3.0 PROCESS EVALUATION

3.1 OVERVIEW

A process evaluation and cost estimate was developed for a direct-fired thermal desorption system that is owned by Environmental Chemical Corporation of Burlingame, California. This is the same equipment that will be used for the Allied Feed site at Homebush Bay. This section of the report presents the following items for the direct fired thermal desorption system:

- Process description
- Technology development status
- Historical soil treatment results
- Mass and energy balance
- Emissions estimate
- Process implementation issues

3.2 PROCESS DESCRIPTION

A schematic diagram of the direct-fired rotary dryer system is shown in Figure 3-1. The system includes a feed hopper, weigh belt conveyor, rotary dryer, cyclone, thermal oxidizer, evaporative cooler, baghouse, ID fan, quench, packed scrubber and stack. Brief descriptions of each of the key unit operations in the process are presented below.

- Rotary dryer – The rotary dryer is 11.28 m long with a 2.44 m inside shell diameter (37-foot long by 8-foot diameter). The rotary dryer is equipped with a natural gas fired burner and a combustion air blower. The rotary dryer is constructed of a carbon steel shell with internal lifters. The nominal waste feed rate to the rotary dryer is 31.8 tonnes/hr (35 tons/hour) at an average feed material moisture content of 13% by weight. The rotary dryer will be operated to achieve a treated soil temperature of 454°C (850°F). The residence time of the material in the drum is approximately 10-20 minutes.
- Cyclone – gases from the rotary kiln pass through a hot cyclone to remove large particulate matter.
- Thermal oxidizer – the gas exiting the cyclone will be directed to a thermal oxidizer operating in the exit gas temperature of approximately 954°C (1,750°F). The thermal oxidizer is equipped with a natural gas fired burner with a capacity of approximately 47 GJ/hr (45 MM Btu/hr).
- Evaporative Cooler – the gas exiting the thermal oxidizer is partially quenched in a refractory lined evaporative cooler. Process water is injected at the top of the evaporative cooler and atomized with compressed air to make small droplets. As the water droplets evaporate, the gas is cooled to a temperature of approximately 192°C (377°F). This temperature must be controlled to stay below the maximum temperature rating on the baghouse bags (~232°C or 450°F) but above the temperature at which condensation of acid gases could occur (~149°C or 300°F).
- Activated Carbon Injection System - an activated carbon injection system will meter powdered activated carbon into the flue gas upstream of the baghouse. The objective of the powdered carbon injection will be to control mercury emissions.

- Baghouse – a pulse jet baghouse is used to capture particulates and metals. In order to minimize corrosion, the interior of the baghouse is epoxy coated. Acid resistant P-84 bags will be used in order to achieve a particulate emission concentration of < 30 mg/Nm^3 corrected to 11% oxygen. The baghouse system includes an air compressor to supply air to pulse the baghouse.
- ID fan – an induced draft fan is used as the prime mover to pull gases through the system and exhaust it to the scrubber. The capacity of the ID fan is approximately 1,830 m^3/min at 5 kPa at a temperature of 192°C (66,000 acfm at 20 inch w.c. at temperature of 377°F).
- Quench - the gas exiting the ID fan is directed to a full quench. Fresh process water is sprayed into the quench to cool the gas to the adiabatic saturation temperature of approximately 85°C (185°F). Excess water from the quench drains into the packed scrubber sump.
- Scrubber – the gas exiting the ID fan is directed to a packed scrubber. The scrubber is packed with approximately 2 meters (6 feet) of 5-cm (2-inch) Tellerette packing. A sodium hydroxide solution is injected into the scrubber sump to neutralize acid gases (HCl and SO_2). A recirculation pump recycles scrubber water from the sump to the top of the packing. The scrubber gas exhausts to the stack.

3.3 TECHNOLOGY DEVELOPMENT STATUS

The purpose of evaluating a technology's development status is to compare relative risks with other technologies from project implementation, technical, performance, and cost standpoints. In general, technologies that have been used on a number of other similar projects present fewer risks because potential operating problems have been identified, solved and a knowledge base exists from which to estimate system performance, schedules and costs.

This section summarizes the historical usage of direct thermal desorption systems for treating soil contaminated with halogenated organic compounds. Table 3-1 presents a list of applications that identifies key information, such as the site name and location, types of contaminants treated, type of thermal desorption equipment used, etc. As shown in Table 3-1, 44 projects have been completed in which a directly heated thermal desorption system was used to treat soils contaminated with chlorinated compounds. The total quantity of soil treated during these projects was approximately 739,000 tonnes (813,000 tons).

3.4 HISTORICAL SOIL TREATMENT RESULTS

Table 3-2 summarizes treated soil data for a project (Woods Industries) where a directly heated thermal desorber was used to treat soils that were contaminated with pesticides. Hexachlorobenzene was spiked into the soil in order to determine the capability of the system to meet soil cleanup standards and stack emissions standards. It should be noted that in all cases, residual soil concentrations of HCB were achieved that met the site specific performance standard of 0.65 mg/kg for HCB. The measured results were higher than the 0.10-0.25 mg/kg concentrations that may be required for individual compounds to achieve a "non-waste" status for the Orica project (depending on the number of SCW compounds present). Soil treatment outcomes from the Orica project would be project specific and depend on the characteristics of the plant chosen to undertaken the work, as well as the characteristics of the soil and contaminants. The above result provides an indication of the likely outcome.

3.5 MASS & ENERGY BALANCE

A mass and energy balance was performed for the rotary dryer system. A detailed printout from the mass and energy balance is included in Appendix A. Key inputs that were used in developing the mass and energy balance and key results from the mass and energy balance include:

• Soil feed rate	31.8 tonnes/hr	(35 tons/hour)
• Rotary dryer fuel usage	42.63 MM Btu/hr	(44.76 GJ/hr)
• Thermal oxidizer fuel usage	43.25 MM Btu/hr	(45.41 GJ/hr)
• Treated soil temperature	454°C	(850°F)
• Thermal oxidizer outlet gas temperature	954°C	(1,750°F)
• Evaporative cooler exit gas temperature	192°F	(377°F)
• Scrubber exit gas temperature	84°C	(184°F)
• Cyclone pressure drop	1.5 kPa	(6.0 inches w.c.)
• Baghouse pressure drop	1.5 kPa	(6.0 inches w.c.)
• Scrubber pressure drop	0.75 kPa	(3.0 inches w.c.)
• Evaporative cooler water usage	280 liters/min	(74 gpm)
• Pugmill water usage	91 liters/min	(24 gpm)
• Quench water usage	60 liters/min	(16 gpm)
• Packed scrubber water usage	23 liters/min	(6 gpm)
• Scrubber purge water flow rate	45 liters/min	(12 gpm)
• NaOH usage	92.3 kg/hr	(203 lb/hr).

3.6 EMISSION ESTIMATE

An emission estimate was developed for the Orica application based on the following factors:

- Site specific waste composition information
- Site specific waste quantity information
- Mass and energy balance calculations
- Historical data from other projects.

Table 3-3 summarizes actual stack emission results for five different projects in which a directly heated thermal desorption system was used to treat contaminated soils. Table 3-4 summarizes stack emission data for a project in which HCB was the primary contaminant (Woods Industries). These data show that the destruction and removal efficiency (DRE) for HCB was greater than 99.99%. DRE is calculated as:

$$\frac{\text{(HCB mass in feed soil)} - \text{(HCB mass in stack gas)}}{\text{(HCB mass in feed soil)}} \times 100\% \qquad \text{Equation 1.}$$

An emissions estimate was prepared for a direct thermal desorption system operating at the Orica site. Emissions estimates are presented as both concentrations and mass emission rates. A summary of these estimates is presented in Table 3-5. Appendix C presents emission estimate calculations. Insufficient waste characterization data is available to develop emissions estimates for many of the projected emission parameters.

