widely accepted for the measurement of organic compounds with boiling points above 100°C. Gaseous organics were trapped in a single adsorbent tube containing about 40 grams of Amberlite XAD-2 resin. As the temperature of the resin must be kept below 20°C for optimal collection efficiency, the hot gases leaving the filter enclosure were cooled by passing them through a condenser cooled with ice bath water. The tube containing the XAD-2 resin was also water-cooled. Condensate formed in the cooling coil percolated through the resin bed and was collected in a condensate trap. An impinger containing ethylene glycol inserted downstream of the Amberlite acted as a back-up collection media in the event of breakthrough of organics through the resin. The resin tube was covered with aluminum foil during sampling and storage to prevent photodegradation of the trapped organics. All glassware joints were wrapped with Teflon tape as vacuum greases are not permitted for organic sampling. Sampling duration was four hours. Quartz nozzles and liners were used in the sampling train.

### **3.3.1 Glassware Cleaning and Proofing**

Prior to the test program, all train glassware, probe brushes, glass wool and aluminum foil were cleaned following the rigorous procedure in the Reference Method. The glassware cleaning procedures were verified by analyzing the proofing rinses of the sampling trains. Pre-cleaned and proofed commercial sample storage bottles were used for this test. Four complete sets of train glassware were prepared for this survey. The XAD-2 was pre-cleaned and analyzed for contamination prior to the survey. All reagents were distilled-in-glass grade. Details of the cleaning and proofing procedures are given in Report EPS 1/RM/2.

### **3.3.2 Sample Recovery**

Following the completion of each run, the organic train was recovered in the ERMD mobile laboratory. During the transportation between the sampling site and the lab, all openings were sealed with pre-cleaned glass plugs or caps or aluminum foil. The recovery procedures involved the brushing and rinsing of the train components with acetone and hexane. Only Teflon wash bottles were used during sample recovery. The loaded filter was carefully removed from the holder, sealed in pre-cleaned foil and stored in a pre-cleaned glass petri dish. Amberlite tubes were capped and re-wrapped in aluminum foil. Liquid samples were stored in pre-cleaned amber bottles to prevent photodegradation of the organics. Bottle lids were lined with Teflon. All samples were kept refrigerated following recovery. The sample recovery procedures are detailed in Figure 4. All samples were forwarded to the Analysis and Air Quality Division (AAQD) of Environment Canada for organic analysis.

Sample	Component(s)	Recovery Procedure
1	1,2,3,4	Wash and brush 3 times each with acetone (A) and hexane (H). Rinse 3 times each with A and H.
2	5	Remove filter carefully from filter holder. Place on pre-cleaned foil. Fold in half and crimp the foil edges. Place in pre-cleaned petri dish. Seal petri dish.
3	6,7	Soak 5 minutes each with A and H. Rinse 3 times each with A and H.
4	8	Cap ends and wrap in foil.
5	9,10,11,12	Empty contents into container and rinse 3 times with HPLC water.
6	6 to 15 except 8	Rinse three times each with A and H.

Mark liquid levels on all bottles and wrap all the caps with tape.

*All sample containers are pre-cleaned amber glass bottles with pre-cleaned Teflon lid liners.*

### Figure 4 Recovery Procedure for Dioxins, Furans, PAHs, CBs and OCS

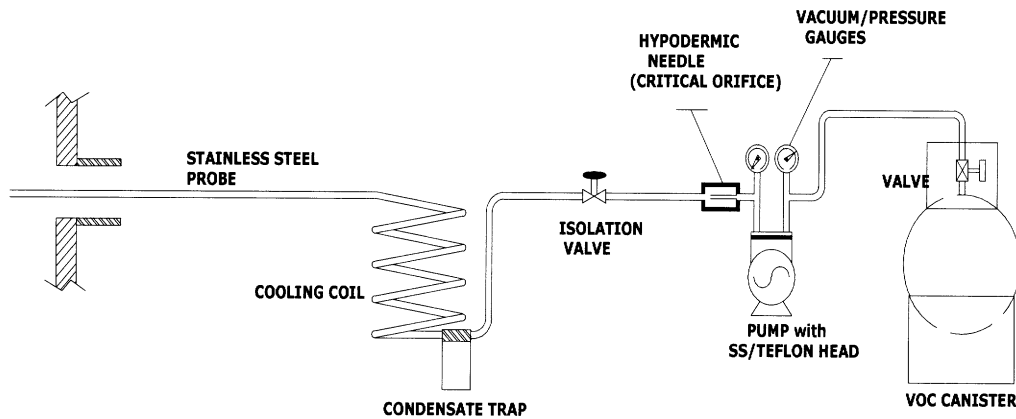
In addition to the regular sampling trains, a blank train was assembled for the tests. The blank train was treated in the same manner as the sampling trains except that no stack gases were sampled. However, a volume of ambient air, equal to that drawn during the leak checks was drawn through the blank train. Essentially, the blank train serves as a check for background levels of organics originating from ambient air, handling of train glassware and rinsing agents.

### 3.4 Volatile Organic Compounds (VOCs)

VOCs are classified as those organics having saturated vapour pressures at 25°C greater than 10<sup>-1</sup> mm Hg. The method is based on the collection of a gaseous sample in a previously cleaned, verified and evacuated 6-liter, stainless-steel canister. The canister's interior surface is covered by pure chrome-nickel oxide which is formed during the SUMMA® passivating process. This vessel provides a stable sample collection and storage media for many organic compounds.

A modified method TO-14 (*Compendium Method TO-14 Quality Assurance Division, Environmental Monitoring Systems Laboratory, U.S. EPA, May 1988*) was used as the basis for the VOC sampling train. The train consisted of a stainless-steel probe connected by Teflon tubing to the canister. The gases were drawn by a Teflon-coated pump through a critical orifice (hypodermic needle) into the canister (Figure 5).

Two canisters were collected for each SVOC run corresponding to the first and second halves of the traverses. Sampling duration for the VOC samples was variable, ranging from 50 to 70 minutes. The sample was collected into the evacuated canister to a final pressure of 18 to 19 psig. Following sample collection, the canister valve was closed and the canisters were transported to the AAQD laboratory for analysis.