For most of the parameters listed, the projected emission limits are likely to be readily achievable. However, achieving the mercury standard will require about 85% control efficiency. Historical data indicates that about 20-50% mercury control efficiency has been achieved in DTD systems that use a baghouse and a wet scrubber only. However, process operations during these projects were not optimized to obtain a high degree of mercury control. Control of mercury emissions is complex and the degree of control depends on the form of the mercury in the waste (elemental or ionic), the chlorine content of the process gas, the temperature of the process gas, and the operating conditions in control devices such as baghouses and scrubbers. In order to enhance the degree of mercury control, it has been assumed that this system will include a system that injects powdered activated carbon into the process gas upstream of the baghouse.

3.7 PROCESS IMPLEMENTATION ISSUES

Several process issues need to be further developed and/or evaluated for the rotary dryer system:

- Fugitive emissions – because of the concentration, volatility, and toxicity of HCBD, a thorough evaluation should be conducted of potential fugitive emissions and control alternatives in the feed preparation area.
- Waste characterization data gaps - Inadequate site characterization data are available to estimate emissions rates for many of the regulated parameters (specifically the number of SCW compounds present, sulfur dioxide, hydrogen fluoride, and several heavy metals).
- Stack gas performance standards – the analysis presented in this report assumes that the rotary dryer system is required to meet stack gas emission limits similar to those that were developed for the Allied Feeds site as presented in Table 2-3. Based on historical stack gas emission results from similar systems, most of these standards should be readily achievable. However, the existing emission estimate should be completed once waste characterization data gaps are addressed.
- Mercury control - based on the limited existing site characterization data, an emission control efficiency of approximately 85% will be required for mercury. Alternative methods (activated carbon injection, wet scrubbing) to comply with the mercury emissions standards should be evaluated in more detail.

4.0 PROJECT SCHEDULE

An estimated project schedule if presented in Table B-4 of Appendix B. This table includes estimated schedules for many tasks (equipment procurement, planning and design, site preparation and construction, etc.) that are based on historical data for similar projects. The thermal treatment operations schedule is calculated based on the following assumptions:

- 66,750 tonnes of soil (72,889) treated (excluding debris which is not thermally treated)
- Performance test program duration of 30 days (including test execution, sample analysis, and evaluation of data)
- Operating schedule of 24 hours/day, 7 days per week
- Operating factor of 50% during the performance test phase
- Operating factor of 72% during the operations phase.

These assumptions result in the following estimated average daily soil throughput values:

• Performance test period	382 tonnes/day (420 tons/day)
• Production operations	550 tonnes/day (605 tons/day).

Tables

Table 2-1. Waste Characterization Summary

Parameter	Units	Waste Source					
		BCPE Contents	Capping Layer	Landscaping Layer	Base Layer 0 to 1 m below base layer	Base Layer 1 to 2 m below base layer	Total
Waste Volume							
Bitumen	(m^3)	NA	Incl. below				0
Crushed Rock	(m^3)	NA	2,484				2,484
Sand	(m^3)	26,000	Incl. above	17,020	13,250	14,350	70,620
Ash	(m^3)	17,090					17,090
Peat	(m^3)	2,500					2,500
Debris	(m^3)	2,227					2,227
Other (assumed)	(m^3)	915					915
Hypalon liner	(m^3)	16					16
Subtotal	(m^3)	48,748	2,484	17,020	13,250	14,350	95,852
Waste Density							
Bitumen	tonnes/m^3						
Crushed Rock	tonnes/m^3						
Sand	tonnes/m^3	1.64					1.64
Ash	tonnes/m^3	1.26					1.26
Peat	tonnes/m^3	1.00					1.00
Debris (assumed)	tonnes/m^3	1.00					1.00
Other (assumed)	tonnes/m^3	1.00					1.00
Hypalon liner (assumed)	tonnes/m^3	1.00					1.00
Calc. Weighted Avg	tonnes/m^3	1.43					1.43
Assumed Wt. Avg (min)	tonnes/m^3	1.45					1.45
Assumed Wt. Avg (max)	tonnes/m^3	1.65					1.65
Assumed Wt. Avg (avg)	tonnes/m^3	1.55	1.8	1.6	1.8	1.8	8.55

Table 2-1. Waste Characterization Summary

Parameter	Units	Waste Source					
		BCPE Contents	Capping Layer	Landscaping Layer	Base Layer 0 to 1 m below base layer	Base Layer 1 to 2 m below base layer	Total
Waste Mass							
Bitumen	(tonnes)						
Crushed Rock	(tonnes)		4,471				4,471
Sand	(tonnes)	42,575		27,232	23,850	25,830	119,487
Ash	(tonnes)	21,533					21,533
Peat	(tonnes)	2,500					2,500
Debris	(tonnes)	2,227					2,227
Other (assumed)	(tonnes)	915					915
Hypalon liner	(tonnes)	16					16
Subtotal (calc. from vol & density)	(tonnes)	69,766	4,471	27,232	23,850	25,830	151,150
Reported Mass (min)	(tonnes)	64,570					64,570
Reported Mass (avg)	(tonnes)	69,750					69,750
Reported Mass (max)	(tonnes)	75,075					75,075
Organic Chemicals							
HCBD	(mg/kg)	2,145	2.2	19.0			
HCE	(mg/kg)	455		1.2			
HCB	(mg/kg)	150		0.1			
OCS	(mg/kg)	202					
PCE	(mg/kg)	64		67.0			
EDC	(mg/kg)	No data					
1,1,2-TCA	(mg/kg)	No data					
1,1,2,2-PCA	(mg/kg)	No data					
Other Volatile CHC	(mg/kg)	3.6					
Other Semi-Volatile CHC	(mg/kg)	0.9					
TPH	(mg/kg)			1,460			
MAHs (total)	(mg/kg)			102			
Subtotal	(mg/kg)	3,021	2.2	1,649			
Reported Subtotal	(mg/kg)	3,600					

Table 2-1. Waste Characterization Summary

		Waste Source					
Parameter	Units	BCPE Contents	Capping Layer	Landscaping Layer	Base Layer 0 to 1 m below base layer	Base Layer 1 to 2 m below base layer	Total
Metals							
Cadmium	(mg/kg)	0.7					
Chromium	(mg/kg)	25					
Copper	(mg/kg)	9.7					
Lead	(mg/kg)	20.6					
Zinc	(mg/kg)	76.5					
Mercury	(mg/kg)	0.86					
Physical Parameters							
Moisture	(wt%)	13	4	8	7	7	
TOC	(mg/kg)	13,000	Low	Low	Low	Low	
COD	(mg/kg)	99,200					
pH (1 to 5 water extract)	std. units	7.9					
TDS (1 to 5 water extract)	mg/l	1,161					
Particle Size Analysis (Avg)							
< 0.05	(mm)	9					
0.05 - 0.2 mm	(mm)	19					
0.2 - 0.6	(mm)	58					
0.6 - 2.0	(mm)	8					
2.0 - 6.0	(mm)	4					
6.0 - 20	(mm)	2					
Cumulative Particle Size							
< 0.05	(mm)	9					
< 0.2	(mm)	28					
< 0.6	(mm)	86					
< 2.0	(mm)	94					
< 6.0	(mm)	98					
< 20	(mm)	100					

Table 2-1. Waste Characterization Summary

Parameter	Units	Waste Source					
		BCPE Contents	Capping Layer	Landscaping Layer	Base Layer 0 to 1 m below base layer	Base Layer 1 to 2 m below base layer	Total
Ultimate Analysis							
Carbon	(%)	1.30					
Hydrogen	(%)	0.12					
Oxygen	(%)	0.66					
Nitrogen	(%)	0.04					
Chlorine	(%)	0.24					
Sulfur	(%)	0.01					
Subtotal	(%)	2.36					
Proximate Analysis							
Moisture	(%)	13					
Volatiles	(%)	2.36					
Ash	(%)	84.64					
Calorific Value							
Higher heating value	Btu/lb	217					
Higher heating value	MJ/kg	0.503					

(a) Includes polyethylene granules, drums, drum liners, steel reinforcement,
Scrap steel sections, scrap pipework, timber, logs, Raschig rings.
(b) Sodium carbonate, catalyst pellets

Table 2-2. Physical and Chemical Properties of Organic Contaminants

					Molecular Composition									Physical Properties		
Chemical or Constituent	Acronym	CAS No.	Formula	Molecular Weight (g-g-mole)	C (%)	H (%)	Cl (%)	S (%)	O (%)	N (%)	Inert (%)	Total (%)	Conc. in Soil (mg/kg)	Boiling Point (°C)	Melting Point (°C)	Water Solubility (mg/l)
Hexachlorobenzene	HCB	118741	C_6Cl_6	284.8	25.3	0.0	74.7					100.0	150	325	231	0.0062
Hexachlorobutadiene	HCBD	87683	C_4Cl_6	260.8	18.4	0.0	81.6					100.0	2,145	215	-21	3.2
Hexachloroethane	HCE	67721	C_2Cl_6	236.7	10.1	0.0	89.9					100.0	455	186		50
Tetrachloroethylene	PCE	127184	C_2Cl_4	165.8	14.5	0.0	85.5					100.0	64	121	-19	206
Octachlorostyrene	OCS	29082744	C_8Cl_8	379.7	25.3	0.0	74.7					100.0				Insoluble
Dichloroethane, 1,2-	EDC	107062	$C_2H_4Cl_2$	99.0	24.3	4.1	71.7					100.0		57.4	-96.9	5,100
Trichloroethane, 1,1,2-	1,1,2-TCA	79005	$C_2H_3Cl_3$	133.4	18.0	2.3	79.7					100.0		113.8	-36.6	1,100
Tetrachloroethane, 1,1,2,2-	1,1,2,2-PCA	79345	$C_2H_2Cl_4$	167.9	14.3	1.2	84.5					100.0		146.5	-44	2,870
Peat, dry basis (a)	NA	NA	NA		53.6	5.0			28.3	1.7	11.4	100.0	23,225			
Hypalon	NA	NA	C_2H_2ClS (b)	93.6	25.7	2.2	37.9	34.3				100.0	229			
Total													26,269			

(a) Pajunen, Hannu, Physical and Chemical Properties of Peat in Rwanda, Central Africa. Geological Survey of Finland, Bulletin 394, http://www.gsf.fi/info/bt394.html.

Table 2-3. Stack Emission Standards and Regulations

		Stack Emission Concentration[1]						
						2000/76/EC**		
Parameter	Units of Measure	Lednez ITD Stack Consent[2]	Allied Feeds DTD Consent[3]	Orica GTP Operating License Limits	CAPER*	Daily Avg.[4]	Half Hourly Avg. (100%)	Half Hourly Avg. (97%)
Sulphuric acid mist (H_2SO_4) or sulphur trioxide (SO_3), or both (as SO_3)	mg/m^3	-	100	-	100	-	-	-
Sulfur dioxide	mg/m^3	-	-	100	-	50	200	50
Chlorine (Cl_2)	mg/m^3	200	200	30	200	-	-	-
Hydrogen chloride (HCl)	mg/m^3	100	100	30	100	10	60	10
Any fluorine compound (HF)	mg/m^3	-	50	-	50	1	4	2
Nitrogen dioxide (NO_x) or nitric oxide (NO) or both	mg/m^3	150	500	400	2000[5]	200	400	200
Hazardous substances (Sb, As, Cd, Pb, Hg, Be, Cr, Co, Mn, Ni, Se, Sn, V)	mg/m^3	-	0.5	-	5	-	-	-
Cadmium	mg/m^3	-	0.1	-	1	-	-	-
Mercury	mg/m^3	-	0.1	-	1	0.05	-	-
Hazardous substances (Sb, As, Pb, Cr, Co, Cu, Mn, Ni, V)	mg/m^3	-	-	-	-	0.5	-	-
Cadmium & Thallium	mg/m^3	-	-	-	-	0.05	-	-
Solid particles	mg/m^3	30	30	20	100[5]	10	30	10
Dioxins and furans (ITEQ)	ng/m^3	0.1	0.1	0.1	-	-	-	-
Total VOCs	ppm$_v$	10	10	-	-	-	-	-
Total VOCs	mg/m^3	-	-	10	-	-	-	-
Carbon monoxide	ppm$_v$	100	100	-	-	-	-	-
Carbon monoxide	mg/m^3	-	-	100	-	-	-	-
Gaseous and vaporous organic substances, expressed as total organic carbon	mg/m^3	-	-	-	-	10	20	10

Note: * CAPER: Clean Air (Plant & Equipment) Regulation 1997
** 2000/76/EC: Directive 2000/76/EC of the European Parliment and of the Council of 4 December 2000 on the incineration of waste.
*** POEO Act License 2148 conditions for the Groundwater Treatment Plant