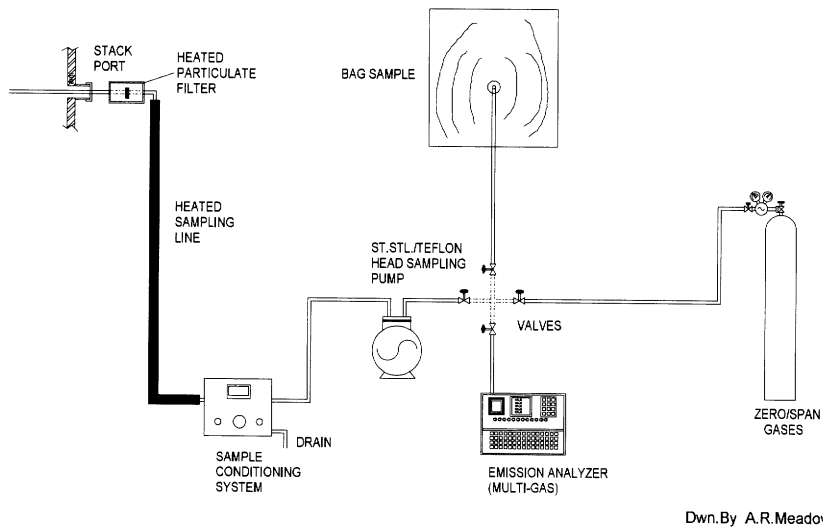


**Figure 5 Volatile Organic Compounds Sampling Train**

### 3.5 Flue Gases

An integrated gaseous sample method was employed to collect a representative sample from the stack. This was accomplished by drawing sample gas through a 30-inch Inconel probe located directly in the exhaust stream. Following particulate removal in a heated filter and conditioning (drying and cooling) of the sample gas, the sample gas was drawn through a stainless steel/Teflon head pump into a high volume aluminized Tedlar sample bag. A sampling rate of 1 liter per minute was used over a 30-minute sampling period per sample. A schematic of the system is shown in Figure 6.

Each integrated sample was then analyzed using both an ECOM Model KD (electrochemical analysis of  $O_2$ ,  $CO$ ,  $SO_2$  and  $NO$  and  $NO_2$ ) and a Nova Model 306 BD (infrared analysis of  $CO_2$ ), to determine target species concentration. Each instrument was individually calibrated twice a day using two ranges of certified gas standards. Initial calibration was carried out prior to the commencement of sampling, once all equipment had reached operating conditions, while final calibration was performed at the end of sampling.



**Figure 6 Flue Gas Monitoring System**

#### 4. QUALITY ASSURANCE/QUALITY CONTROL (QA/QC)

All stack sampling equipment was calibrated prior to sampling using accepted techniques. Items that were calibrated included:

- Dry Gas Meter ( $\gamma$ )
- Orifice ( $K_0$ )
- Pitot Tubes ( $C_p$ )
- Barometers ( $P_{\text{bar}}$ )
- Inclined Gauges ( $\Delta p$ )
- Nozzle Diameters ( $N_d$ )
- Temperature Readers (T)

The dry gas and orifice meters were calibrated using a spirometer. Pitot tubes were calibrated at the National Research Council wind tunnel. Barometers and inclined gauges were calibrated against a standard reference mercury barometer and an inclined manometer respectively. Thermocouple readers were calibrated using an ice bath and boiling water. Nozzle openings were measured by averaging three measurements with a vernier caliper. In addition to the above, the sampling consoles and inclined gauges were checked for leaks and the operation of all probe and box heaters was verified.

#### 5. ANALYTICAL METHODS

##### 5.1 Particulate and Metals

Particulate was determined gravimetrically following desiccation of the front-half acetone rinse and loaded filter. Acid gases were determined by ion chromatography analysis of the first impinger contents. Chloride and fluoride were expressed as HCl and HF. The samples were acid digested, and appropriate fractions were analyzed for mercury by cold vapour atomic absorption spectroscopy (CVAAS) and the remainder of the metals was analyzed by inductively coupled argon plasma emission spectroscopy (ICAP). The front- and back-half components were analyzed separately.

##### 5.2 Semi-volatile Organic Compounds

Upon receipt in the laboratory the samples were inspected to ensure integrity and proper labeling. The samples were then entered into the laboratory information management system (LIMS) where they were assigned a laboratory code. The code was then entered onto each of the containers which were then stored in a fridge at 4°C until sample processing proceeds.

Typically the train samples are divided into the front-half (probe rinse, filter, and front-half filter holder rinse) and back-half sections (back-half filter holder rinse, XAD, condensate trap, glycol impinger and back-half glassware rinses). The solvent fractions were dried by passage through sodium sulphate and reduced in volume by rotary evaporation. The solids (filter and XAD) were air dried prior to a 20-hour soxhlet extraction using cyclohexane/toluene (8:2 v/v). Prior to extraction, each sample was spiked with

a solution containing a known amount of carbon-13 labelled dioxin/furans and chlorobenzenes as well as deuterated PAH. These were used to assess losses incurred during the extraction and sample cleanup procedures. Analytical results for dioxin/furan and chlorobenzenes/octachlorostyrene were corrected for the recovery of these surrogates. PAH results were not corrected for surrogate recovery.

After extraction, the solvent extracts of the solids were reduced in volume and combined with the train rinses prior to cleanup. The samples were split into two equal fractions. One fraction was used for PAH cleanup and analysis while the other was used for dioxin/furan and chlorobenzene/octachlorostyrene cleanup and analysis.

The PAH cleanup involved passing the sample extract through an activated silica column. Co-extracted compounds which may cause interference during analysis were eluted out of the column while the PAHs were retained on the column. A more polar solvent was then applied to the column to elute the PAHs. The cleaned sample extract was concentrated to 500  $\mu$ L and an internal standard was added to monitor instrumental performance and was used to correct for any variations in injection and sample volume. The sample was analyzed using low resolution mass spectroscopy. Calibration standards containing various known amounts of the analytes were injected into the instrument before, during and after the samples were injected. These standards were used to determine the concentrations of the analytes in the sample. The accuracy of the standards was periodically assessed using standard reference materials.

The dioxin/furan and chlorobenzene/octachlorostyrene cleanup is more rigorous since the concentrations of the dioxin/furans are much lower than other compounds that may be present in the extract. These co-extractants could interfere with the final analysis. Initially the sample extract was passed through a multi-bed silica column containing layers of acid, base and silver nitrate. Some of the co-extractants were retained on the column and others may be reduced or oxidized. Sulphur containing compounds were removed by the silver nitrate. The extract was then passed through an alumina column to separate out the dioxin/furans from other compounds such as PCBs and chlorobenzenes/octachlorostyrene. The fraction containing the chlorobenzenes/octachlorostyrene was reduced to 500  $\mu$ L and an internal standard was added to monitor instrumental performance and to correct for any variations in injection and sample volume. The sample was analyzed using low resolution mass spectroscopy. The fraction containing dioxin/furans was reduced to 20  $\mu$ L and an internal standard was added to monitor instrumental performance and to correct for any variations in injection and sample volume. The sample was analyzed using high resolution mass spectroscopy.

As a part of quality assurance and quality control, a method blank is usually processed along with the samples to assess cross contamination. A control sample, usually a standard reference material containing a known amount of analytes, may also be processed along with the samples to check extraction, cleanup and analytical efficiency. The division also participates in inter-laboratory studies. The results of these studies are used to compare the results obtained in-house with the results obtained from several different laboratories. These studies involve various analytes from a variety of matrices. The division is accredited by CAEAL for the analysis of PAH and dioxin/furan.