1 Stack reference conditions are dry, 273 K, 101.3 kPa, 11% O_2 except where noted.

2 Stack reference condition for CO is 10% C_2.

3 Stack reference conditions are at 10% O_2 except for dioxins TEQ which are at 11% O_2.

4 Metals values are collected over a sample period of a minimum of 30 minutes and a maximum of 8 hours.

Table 3-1. Direct Fired Rotary Dryer Projects - Chlorinated Compounds

SITE NAME	SITE LOCATION	WASTE SOURCE INDUSTRY	SPECIFIC CONTAMINANTS	OXIDIZER TYPE	EMISSION CONTROL EQUIPMENT	COMPLETION YEAR	SITE SIZE (TONS)
ABERDEEN PESTICIDE DUMPS	ABERDEEN, NC	PEST. MFG/ FORM.	PESTICIDES	THERMAL OXIDIZER	CYCLONE, PARTIAL QUENCH, BAGHOUSE, PACKED SCRUBBER	1998	127,027
AMERICAN THERMOSTAT (PH I)	CAIRO, NY	MFG - OTHER	PCE, TCE	THERMAL OXIDIZER	BAGHOUSE, PACKED BED SCRUBBER, QUENCH	1994	15,000
AMERICAN THERMOSTAT (PH II)	CAIRO, NY	MFG - OTHER	VOCS, METALS	THERMAL OXIDIZER	BAGHOUSE, PACKED BED SCRUBBER, QUENCH	1996	50,000
AMERICAN VALVE - PHASE II	COXSACKIE, NY	MFG - OTHER	CHLORINATED SOLVENTS	THERMAL OXIDIZER	BAGHOUSE, QUENCH, SCRUBBER	2002	9,565
AMERICAN VALVE (PHASE I)	COXSACKIE, NY	MFG - OTHER	VOCS	THERMAL OXIDIZER	ADSORPTION SCRUBBER	2001	20,000
BFX HOSPITALITY	VESTAL, NY	MFG - OTHER	VOCS	CATALYTIC OXID.	BAGHOUSE	1996	6,000
CAMP LEJEUNE	CAMP LEJEUNE, NC	NAVAL BASE	CHLORINATED SOLVENTS	THERMAL OXIDIZER	BAGHOUSE, SCRUBBER	2000	32,000
CATERPILLAR, INC.	JOLIET, IL	MFG - OTHER	TCE, DCE	CATALYTIC OXID.	BAGHOUSE	1994	1,646
CECIL FIELD NAVAL AIR STATION	JACKSONVILLE, FL	NAVAL BASE	FUELS, SOLVENTS	THERMAL OXIDIZER	BAGHOUSE	1995	28,267
CHEMURGIC AGCHEM	TURLOCK, CA	PEST. MFG/ FORM.	PESTICIDES	THERMAL OXIDIZER	WET SCRUBBER (NaOH ADDITIVE)	1995	2,400
CLAREMONT POLYCHEMICAL	BETHPAGE, NY	CHEMICAL MFG.	TCE	CATALYTIC OXID.	BAGHOUSE, CATALYTIC OXIDIZER, pH SCRUBBER, ID FAN, EXHAUST S	1996	8,000
CONFIDENTIAL (SR2)	METTLER, CA	AGRICULTURE	DINOSEB	CATALYTIC OXID.	BAGHOUSE	1996	4,500
CONFIDENTIAL (SR2)	PHOENIX, AZ	PEST. MFG/ FORM.	ALDRIN, DDD, DDT, TOXAPHENE	THERMAL OXIDIZER	DRY SCRUBBER (LIME ADDITIVE TO AIR STREAM)	1996	2,100
DEL COOK	ADEL, GA	WOOD TREATMENT	PCP, DIOXIN	THERMAL OXIDIZER	BAGHOUSE	2005	69,469
DREXLER-RAMCOR	ORTING, WA	WASTE DISPOSAL	VOCS	CATALYTIC OXID.	CYCLONE, BAGHOUSE, CONDENSER CARBON	1992	2,900
ECONOMY PRODUCTS	SHENANDOAH, IA	PEST. MFG/ FORM.	PESTICIDES	THERMAL OXIDIZER	BAGHOUSE, QUENCH, SCRUBBER	2004	7,140
FIELDS BROOK	ASHTABULA, OH	MFG - OTHER	PCBS	THERMAL OXIDIZER	CYCLONE, BAGHOUSE, PACKED BED SCRUBBER, CARBON	2002	18,000
FIELDS BROOK (PHASE 1)	ASHTABULA, OHIO	MFG - OTHER	PCBS	THERMAL OXIDIZER	ADSORPTION SCRUBBER	2001	1,000
FORT BLISS	EL PASO, TX	ARMY BASE	2,4-D	THERMAL OXIDIZER	BAGHOUSE	1996	36,400
FULTON TERMINALS	FULTON, NY	MFG - OTHER	VOCS	THERMAL OXIDIZER	CYCLONE, BAGHOUSE, PACKED BED SCRUBBER, CARBON	1996	17,640
GARLAND RD	WEST MILTON, OH	LANDFILL	TCE, PCE, VOCS	THERMAL OXIDIZER	ADSORPTION SCRUBBER	1997	14,900
HOOPER SANDS	SOUTH BERWICK, ME	LANDFILL	DICHLOROBENZENE	THERMAL OXIDIZER	CYCLONE, VENTURI SCRUBBER	1992	1,700
IMPERIAL CHEMICAL	ALBERT LEA, MN	AGRICULTURE	ALDRIN, DIALRIN, DDT	THERMAL OXIDIZER	CYCLONE, BAGHOUSE	1997	4,300
KERN WATER BANK AUTHORITY	BAKERSFIELD, CA	AGRICULTURE	DINOSEB, TOXAPHENE	CATALYTIC OXID.	BAGHOUSE	1999	750
LAKELAND DISPOSAL LANDFILL	CLAYPOOL, IN	CHEMICAL MFG.	VOCS	THERMAL OXIDIZER	BAGHOUSE, STACK	1999	9,187
LETTERKENNEY (PHASE II)	CHAMBERSBURG, PA	AMMO PLANT/DEPOT	PCE, TCE	THERMAL OXIDIZER	BAGHOUSE	1992	27,389
LONGHORN AAP	KARNACK, TX	AMMO PLANT/DEPOT	TCE, METHYLENE CHLORIDE	CATALYTIC OXID.	BAGHOUSE, SCRUBBER	1998	51,669
MALONE	MALONE, FL	AGRICULTURE	TOXAPHENE	THERMAL OXIDIZER	CYCLONE, VENTURI SCRUBBER, BAGHOUSE	1990	2,900
METALTEC AEROSPACE	FRANKLIN BOROUGH, NJ	AEROSPACE	VOCS	THERMAL OXIDIZER	BAGHOUSE, QUENCH, PACKED BED SCRUBBER	1995	6,745
MISSOURI ELECTRIC WORKS	CAPE GIRARDEAU, MO	MFG - ELEC EQUIP	PCBS	THERMAL OXIDIZER	BAGHOUSE, QUENCH, PACKED SCRUBBER	1999	38,112
REICH FARM	PLEASANT PLAINS, NJ	CHEMICAL MFG.	VOCS, SVOCS	THERMAL OXIDIZER	CYCLONE, BAGHOUSE, CONDENSER, CARBON	1995	13,500
ROBINTECH / NATIONAL PIPE	VESTAL, NY	MFG - OTHER	CHLORINATED SOLVENTS	THERMAL OXIDIZER	BAGHOUSE, SCRUBBER	2000	9,150
S&S FLYING	MARIANNA, FL	AGRICULTURE	TOXAPHENE	THERMAL OXIDIZER	CYCLONE, VENTURI SCRUBBER	1990	4,041
SANDERS AVIATION	TEMPE, AZ	AGRICULTURE	TOXAPHENE (POHC)	CATALYTIC OXID.	BAGHOUSE, WET SCRUBBER	1997	30,000
SARATOGA TREE NURSERY	NEW YORK	AGRICULTURE	DDT	THERMAL OXIDIZER	CYCLONE, EVAP COOLING CHAMBER, DRY SCRUBBER, BAGHOUSE	1998	28,000
SARNEY FARM	DOVER PLAINS, NY	LANDFILL	VOCS	THERMAL OXIDIZER	BAGHOUSE	1997	10,571
SAVANNA ARMY DEPOT	SAVANNA, IL	AMMO PLANT/DEPOT	TCE	CATALYTIC OXID.	CYCLONE, BAGHOUSE, PACKED BED SCRUBBER, CARBON	1996	22,500

Table 3-1. Direct Fired Rotary Dryer Projects - Chlorinated Compounds

SITE NAME	SITE LOCATION	WASTE SOURCE INDUSTRY	SPECIFIC CONTAMINANTS	OXIDIZER TYPE	EMISSION CONTROL EQUIPMENT	COMPLETION YEAR	SITE SIZE (TONS)
TEXTRON	NEW JERSEY	CHEMICAL MFG.	VOCS	THERMAL OXIDIZER		1992	10,000
UNION CARBIDE	BOUND BROOK, NJ	CHEMICAL MFG.	CHLORINATED VOCS	THERMAL OXIDIZER	CYCLONE, PARTIAL QUENCH, BAGHOUSE, PACKED BED SCRUBBER	1999	23,277
WALDICK AEROSPACE (OU-2)	WALL TOWNSHIP, NJ	AEROSPACE	TCE, TPH	THERMAL OXIDIZER	CYCLONE, BAGHOUSE, PACKED SCRUBBER, CONDENSER, CARBON	1993	6,048
WAMCHEM	BEAUFORT, SC	WASTE DISPOSAL	SVOCS, VOCS	CATALYTIC OXID.	CYCLONE, BAGHOUSE, CONDENSER, CARBON	1993	1,800
WILLIAM DICK LAGOON	PAXTON, PA	WASTE DISPOSAL	TCE	THERMAL OXIDIZER	BAGHOUSE		8,000
WOODS INDUSTRIES	YAKIMA, WA	PEST. MFG/ FORM.	PESTICIDES	THERMAL OXIDIZER	BAGHOUSE, QUENCH, PACKED BED SCRUBBER	1995	25,978
WV AIR NATIONAL GUARD	MARTINSBURG, WV	AIR FORCE BASE	TCE, PCE, PYRENE, CHRYSENE	THERMAL OXIDIZER	BAGHOUSE	1996	3,480
						Total	**813,051**

Table 3-2. Hexachlorobenzene - Soil Treatment Results (a,b)