### 5.3 Volatile Organic Compounds

The stack samples in canisters were analyzed using thermal desorption technique with a high-resolution gas chromatograph and quadrupole mass-selective detector (GC-MSD) as described in EPA Methods TO-15 and TO-17. A Dynatherm Analytical Instruments ACEM Model 900 thermal desorption system was used for sample preconcentration. Sorbent tubes packed with 20/35 mesh Tenax-TA, 60/80 mesh Carboxen 1000 and 60/80 mesh Carbosieve SIII were used for sample concentration. An Agilent 5890 series II gas chromatograph and an Agilent 5972 MSD were used for species identification and quantification. Volatile organic compounds were separated on a 60 meter, 0.32 mm I.D. fused silica capillary column with a 1.0  $\mu\text{m}$  film thickness of J&W DB-1 bonded liquid phase.

Air from the canister was drawn through the LiOH packed tube and concentrated onto a sorbent. Sample volumes were measured with a mass flow controller at a fixed flow rate, 100 mL/min. Normally, 500 mL of stack sample was passed through a LiOH tube to remove acid and  $\text{CO}_2$  from stack gas and then concentrated onto the sorbent tube. Ten mL of internal standard was loaded onto the sorbent tube at the same time. The sorbent tube was purged with 500 mL of UHP air to flush out  $\text{CO}_2$  from the sorbent tube. The sorbent tube was loaded onto ACEM Model 900 thermal desorption system. An internal flow of helium purges the tube of residual water vapour and air prior to transfer of the collected analytes to a capillary packed trap for refocusing, then into a GC-MS equipped with wide-bore capillary column and mass spectrometer.

Optimum results were obtained by temperature programming the GC column. Column temperature was initially held for 3 min at  $-60^\circ\text{C}$ , then raised to  $250^\circ\text{C}$  at a rate of  $8^\circ\text{C min}^{-1}$ . The GC-MSD was operated in the selected ion monitoring mode (SIM). Identification of target analytes by SIM is based on a combination of chromatographic retention time and relative abundance of selected monitored ions. Two or three characteristic ions were monitored for each of approximately 145 hydrocarbon compounds found in urban air samples. Since the MSD acquires data for only target ions, this detection technique is considered highly specific and sensitive.

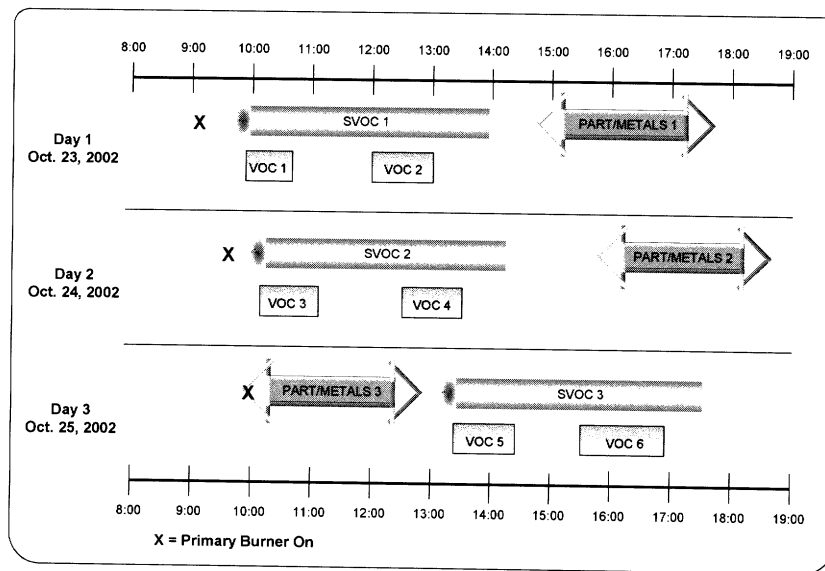
An instrument calibration standard was made from gas standards prepared in the laboratory of Environment Canada from three multi-component liquid mixtures and gas mixture cylinders purchased from Scott Environmental Technology Inc. Quantification was based on five-point linear regression calibration curves.

## 6. RESULTS

### 6.1 General Sampling Data

The general sampling data for the test program is presented in Table 1. This table includes the average velocity, volumetric flow rate (referenced to 25°C and 101.3 kPa), average stack temperature and average moisture. Average oxygen and carbon dioxide levels were determined from the flue gas samples by the procedure described in Section 3.5. The traverse data for each run and summaries are presented in Appendix I. Operating temperatures for the dual primary and single secondary chambers are also included in Appendix I.

The sampling strategy was devised to collect the samples over different segments of the cycle. This approach provides a more realistic profile of the emissions during the incineration cycle. During the first two days, the SVOC sampling was commenced at the start of the cycle. The particulate/metals run followed with the sampling on the second day commencing about 1 hour later than the sample collected on the first day. On the third day, sampling started with the particulate/metals followed by the SVOC run. The sampling for each test day commenced 35, 23 and 15 minutes following ignition of the primary burners. One VOC canister was collected during each SVOC traverse. The sampling schedule is illustrated in Figure 7.



**Figure 7 Eco Waste Sampling Schedule**

The waste for the three days was delivered and piled outside the facility. Waste loaded to each primary chamber is recorded in Table 1. Two scenarios were used for the purpose of calculating emission rates – 100 and 250 cycles per year. These correspond to 2 and 5 cycles per week.

**Table 1 Summary of General Stack Sampling Data**

Process Conditions		Day 1		Day 2		Day 3	
Date (Oct 2002)		23		24		25	
Mass loaded (kg)	Primary 1	914		909		912	
	Primary 2	916		917		917	
Time Burners On	Secondary	08:55		09:25		09:30	
	Primary	09:10		09:38		10:03	
Primary Temperature (°C)		See temperature profiles in Appendix I					
Secondary Temperature (°C)		See temperature profiles in Appendix I					
Sampling Conditions		SVOC 1	Part/M-1	SVOC 2	Part/M-2	Part/M-3	SVOC 3
Date (Oct 2002)		23	23	24	24	25	25
Sampling Time (local)		09:45 - 13:53	15:07 – 17:15	10:01 - 14:10	16:07 – 18:11	10:18 – 12:24	13:16 – 17:26
Test Duration (min)		240	120	240	120	120	240
Isokineticity (%)		96.1	96.0	99.4	96.9	100.3	100.3
Sample Volume (m³)		4.075	1.891	3.894	1.903	1.983	4.043
Stack Gas Characteristics							
Flow Rate (m³/min)		71.64	66.79	65.73	66.72	67.04	67.74
Actual Velocity (m/s)		6.78	5.90	5.98	5.88	6.25	6.13
Temperature (°C)		705	666	669	671	688	675
Moisture (%)		10.09	7.59	10.10	6.92	10.25	8.13
Oxygen (%)		13.9	15.2	13.9	14.7	14.3	14.8
Carbon Dioxide (%)		4.5	3.2	4.5	3.6	4.5	3.7
Molecular Weight (lb/lb-mole)		29.28	29.12	29.28	29.16	29.29	29.18

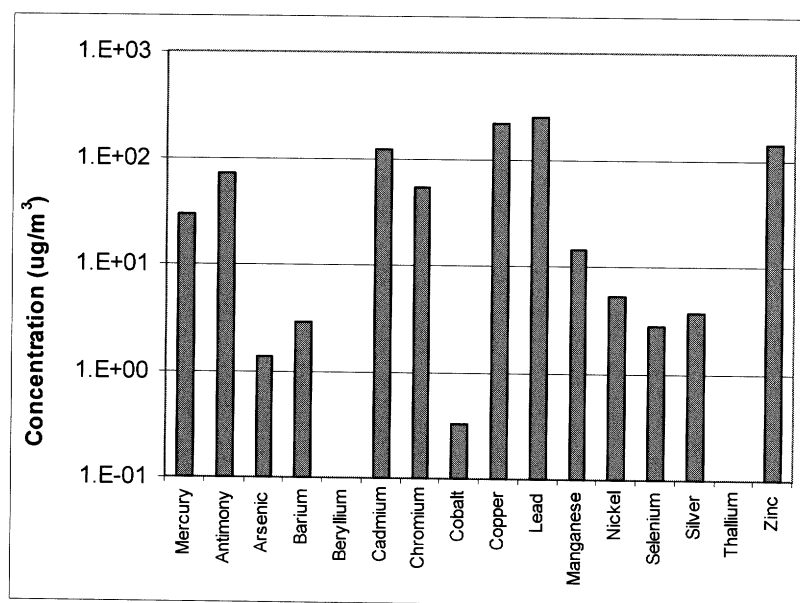
*All volumes are expressed on a dry basis referenced to 25°C and 101.325 kPa.*

## 6.2 Particulate, Acid Gases and Metals

The concentrations of particulate, acid gases and metals are shown in Table 2. Particulate emissions ranged from 6 to 23 mg/m<sup>3</sup> (average 10.5 mg/m<sup>3</sup>) corrected to 11 percent oxygen. The largest particulate level was observed in the third run where the sample was collected at the beginning of the burn cycle. Particulate levels for the two runs collected towards the end of the burn were 6.0 and 2.9 mg/m<sup>3</sup> with the latter value corresponding to the run collected closest to the end of the cycle. HCl levels ranged from 97 to 262 mg/m<sup>3</sup> with the higher value measured during the beginning of the burn. HF concentrations varied between 1.7 and 3.3 but the higher levels were measured towards the latter part of the batch cycle.

The front- and back-half fractions were analysed separately. As expected, all the mercury was associated with the back-half fraction. With the exception of three metals, the majority was consistently found in the front-half of the train. Two of these three metals, manganese and nickel, exhibited partitioning towards the front-half of the train in the run that was collected at the beginning of the cycle (77 and 84% respectively). The partitioning was skewed towards the back-half in the first and second runs for manganese (88/74%) and nickel (59/61%) respectively. In contrast, selenium distribution was skewed toward the back-half when the sample was collected at the start of the burn (70% in the back-half) compared to the two runs (71 and 66% in the front-half) collected towards the end of the cycle. Two metals, beryllium and thallium were not detected in the train samples. Mercury was detected in all runs but was very variable. Levels varied between 4.7 and 72.2 µg/m<sup>3</sup>. For most of the metals, the levels in Run 3 (start of burn) were substantially higher than concentrations measured towards the end of the burn. No difference was noted for chromium.

The average (see note in Table 2) metal concentrations for the three runs are illustrated in Figure 8.



**Figure 8 Average Metal Concentrations  
(corrected to 11% oxygen)**

Values are plotted on a logarithmic y-axis. Lead, copper, zinc and cadmium accounted for the majority of the reported metals (246, 214, 140 and 120 µg/m<sup>3</sup> respectively). Four metals, mercury, antimony, chromium and manganese, showed average concentrations between 10 and 100 µg/m<sup>3</sup>. The remainder of the metals were below 10 µg/m<sup>3</sup> of which cobalt was below 1 µg/m<sup>3</sup>. As mentioned previously, beryllium and thallium were not detected.

**Table 2 Summary of Particulate, Acid Gases and Metals Concentrations  
(corrected to 11% oxygen)**

Pollutant	Part/M-1		Part/M-2		Part/M-3		Average*	
Particulate (mg/m <sup>3</sup> )	6.0		2.9		22.7		10.5	
HCl / HF (mg/m <sup>3</sup> )	97	3.3	113	4.0	262	1.7	157	3.0
HCl / HF (ppm)	65	4.0	76	4.9	175	2.0	105	3.6
<b>Metals (µg/m<sup>3</sup>)</b>								
Mercury	11.2		72.2		4.7		29.4	
Antimony	32.6		92.3		90.8		71.9	
Arsenic	0.9		0.9		2.2		1.3	
Barium	0.2		3.2		5.3		2.9	
Beryllium	0.0		0.0		0.0		0.0	
Cadmium	21.7		35.4		303		120	
Chromium	56.5		49.2		53.4		53.1	
Cobalt	0.3		0.2		0.5		0.3	
Copper	138		161		343		214	
Lead	62.1		160		515		246	
Manganese	11.6		10.4		21.0		14.4	
Nickel	2.9		2.7		10.2		5.3	
Selenium	2.1		2.7		3.6		2.8	
Silver	3.3		3.5		4.3		3.7	
Thallium	0.0		0.0		0.0		0.0	
Zinc	57.7		88.0		274		140	

All volumes are expressed on a dry basis referenced to 25°C and 101.325 kPa.

"0" denotes not detected.

\* The average was based on the mean of the three runs.

### 6.3 Flue Gases

The concentrations of oxygen, carbon dioxide, carbon monoxide, nitrogen oxides and sulphur dioxide are summarized in Table 3. Carbon monoxide, nitrogen oxides and sulphur dioxide are corrected to 11 percent oxygen. The values summarized in Table 3 represent the arithmetic average of the half-hour integrated bag samples. Detailed data for all the runs is given in Appendix I.

**Table 3 Summary of Flue Gas Concentrations**

Run	O <sub>2</sub> (%)	CO <sub>2</sub> (%)	CO* (ppm)	NO* (ppm)	NO <sub>2</sub> * (ppm)	NO <sub>x</sub> * (ppm)	SO <sub>2</sub> * (ppm)
Part/M-1	15.2	3.2	9	50	4	54	0
Part/M-2	14.7	3.6	6	47	3	51	0
Part/M-3	14.3	4.5	4	45	4	49	0
SVOC 1	13.9	4.5	0	36	2	38	0
SVOC 2	13.9	4.5	3	40	3	43	2
SVOC 3	14.8	3.7	4	40	3	43	0
Ave**	14.4	4.1	3.6	41.7	3.0	44.7	0.5
Std Dev**	0.5	0.5	2.7	8.0	1.7	9.6	1.9

\* Corrected to 11% oxygen. \*\* All data points

In general, oxygen levels were 13.5 to 14 % at the start of the burn and increased to 15% by the end of the daily testing. Carbon dioxide followed the reverse trend, starting around 4.6 to 4.9% and decreasing to 3.1 to 3.5%. Sulphur dioxide was detected in only three of the integrated bag samples (SVOC 2). Carbon monoxide levels were below 10 ppm with only one bag sample slightly above 10 ppm. On average, NO represented 93% of the total NO<sub>x</sub>. NO<sub>x</sub> levels showed a declining trend for the first four to five hours after the start of the daily sampling after which they increased for the remainder of the burn.