Run No.	Soil Treatment Temperature (°F)	Soil Treatment Temperature (°C)	Concentrations in Soil Treatment Goal (mg/kg)	Concentrations in Soil Feed Soil (mg/kg)	Concentrations in Soil Treated Soil (mg/kg)	Removal (%)
1A	809	432	0.625	310	0.34	99.89
1B	792	422	0.625	130	0.48	99.63
2A	NR (b)	NR (b)	0.625	290	0.26	99.91
2B	NR (b)	NR (b)	0.625	360	0.38	99.89
3	802	428	0.625	260	0.35	99.87
Average				**270**	**0.362**	**99.87**

(a) Focus Environmental, Woods Industries Site Performance Test Report, July 1995.
(b) NR - not reported

Table 3-3. Stack Emissions Historical Data

				Site Name			
Parameters	Formula	Units	Performance (a) Standard	Aberdeen	Madisonville Creosote Works	Missouri Electric Works	Woods Industries
Carbon monoxide	CO	mg/Nm^3	100	0	4.6	0	
Sulfuric acid mist	H_2SO_4	mg/Nm^3	100				
Sulfur trioxide	SO_3	mg/Nm^3	(b)				
Sulfur dioxide	SO_2	mg/Nm^3	100	437	151		
Nitrogen oxides	$NO_2 + NO$	mg/Nm^3	500		149		
Hydrogen chloride	HCl	mg/Nm^3	100	54		4.8	3.15
Chlorine	Cl_2	mg/Nm^3	200	18		0.03	0.20
Hydrogen fluoride	HF	mg/Nm^3	50				
Particulates		mg/Nm^3	30	28.3	6.8	8.7	71.1
Dioxins/furans TEQ	I-TEQ	ng/Nm^3	0.1	0.0048	0.0057	0.6501 (c)	0.006
Mercury	Hg	µg/Nm^3	100		44.38		1,054.00
Cadmium	Cd	µg/Nm^3	100		< 0.10		1.04
Hazardous Metals	See footnote	µg/Nm^3	500				
Antimony		µg/Nm^3			< 4.83		< 2.02
Arsenic		µg/Nm^3		12.58	< 2.70		< 1.27
Barium		µg/Nm^3			35.02		8.04
Beryllium		µg/Nm^3			< 0.09		0.29
Cadmium		µg/Nm^3			< 0.10		< 1.04
Chromium		µg/Nm^3			2.19		5.72
Cobalt		µg/Nm^3					
Lead		µg/Nm^3		41.37	3.62		14.31
Manganese		µg/Nm^3					
Mercury		µg/Nm^3			44.38		1,054.00
Nickel		µg/Nm^3			1.97		7.73
Selenium		µg/Nm^3			< 0.14		< 6.52
Vanadium		µg/Nm^3					
Total		µg/Nm^3		53.95	95.03		1100.94

(a) Standard reference conditions: dry, 0°C, 101.3 KPa, 11% O_2

(b) Included with sulfuric acid mist

(c) Results likely impacted by burner failure during test program.

Table 3-4. Hexachlorobenzene - Stack Emission Results (a,b)

Run No.	Soil Feed Rate (tonnes/hr)	Soil Feed Rate (tons/hr)	HCB Conc. in Feed Soil (mg/kg)	HCB Mass Feed Rate (lb/hr)	HCB Mass Emission Rate (lb/hr)	DRE (a) (%)
1A	28.85	26.23	310	16.26	4.66E-04	99.9971
2A	26.92	24.47	290	14.19	4.26E-04	99.9970
3	28.45	25.86	260	13.45	3.09E-04	99.9977
Average						**99.9973**

(a) Destruction and removal efficiency

Table 3-5. Stack Emissions Estimate

Parameters	Formula	Units	Proposed (a,b) Performance Standard	Estimated (a) Stack Gas Concentration	Estimated Concentration at Actual O_2 Content				Estimated Emission Rate		
					Value	Units	Value	Units	(g/sec)	(kg/hr)	(tonnes) (c)
Carbon Monoxide	CO	mg/Nm^3	100	40	57.2	mg/Nm^3	46	ppm_v	0.50	1.80	3.76
Sulfuric acid mist	H_2SO_4	mg/Nm^3	100	(e)		mg/Nm^3		ppm_v			
Sulfur trioxide	SO_3	mg/Nm^3	(d)	(e)		mg/Nm^3					
Sulfur dioxide	SO_2	mg/Nm^3	100	(e)		mg/Nm^3		ppm_v			
Nitrogen oxides	$NO_2 + NO$	mg/Nm^3	500	116	166	mg/Nm^3	81	ppm_v	1.45	5.23	10.89
Hydrogen chloride	HCl	mg/Nm^3	100	17	24	mg/Nm^3	15	ppm_v	0.21	0.75	1.55
Chlorine	Cl_2	mg/Nm^3	200	8	12	mg/Nm^3	4	ppm_v	0.11	0.38	0.79
Hydrogen fluoride	HF	mg/Nm^3	50	(e)		mg/Nm^3		ppm_v			
Particulates		mg/Nm^3	30	30	43	mg/Nm^3			0.38	1.35	2.82
Dioxins/furans TEQ	I-TEQ	ng/Nm^3	0.1	0.05	0.072	ng/Nm^3			6.26E-10	2.25E-09	4.69E-09
Mercury	Hg	$\mu g/Nm^3$	100	91	130	$\mu g/Nm^3$			1.14E-03	4.10E-03	8.54E-03
Cadmium	Cd	$\mu g/Nm^3$	100	0.49	0.71	$\mu g/Nm^3$			6.18E-06	2.22E-05	4.63E-05
Hazardous Metals - Total		$\mu g/Nm^3$	500	(e)		$\mu g/Nm^3$					
Antimony		$\mu g/Nm^3$		(e)							
Arsenic		$\mu g/Nm^3$		(e)							
Barium		$\mu g/Nm^3$		(e)							
Beryllium		$\mu g/Nm^3$		(e)							
Cadmium		$\mu g/Nm^3$		0.49							
Chromium		$\mu g/Nm^3$		17.62							
Cobalt		$\mu g/Nm^3$		(e)							
Lead		$\mu g/Nm^3$		14.52							
Manganese		$\mu g/Nm^3$		(e)							
Mercury		$\mu g/Nm^3$		91							
Nickel		$\mu g/Nm^3$		(e)							
Selenium		$\mu g/Nm^3$		(e)							
Vanadium		$\mu g/Nm^3$		(e)							
Total		$\mu g/Nm^3$		124							

(a) Standard reference conditions: dry, 0°C, 101.3 KPa, 11% O_2

(b) Performance standards from Table 2-3, Allied Feeds Site and Orica GTP (SO_2 only).

(c) Mass emission from project based on:

72,889	tons	66,263	tonnes of soil treated
2,083	operating hr	2,083	operating hours

(d) Included with sulfuric acid mist

(e) Not estimated, inadequate waste characteriazation data to serve as basis for emission estimate.