### 6.4 Dioxins and Furans

PCDD/PCDF data is reported on the basis of the seventeen 2,3,7,8-substituted dioxin and furan congeners. This data is further transformed by multiplying each of the 17 congeners by their respective toxicity equivalency factor (International-TEF or I-TEF). The factors range from 1.0 for 2,3,7,8- TCDD to 0.001 for OCDD and OCDF. The sum of all the 17 factored compounds is known as the TEQ. Analytical results of the loaded trains, field blank train, proofing and method blank samples are presented in Appendix II.

The emission summaries for the TEQ dioxins and furans are given in Table 4. The front- and back-half components of the SVOC train which correspond to the particulate and gaseous

fractions respectively in the sample gas were combined for analysis. Train catches were corrected for the blank train. The blank train level was less than 0.35 pg TEQ/m<sup>3</sup>.

The levels of the 17 congeners are shown in Figure 9. In all runs, the furan TEQ outweighed the dioxin TEQ. On a train total basis, the 10 furan compounds were very consistent representing 81 to 88% of the total train TEQ. Four furan congeners, 2,3,7,8-T4CDF, 2,3,4,7,8-P5CDF, 1,2,3,4,7,8-H6CDF and 2,3,4,6,7,8-H6CDF accounted for 67 to 71% of the total TEQ. On the TEQ basis, the 2,3,4,7,8-P5CDF congener was the largest component (26 to 30% of total) followed equally by 1,2,3,4,7,8-H6CDF (14 to 17%) and 2,3,4,6,7,8-H6CDF (14 to 18%). The 2,3,7,8-T4CDD congener was detected in all runs and accounted for 2.6 to 5.2% of the total TEQ. The congener profiles among the three runs are essentially identical.

Varying TEQ concentrations were measured during the testing. The highest level (71 pg TEQ/m<sup>3</sup>) was measured in SVOC 3 which started about three hours after the ignition of the primary chambers. TEQ concentrations for the two tests conducted shortly after ignition were 10 and 36 pg TEQ/m<sup>3</sup>. The simple average concentration was 38.9 pg TEQ/m<sup>3</sup>. All concentrations are at 11% oxygen.

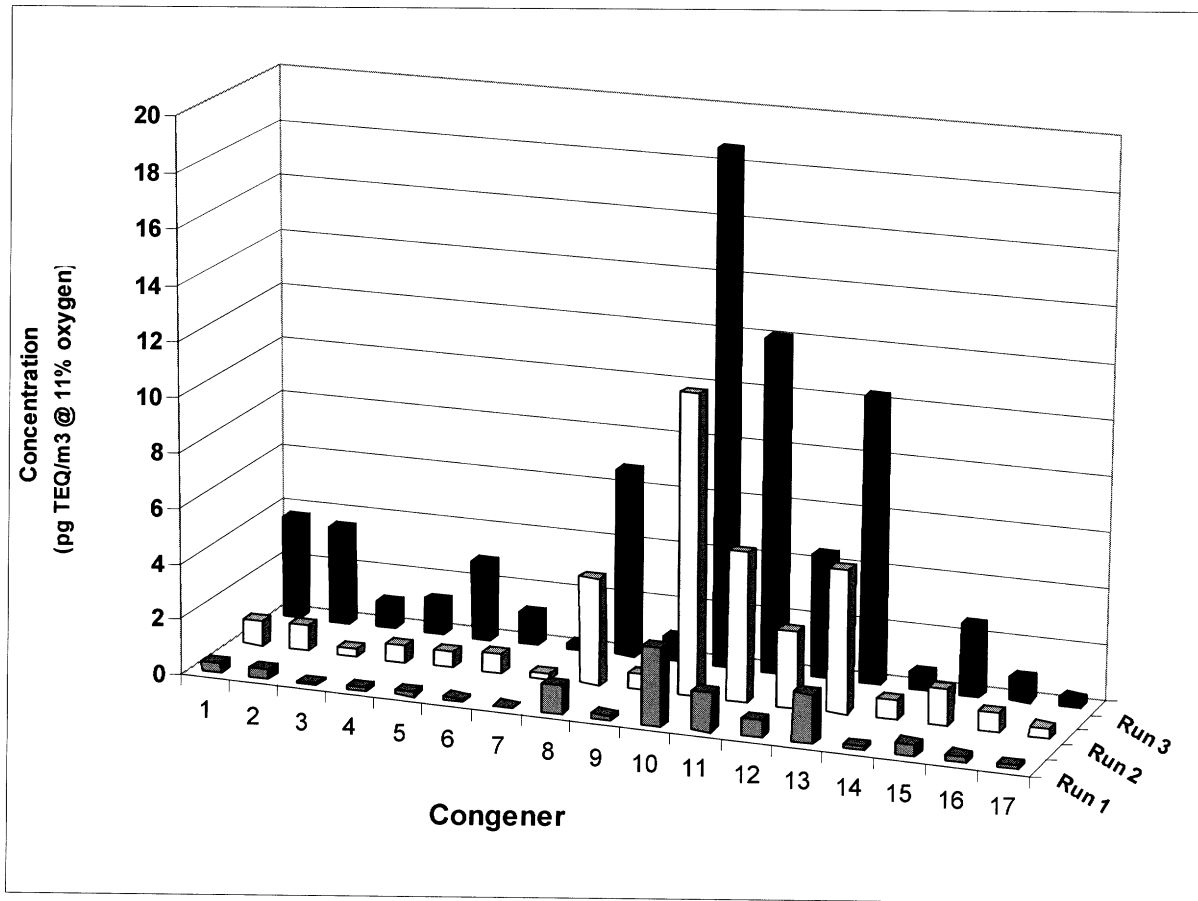


Figure 9 Distribution of TEQ Congeners

**Table 4 Concentrations of Dioxins and Furans**  
**(pg TEQ/m<sup>3</sup> @11% oxygen)**

Compound	SVOC 1	SVOC 2	SVOC 3
2378-T4CDD	0.41	0.92	3.69
12378-P5CDD	0.35	0.92	3.48
123478-H6CDD	0.05	0.29	0.96
123678-H6CDD	0.11	0.59	1.24
123789-H6CDD	0.14	0.56	2.81
1234678-H7CDD	0.12	0.71	1.17
OCDD	0.03	0.18	0.19
2378-T4CDF	1.03	3.84	6.73
12378-P5CDF	0.15	0.56	0.85
23478-P5CDF	2.81	10.82	18.63
123478-H6CDF	1.42	5.36	12.06
123678-H6CDF	0.65	2.78	4.45
234678-H6CDF	1.77	5.15	10.31
123789-H6CDF	0.13	0.70	0.63
1234678-H7CDF	0.44	1.30	2.56
1234789-H7CDF	0.23	0.69	0.88
OCDF	0.13	0.37	0.33
<b>TOTAL</b>	<b>9.98</b>	<b>35.73</b>	<b>70.98</b>

*All values are expressed on a dry basis referenced to 25°C and 101.325 kPa.  
Totals may not add due to rounding.*