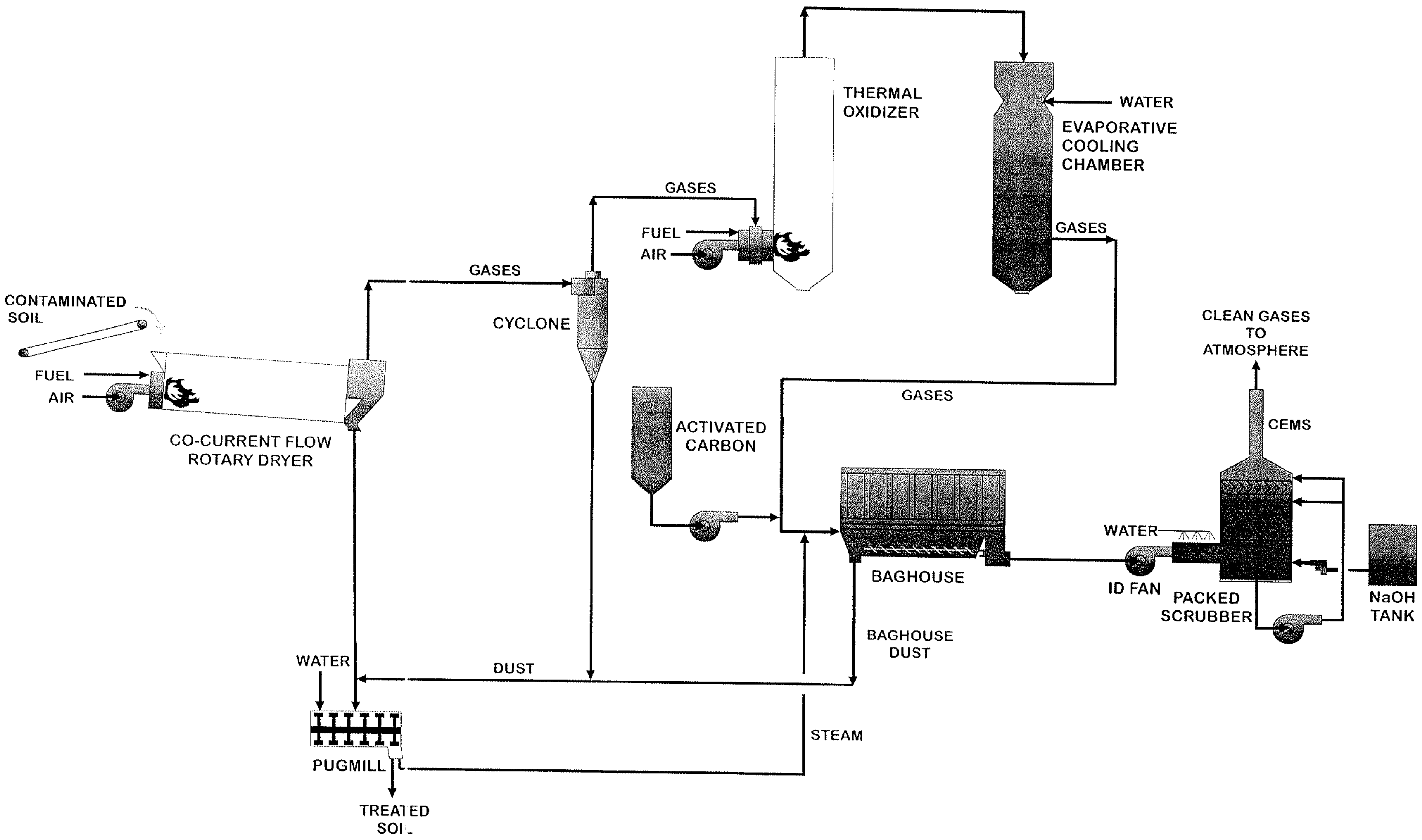

FIGURE 3-1. DIRECT FIRED ROTARY DRYER SYSTEM

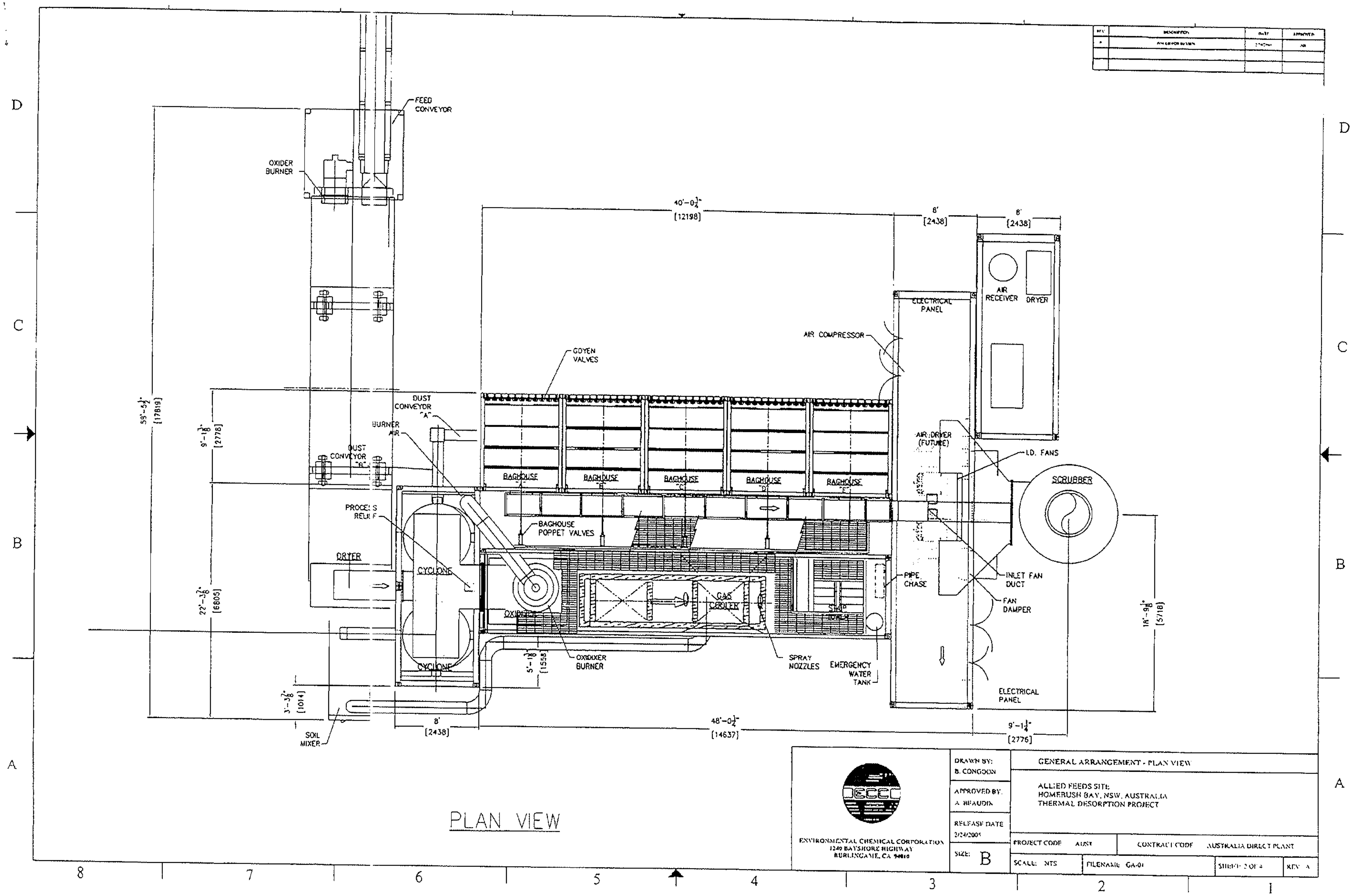

FIGURE 3-2. EQUIPMENT LAYOUT

Appendix A

Direct Thermal Desorber

Mass and Energy Balance

Orica Carpark Site - Mass & Energy Balance Case Summary - Metric Units

Case No. >			**Maximum**	**Orica TS1-350**	**Orica TS1-420**	**Orica TS2-350**	**Orica TS2-420**	**Minimum**	**Average**	**Maximum**	**Maximum**	**Minimum**
File Name >			**Design**	MEB2-Orica TS1-350	MEB2-Orica TS1-420	MEB2-Orica TS2-350	MEB2-Orica TS2-420				**as a %**	**as a %**
PTU Temperature >			**Limit**	**350**	**420**	**350**	**420**				**of Design**	**of Design**
Wt % Free Water in Feed Solids >				**15**	**15**	**10**	**10**				**Maximum**	**Maximum**
Wt % Salts in Feed Solids >				**0**	**0**	**0**	**0**				**(g)**	**(g)**
Parameter	Stream No.	Units										
Soil Feed Data												
Soil feed rate	1	tonnes/hr		28.8	25.5	37.7	31.9	25.5	31.0	37.7		
LIMITING CONDITION				**STU Res Time**	**PTU Velocity**	**STU Res Time**	**PTU Velocity**					
Composition (a)	1											
Carbon	1	%, wet basis		5.38	5.38	5.68	5.68	5.4	5.5	5.7		
Hydrogen	1	%, wet basis		0.17	0.17	0.20	0.20	0.2	0.2	0.2		
Oxygen	1	%, wet basis		1.17	1.17	1.23	1.23	1.2	1.2	1.2		
Nitrogen	1	%, wet basis		0.030	0.030	0.036	0.036	0.0	0.0	0.0		
H_2O Total	1	%		15.0	15.0	10.0	10.0	10.0	12.5	15.0		
H_2O free (moisture)	1	%		15.0	15.0	10.0	10.0	10.0	12.5	15.0		
H_2O bound (hydration)	1	%		0.0	0.0	0.0	0.0	0.0	0.0	0.0		
Cl	1	%, wet basis		0.23	0.23	0.16	0.16	0.2	0.2	0.2		
S	1	%, wet basis		0.058	0.058	0.036	0.036	0.0	0.0	0.1		
Ash	1	%, wet basis		77.97	77.97	82.65	82.65	78.0	80.3	82.7		
NaCl	1	%, wet basis		0.0	0.0	0.0	0.0	0.0	0.0	0.0		
$CaCO_3$	1	%, wet basis		0.0	0.0	0.0	0.0	0.0	0.0	0.0		
CaO	1	%, wet basis		0.0	0.0	0.0	0.0	0.0	0.0	0.0		
$CaSO_4$	1	%, wet basis		0.0	0.0	0.0	0.0	0.0	0.0	0.0		
Other salts	1	%, wet basis		0.0	0.0	0.0	0.0	0.0	0.0	0.0		
Hg	1	mg/kg, wet basis		1.59	1.59	1.68	1.68	1.59	1.64	1.68		
Higher Heating Value	1	kJ/kg		1,940	1,940	2,072	2,072	1,940	2,006	2,072		
Potential Maximum Heat of Dehydration/Calcination	1	kJ/kg		0	0	0	0	0.0	0.0	0.0		
Rotary Dryer												
Soil feed rate	1	tonnes/hr		28.7	25.5	37.7	31.9	25.5	31.0	37.7		
Fuel firing rate	2	GJ/hr	79.1	27.9	31.3	26.5	29.6	26.5	28.8	31.3	40	34
Fuel firing rate	2	l/hr		105,144	117,653	99,705	111,563	99,705.1	108,516.2	117,652.5		
Heat to remove free moisture	NA	GJ/hr		14.1	13.1	12.4	11.0	11.0	12.7	14.1		
Net Heat of Dehydration + Calcination Reaction	NA	GJ/hr		0.0	0.0	0.0	0.0	0.0	0.0	0.0		
Heat to Evaporate Reacted Water	NA	GJ/hr		0.0	0.0	0.0	0.0	0.0	0.0	0.0		
Total Heat of Dehydration + Calcination + Evap	NA	GJ/hr		0.0	0.0	0.0	0.0	0.0	0.0	0.0		
Reacted Water Formed	NA	kg/hr		0.0	0.0	0.0	0.0	0.0	0.0	0.0		
Soil treatment temperature	4	^oC		350	420	350	420	350.0	385.0	420.0		
Burner excess air (c)	3	%		74.8	68.4	94.8	81.9	68.4	80.0	94.8		
Air leakage	5	m^3/min		17.0	17.0	17.0	17.0	17.0	17.0	17.0		
Exit gas oxygen	6	% dry		6.8	6.9	6.5	6.7	6.5	6.7	6.9		
Organics removed from feed that oxidize in dryer	NA	%		50	50	50	50	50.0	50.0	50.0		
Ambient air temperature	3	^oC		16	16	16	16	15.6	15.6	15.6		
Combustion air flow	3	am^3/min		232	248	244	254	231.7	244.5	254.0		
Combustion air flow	3	Nm^3/min		253	271	266	277	252.5	266.5	276.8		
Offgas exit gas flow rate	6	am^3/min		895	996	924	996	894.8	952.8	996.5		
Offgas exit gas flow rate	6	Nm^3/min		261	275	285	289	261.1	277.6	289.5		
Exit gas temperature	6	^oC		433	503	433	503	433.3	468.3	503.3		
Temperature difference between soil and gas	NA	^oC		66	66	66	66	65.6	65.6	65.6		
Pressure drop	Amb-6	kPa		0.5	0.5	0.5	0.5	0.5	0.5	0.5		
Heat loss	NA	GJ/hr		1.7	2.1	1.7	2.1	1.7	1.9	2.1		
Gas velocity in dryer	NA	m/sec	3.6	3.2	3.6	3.3	3.6	3.2	3.4	3.6	100	90
Dryer diameter	NA	m		2.4	2.4	2.4	2.4	2.4	2.4	2.4		
Entrainment - ash	6	% feed		30	30	30	30	30.0	30.0	30.0		
Entrainment - salt	6	% feed		30	30	30	30	30.0	30.0	30.0		
Fraction of CaSO4.2H2O dehydrated		% of feed		0	0	0	0	0.0	0.0	0.0		
Fraction of Ca(OH2) dehydrated		% of feed		0	0	0	0	0.0	0.0	0.0		
Fraction of CaCO3 disassociated		% of feed		0	0	0	0	0.0	0.0	0.0		
Solids from DTD	4	tonnes/hr		16.9	15.0	23.4	19.8	15.0	18.8	23.4		
Multiclone												
Gas entry flow rate	6	am3/min		895	996	924	996	894.8	952.8	996.5		
Offgas exit gas flow rate	7	am^3/min		885	982	915	983	884.6	941.1	983.0		