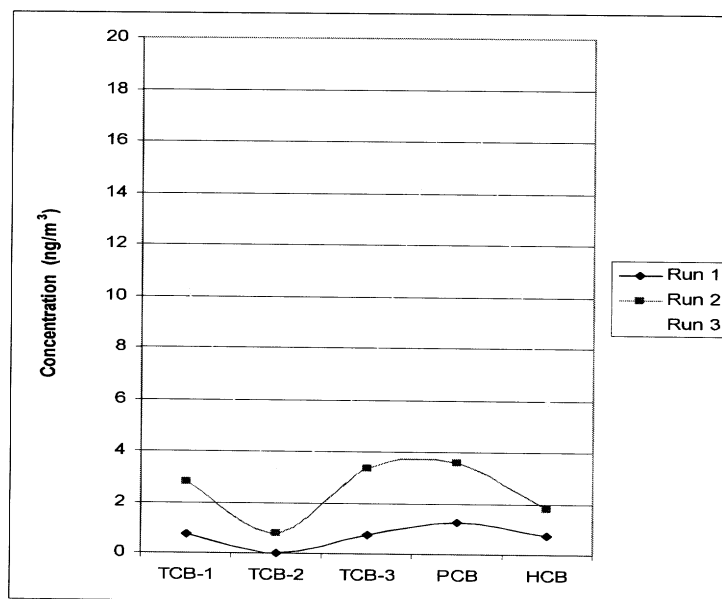
## 6.5 Chlorobenzenes and Octachlorostyrene

The analysis of the SVOC train samples also included chlorobenzenes (CBs) and octachlorostyrene (OCS). Chlorobenzene compounds included 1,2,3,5-tetrachlorobenzene, 1,2,4,5-tetrachlorobenzene, 1,2,3,4-tetrachlorobenzene, pentachlorobenzene and hexachlorobenzene. Concentrations for the five selected chlorobenzenes and octachlorostyrene are summarized in Table 5 and Figure 10. Both train fractions were combined for the analysis of selected chlorobenzenes and octachlorostyrene. Pentachlorobenzene represented the largest component of the chlorobenzene isomers. Total selected CBs ranged between 3.4 and 44 ng/m<sup>3</sup>. Similar to the TEQ dioxins and furans, the highest level for each of the detected compounds was measured in the run collected three hours after ignition. OCS was not detected in any of the three runs. Chlorobenzene concentrations are not corrected to 11 % oxygen.

**Table 5 Concentrations of Chlorobenzenes and Octachlorostyrene (ng/m<sup>3</sup>)**

Compound	SVOC 1	SVOC 2	SVOC 3
1,2,3,5-Tetrachlorobenzene	0.7	2.8	10.1
1,2,4,5-Tetrachlorobenzene	0.0	0.8	3.5
1,2,3,4-Tetrachlorobenzene	0.7	3.3	7.2
Pentachlorobenzene	1.2	3.6	17.3
Hexachlorobenzene	0.7	1.8	5.9
<b>Total selected CBs</b>	<b>3.4</b>	<b>12.3</b>	<b>44.0</b>
Octachlorostyrene	0.0	0.0	0.0

Concentrations are expressed on a dry basis referenced to 25°C and 101.325 kPa.  
 "0" denotes not detectable.



**Figure 10 Chlorobenzene Concentrations**

## 6.6 Polycyclic Aromatic Hydrocarbons (PAHs)

PAH concentrations are summarized in Table 6. As mentioned previously, the front- and back-halves of the sampling train were combined for analysis. Train catches were corrected for the PAHs detected in the blank train. Due to the low PAH loadings from this source, the PAH contribution from the blank, was substantial ranging from 44 to 66% of the uncorrected train catch. PAH analytical results of the loaded trains, blank train, proofing and control samples are presented in Appendix II.

Retene, a compound associated with wood combustion was added to the PAH list. The lighter half of the reported PAHs accounted for 82 to 99 % of the total. The heaviest PAH compound detected in at least one of the runs was benzo(g,h,i)perylene. Fluorene, phenanthrene, fluoranthene, pyrene and retene were the most abundant compounds accounting for 70 to 86% of all the reported PAHs for the three runs. Phenanthrene accounted for 33 to 42% of the total.

The totals for each train were low, ranging from 15 to 39 ng/m<sup>3</sup> (simple average 29 ng/m<sup>3</sup>). These concentrations are not corrected to 11% oxygen. The highest levels were found in the runs that commenced sampling shortly after ignition of the primary. Little difference was noted between Run 1 and Run 2. A plot of the detected PAHs above 1 ng/m<sup>3</sup> is shown in Figure 11.

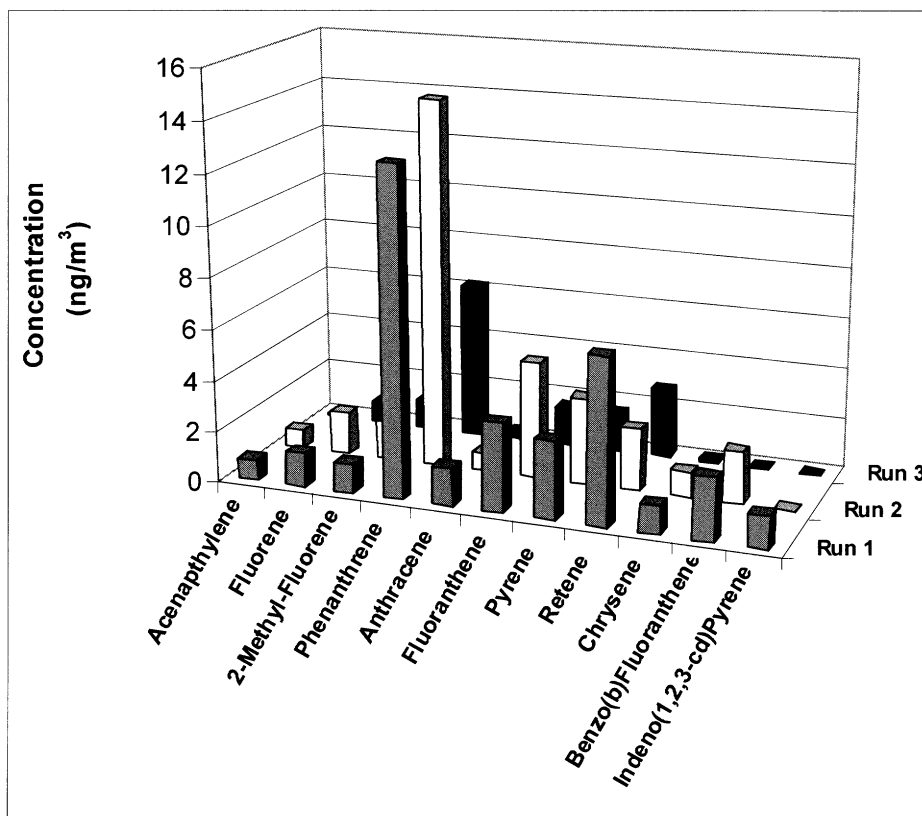


Figure 11 Selected PAH Concentrations

**Table 6 Concentrations of PAHs (ng/m<sup>3</sup>)  
(corrected for blank train)**

Compound	SVOC 1	SVOC 2	SVOC 3
Acenaphthylene	0.8	0.7	0.1
Acenaphthene	0.0	0.0	0.2
Fluorene	1.3	1.7	0.8
2-Methyl-Fluorene	1.2	1.5	1.1
Phenanthrene	12.8	14.5	6.1
Anthracene	1.5	0.7	0.2
Fluoranthene	3.5	4.6	1.5
Pyrene	3.0	3.4	1.5
Retene	6.5	2.4	2.7
Benzo(a)Fluorene	0.0	0.2	0.2
Benzo(b)Fluorene	0.0	0.0	0.0
1-Methyl-Pyrene	0.0	0.2	0.1
Benzo(g,h,i)Fluoranthene	0.0	0.3	0.0
Benzo(a)Anthracene	0.5	0.4	0.0
Triphenylene	0.4	0.3	0.1
Chrysene	1.1	1.0	0.1
7-Methyl-Benzo(a)Anthracene	0.0	0.0	0.0
Benzo(b)Fluoranthene	2.4	2.0	0.0
Benzo(k)Fluoranthene	0.5	0.0	0.0
Benzo(e)Pyrene	0.9	0.7	0.0
Benzo(a)Pyrene	0.0	0.0	0.0
Perylene	0.0	0.0	0.0
3-Methyl-Cholanthrene	0.0	0.0	0.0
Indeno(1,2,3-cd)Pyrene	1.3	0.0	0.0
Dibenzo(a,h)Anthracene	0.0	0.0	0.0
Benzo(b)Chrysene	0.0	0.0	0.0
Benzo(g,h,i)Perylene	0.9	0.0	0.0
Anthanthrene	0.0	0.0	0.0
<b>TOTAL</b>	<b>38.6</b>	<b>34.7</b>	<b>14.9</b>

*Values expressed on a dry basis referenced to 25°C and 101.325 kPa.*

*"0" denotes not detectable.*

## 6.7 Volatile Organic Compounds (VOCs)

The full VOC target list contains 145 compounds, however this list was pared down for reporting purposes as many of the species are of lesser interest. Normally the list is reduced to include BTEX (benzene, ethylbenzene, toluene and xylenes) and halogenated hydrocarbons. Benzene and some halogenated hydrocarbons such as vinyl chloride, 1,3-butadiene, dichloromethane, tri and tetrachloroethene, carbon tetrachloride, 1,1,1-trichloroethane, 1,2-dichloroethane and hexachlorobutadiene are classified as CEPA-toxic substances. Naphthalene, a PAH compound, was also included since it is not reliably determined using the modified Method 5 type train. The full list of VOC concentrations is given in Appendix II.

The emission data for VOCs of interest is summarized in Table 7. Two canister samples were collected during each SVOC run. These are reported separately in Table 7.

**Table 7 Concentrations of Selected VOCs ( $\mu\text{g}/\text{m}^3$ )**

Compound	SVOC 1		SVOC 2		SVOC 3		Overall Average
	Sample 1	Sample 2	Sample 1	Sample 2	Sample 1	Sample 2	
Chloromethane	0.79	4.56	1.34	2.31	1.57	0.85	1.90
<b>Vinyl chloride</b>	0.00	1.72	0.26	1.07	0.36	0.44	0.64
<b>1,3 Butadiene</b>	0.00	11.00	0.00	0.00	0.00	0.00	1.83
<b>Dichloromethane</b>	2.55	2.64	2.24	2.82	1.43	1.03	2.12
<b>Benzene</b>	1.79	99.80	1.60	1.43	1.87	0.95	17.91
Toluene	5831	2072	1258	2660	1170	713	2284
Chlorobenzene	0.10	3.72	0.12	0.26	0.09	0.07	0.73
Ethylbenzene	1.88	17.64	0.79	1.08	0.52	0.28	3.70
Total Above	5838	2213	1265	2668	1176	717	2313
All reported VOCs	5871	3213	1293	2695	1191	731	2499

*All values are expressed on a dry basis referenced to 25°C and 101.325 kPa.*

*Compounds denoted in bold are CEPA-toxic compounds.*

With the exception of sample 2 in SVOC 1, the VOCs reported in Table 7 accounted for +98% of the total VOCs. A high level of propene (verified by reanalysis) was measured in second sample of the first SVOC run. Three CEPA-toxic compounds, 1,2-dichloroethane and 1,1,1-trichloroethane and hexachlorobutadiene were analyzed for but not detected. Other toxics such as carbon tetrachloride, tri and tetra chloroethene were detected but at levels below those usually found in ambient air. Two of the naphthalene results showed levels slightly above ambient.

Toluene, normally found in combustion sources, was the most abundant compound accounting for practically all the detected volatile organic compounds. The higher toluene value in the first canister of the first SVOC run was confirmed by reanalyzing the canister. Except for the benzene, toluene and ethylbenzene reported above, other components of BTEX were detected but were found to be around those levels normally found in ambient air.

No agreement was evident among the three pairs of canisters. Using pair averages, the total VOCs for each of the three runs were 4540, 1994 and 960  $\mu\text{g}/\text{m}^3$ . The average VOC level is in the order of 600 ppb on a volume/volume basis. The highest levels of VOCs were measured in

the samples collected at the start of the cycle (SVOC1 and SVOC 2). No pattern was evident between the first and second canister of each SVOC run.

## 6.8 Estimated Emission Rates

The annual emission rates for the particulate/metals and organic runs are given in Table 9. One of the difficulties associated with the calculation of the emission rates is the estimation of the concentration over the oxidizer cycle for each of the pollutants. Pollutant levels are a result of feed material, process operation and the portion of the burn cycle in a batch process. In this program, sampling was staggered as much as possible to provide a more representative variation of the emissions over the cycle.

Normally, the concentration used for calculating emission rates is the arithmetic average of three runs. In this case, this approach may introduce a bias for some of the pollutants as two of the runs were essentially duplicates of the same portion of the cycle. A selective average was also calculated based on the average between the two runs collected during the same part of the cycle and the remaining run. A comparison of these two averaging techniques is illustrated in Table 8.

**Table 8 Effect of Averaging Method on Uncorrected Concentrations**

Pollutant	Three Run Average		Selective Average	
Particulate/Acid Gases/Metals				
Particulate (mg/m <sup>3</sup> )	6.78		8.87	
HCl / HF (mg/m <sup>3</sup> )	100.3	1.8	118.9	1.6
Mercury	18.27		14.49	
Antimony	45.70		49.40	
Arsenic	0.86		1.01	
Barium	1.89		2.30	
Cadmium	78.9		109.7	
Chromium	33.00		33.66	
Cobalt	0.20		0.23	
Copper	136.4		159.5	
Lead	159.7		205.6	
Manganese	9.09		10.32	
Nickel	3.39		4.23	
Selenium	1.75		1.90	
Silver	2.33		2.46	
Zinc	90.3		113.3	
Organics				
Dioxins and Furans (pg TEQ/m <sup>3</sup> )	25.35		29.95	
PAHs (ng/m <sup>3</sup> )	29.40		25.78	
CBs (ng/m <sup>3</sup> )	19.93		25.95	
VOCs (µg/m <sup>3</sup> )	2499		2115	

Table 8 shows that the selective approach results in higher average concentrations for particulate, HCl, most metals, dioxins and furans and chlorobenzenes. VOCs and PAHs display the opposite bias. The difference for mercury is irrelevant as the emissions are probably directly related to the feed input. Neither method is invalid but this exercise serves to illustrate that the assumptions have an impact on emission levels. For the purpose of this program, the simple average of three runs will be used to estimate annual emissions. Two scenarios were used for estimating annual emission rates – 100 and 250 cycles per year.

**Table 9 Estimated Annual Emission Rates**

BASIS: AVERAGE OF THREE RUNS			
Ten hour cycle			
100 and 250 batches per year			
Stack flow rate - average of all runs			
Pollutant	Average* Concentration	Annual Emission Rate	
		100 batches	250 batches
Particulate, Acid Gases and Metals			
Particulate	6.78 mg/m <sup>3</sup>	27.5 kg/year	68.8 kg/year
HCl	100.2 mg/m <sup>3</sup>	407 kg/year	1017 kg/year
HF	1.83 mg/m <sup>3</sup>	7.4 kg/year	18.5 kg/year
	(µg/m <sup>3</sup> )	(g/year)	(g/year)
Metals			
Mercury	18.3	74	185
Antimony	45.7	185	463
Arsenic	0.9	3	9
Barium	1.9	8	19
Beryllium	not detected	-	-
Cadmium	78.9	320	800
Chromium	33.0	134	335
Cobalt	0.2	1	2
Copper	136.4	553	1384
Lead	159.7	648	1619
Manganese	9.1	37	92
Nickel	3.4	14	34
Selenium	1.7	7	18
Silver	2.3	9	24
Thallium	not detected	-	-
Zinc	90.3	366	916
Organics			
Dioxins and Furans (TEQ)	25.35 pg TEQ/m <sup>3</sup>	0.103 mg/year	0.257 mg/year
TCB (3 isomers)	9.73 ng/m <sup>3</sup>	0.039 g/year	0.099 g/year
PCB	7.38 ng/m <sup>3</sup>	0.030 g/year	0.075 g/year
HCB	2.82 ng/m <sup>3</sup>	0.011 g/year	0.029 g/year
PAHs	29.4 ng/m <sup>3</sup>	0.119 g/year	0.298 g/year
OCS	not detected	-	-
VOCs	2499 µg/m <sup>3</sup>	10.1 kg/year	25.3 kg/year

\*Uncorrected concentrations at reference conditions used to calculate emission rates.

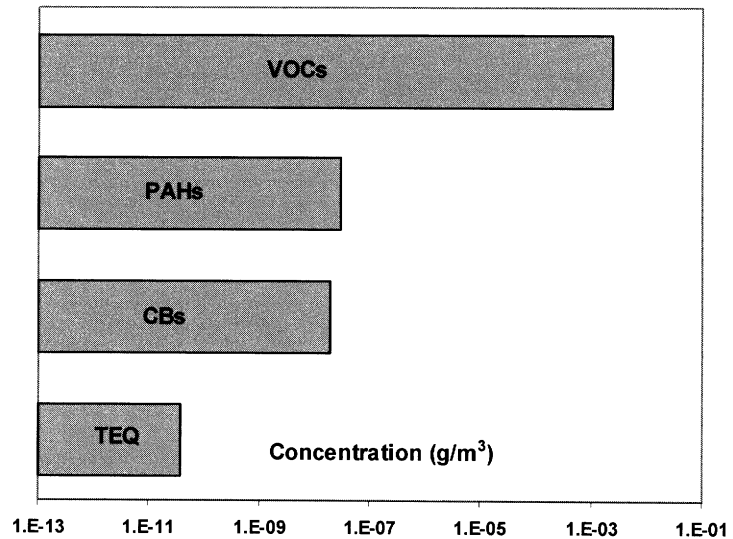
## 7. SUMMARY

Concentration data is summarized below. The relative abundances (on a logarithmic scale) for the organic compounds and metals are illustrated in Figure 12.

Compound	Concentration
PCDDs/PCDFs*	38.9 pg TEQ/m <sup>3</sup>
CBs (5 isomers)	19.9 ng/m <sup>3</sup>
OCS	0 ng/m <sup>3</sup>
PAHs	29.4 ng/m <sup>3</sup>
VOCs	2499 µg/m <sup>3</sup>
Particulate*	10.5 mg/m <sup>3</sup>
HCl*	157 mg/m <sup>3</sup>
HF*	3.0 mg/m <sup>3</sup>

\* at 11% oxygen

0 denotes not detected.



Metals* (µg/m <sup>3</sup> )	
Mercury	29.38
Antimony	71.9
Arsenic	1.3
Barium	2.9
Beryllium	0.0
Cadmium	120.0
Chromium	53.1
Cobalt	0.3
Copper	214.2
Lead	245.5
Manganese	14.4
Nickel	5.3
Selenium	2.8
Silver	3.7
Thallium	0.0
Zinc	139.8

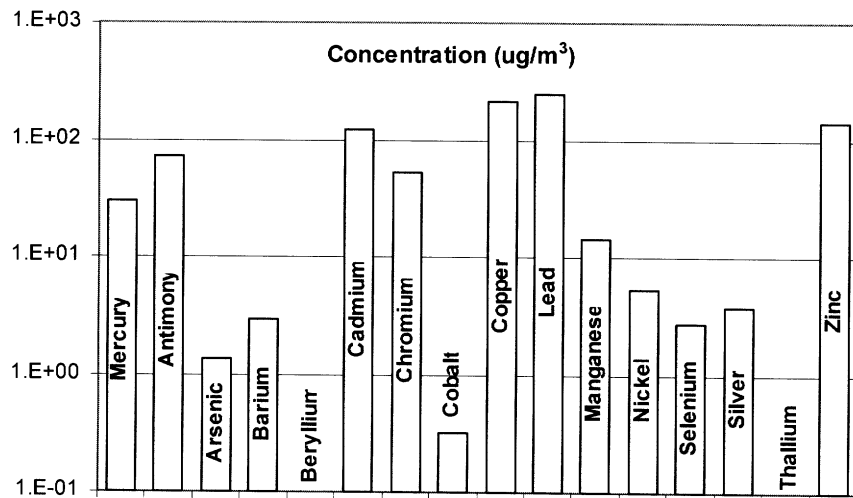


Figure 12 Summary of Emission Results

## **APPENDIX I**

(Only available with hard copy)

**Waste Oxidizer Temperature Data**

**Flue Gas Monitoring Data**

**SVOC Traverse Data**

**Particulate /Metals Traverse Data**

## **APPENDIX II**

(Only available with hard copy)

**Anion, Particulate and Metals Analysis**

**Dioxin, Furan, CB and OCS Analytical Report**

**VOC Analytical Data**