Orica Carpark Site - Mass & Energy Balance Case Summary - Metric Units

Case No. >			**Maximum**	**Orica TS1-350**	**Orica TS1-420**	**Orica TS2-350**	**Orica TS2-420**	**Minimum**	**Average**	**Maximum**	**Maximum**	**Minimum**
File Name >			**Design**	MEB2-Orica TS1-350	MEB2-Orica TS1-420	MEB2-Orica TS2-350	MEB2-Orica TS2-420				**as a %**	**as a %**
PTU Temperature >			**Limit**	**350**	**420**	**350**	**420**				**of Design**	**of Design**
Wt % Free Water in Feed Solids >				**15**	**15**	**10**	**10**				**Maximum**	**Maximum**
Wt % Salts in Feed Solids >				**0**	**0**	**0**	**0**				**(g)**	**(g)**
Parameter	Stream No.	Units										
Offgas exit gas flow rate	7	Nm^3/min		264	278	288	292	264.1	280.7	292.5		
Solids/particulate in	6	tonnes/hr		6.72	5.97	9.36	7.91	6.0	7.5	9.4		
Exit gas temperature	7	^oC		408	473	410	474	407.8	441.1	473.9		
Removal efficiency - ash	NA	%		25	25	25	25	25.0	25.0	25.0		
Removal efficiency - salt	NA	%		25	25	25	25	25.0	25.0	25.0		
Pressure drop	6 to 7	kPa		1.8	1.8	1.8	1.8	1.8	1.8	1.8		
Heat loss	NA	GJ/hr		0.9	1.1	0.9	1.1	0.9	1.0	1.1		
Solids/particulate out	8	tonnes/hr		1.7	1.5	2.3	2.0	1.5	1.9	2.3		
Hot Pugmill												
Solids rate in	4&8	tonnes/hr		1.7	1.5	2.3	2.0	1.5	1.9	2.3		
Temperature out	9	^oC		408	473	410	474	407.8	441.1	473.9		
Heat loss	NA	GJ/hr		0.000021	0.000021	0.000032	0.000032	0.000021	0.000026	0.000032		
Solids rate out	9	tonnes/hr		1.7	1.5	2.3	2.0	1.5	1.9	2.3		
Blower sweep air	15	am^3/min		2.8	2.8	2.8	2.8	2.8	2.8	2.8		
Wet Pugmill												
Solids from DTD	5	tonnes/hr		16.9	15.0	23.4	19.8	15.0	18.8	23.4		
Solids from Hot Pugmill	4	tonnes/hr		1.7	1.5	2.4	2.0	1.5	1.9	2.4		
Solids from Baghouse	6	tonnes/hr		5.1	4.4	7.1	6.0	4.4	5.6	7.1		
Solids in Wet Pugmill	9&11	tonnes/hr		23.6	21.0	32.8	27.8	21.0	26.3	32.8		
Heat of hydration produced	NA	GJ/hr		0.0	0.0	0.0	0.0	0.0	0.0	0.0		
Water feed rate	10	kg/hr		7,346	7,040	10,230	9,328	7,040.3	8,486.1	10,230.0		
Water feed rate	10	l/min		122	117	170	155	117.2	141.4	170.5		
Offgas exit gas flow rate	13	am^3/min		85	85	85	85	84.8	84.8	84.8		
Offgas exit gas flow rate	13	Nm^3/min		6	6	6	6	6.4	6.4	6.4		
Exit gas temperature	13	^oC		100	100	100	100	100.0	100.0	100.0		
Solids exit temperature	12	^oC		82	82	82	82	82.2	82.2	82.2		
Air leakage	14	m^3/min		85	85	85	85	85.0	85.0	85.0		
Fraction of CaSO4 hydrated		%		100	100	100	100	100.0	100.0	100.0		
Fraction of CaO hydrated		%		100	100	100	100	100.0	100.0	100.0		
Treated soil out	16	tonnes/hr		27.9	24.8	38.7	32.7	24.8	31.0	38.7		
Thermal Oxidizer												
Gas inlet flow rate	13	am3/min		885	982	915	983	884.6	941.1	983.0		
Gas inlet flow rate	13	Nm3/min		264	278	288	292	264.1	280.7	292.5		
Exit gas temperature	20	^oC		982	982	982	982	982.2	982.2	982.2		
Fuel firing rate	18	GJ/hr	79.1	56.3	46.0	53.2	41.7	41.7	49.3	56.3	71	53
Fuel firing rate	18	l/hr		211,948	173,060	200,155	156,915	156,915.4	185,519.6	211,948.4		
Net Heat of Dehydration + Calcination Reaction	NA	GJ/hr		0.0	0.0	0.0	0.0	0.0	0.0	0.0		
Heat to Evaporate Reacted Water	NA	GJ/hr		0.0	0.0	0.0	0.0	0.0	0.0	0.0		
Total Heat of Dehydration + Calcination + Evap	NA	GJ/hr		0.0	0.0	0.0	0.0	0.0	0.0	0.0		
Reacted Water Formed	NA	kg/hr		0.0	0.0	0.0	0.0	0.0	0.0	0.0		
Burner excess air (c)	19	%		65.1	57.1	73.6	64.6	57.1	65.1	73.6		
Exit gas oxygen	20	% dry		7.3	6.8	7.2	6.7	6.7	7.0	7.3		
Combustion air flow	19	am^3/min		409	318	406	302	302.1	358.9	409.3		
Combustion air flow	19	Nm^3/min		446	346	443	329	329.2	391.2	446.0		
Offgas exit gas flow rate	20	am^3/min		3,511	3,111	3,511	3,007	3,006.5	3,284.7	3,510.6		
Offgas exit gas flow rate	20	Nm^3/min		660	582	671	573	572.7	621.3	671.0		
Gas residence time (chamber)	NA	sec	1.6	1.6	1.8	1.6	1.9	1.6	1.7	1.9	100	100
Gas residence time (duct, top ECC)	NA	sec		0.4	0.5	0.4	0.5	0.4	0.4	0.5		
Gas residence time (chamber plus duct)	NA	sec		2.0	2.3	2.0	2.3	2.0	2.1	2.3		
Ash load in inlet gas	17	kg/hr		5,037	4,475	7,017	5,935	4,474.8	5,616.0	7,017.2		
Salt load in inlet gas	17	kg/hr		0	0	0	0	0.0	0.0	0.0		
Pressure Drop	17-20	kPa		0.5	0.5	0.5	0.5	0.5	0.5	0.5		
Heat loss	NA	GJ/hr		1.9	1.9	1.9	1.9	1.9	1.9	1.9		
Fraction of CaSO4.2H2O dehydrated	NA	% of inlet		100	100	100	100	100.0	100.0	100.0		
Fraction of Ca(OH2) dehydrated	NA	% of inlet		100	100	100	100	100.0	100.0	100.0		
Fraction of CaCO3 disassociated	NA	% of inlet		100	100	100	100	100.0	100.0	100.0		

Orica Carpark Site - Mass & Energy Balance Case Summary - Metric Units

Case No. >			**Maximum**	**Orica TS1-350**	**Orica TS1-420**	**Orica TS2-350**	**Orica TS2-420**	**Minimum**	**Average**	**Maximum**	**Maximum**	**Minimum**
File Name >			**Design**	MEB2-Orica TS1-350	MEB2-Orica TS1-420	MEB2-Orica TS2-350	MEB2-Orica TS2-420				**as a %**	**as a %**
PTU Temperature >			**Limit**	**350**	**420**	**350**	**420**				**of Design**	**of Design**
Wt % Free Water in Feed Solids >				**15**	**15**	**10**	**10**				**Maximum**	**Maximum**
Wt % Salts in Feed Solids >				**0**	**0**	**0**	**0**				**(g)**	**(g)**
Parameter	Stream No.	Units										
Evaporative Cooler												
Gas inlet flow rate	20	am3/min		3,511	3,111	3,511	3,007	3,006.5	3,284.7	3,510.6		
Gas inlet flow rate	20	Nm3/min		660	582	671	573	572.7	621.3	671.0		
Water feed rate	21	kg/hr		19,378	17,128	19,894	16,946	16,946.0	18,336.4	19,893.7		
Water feed rate	21	l/min		323	285	331	282	282.2	305.4	331.3		
Compressed air (100 psig)	22	kg/hr		1,355	1,355	1,355	1,355	1,355.2	1,355.2	1,355.2		
Compressed air (100 psig)	22	m^3/min		19	19	19	19	18.8	18.8	18.8		
Offgas exit gas flow rate	23	am^3/min		2,166	1,922	2,186	1,874	1,873.5	2,037.0	2,186.2		
Offgas exit gas flow rate	23	Nm^3/min		680	602	691	593	592.9	641.5	691.2		
Exit gas temperature	23	^{o}C		218	218	218	218	218.3	218.3	218.3		
Pressure Drop	20-23	kPa		0.8	0.8	0.8	0.8	0.8	0.8	0.8		
Heat loss	NA	GJ/hr		1.6	1.6	1.6	1.6	1.6	1.6	1.6		
Baghouse												
Compressed air (100 psig) (bag cleaning)	24	kg/hr		41	41	41	41	40.8	40.8	40.8		
Compressed air (100 psig) (bag cleaning)	24	m^3/min		1	1	1	1	0.6	0.6	0.6		
Inlet total gas flow rate	25	am^3/min	2,549	2,371	2,132	2,429	2,117	2,116.8	2,262.1	2,429.1	95	83
Inlet total gas flow rate	25	Nm^3/min		771	693	782	684	683.9	732.6	782.3		
Exit gas temperature	26	^{o}C		170	166	170	165	164.9	167.8	170.2		
Activated carbon injection rate	**HOLD**	kg/hr		13.70	12.16	19.05	16.10	12.16	15.25	19.05		
Pneumatic air delivering carbon	**HOLD**	m^3/min		1.25	1.25	1.25	1.25	1.25	1.25	1.25		
Lime injection rate	**HOLD**	kg/hr		0	0	0	0	0.0	0.0	0.0		
Lime feed ratio (mol/mol acid)	**HOLD**	kg/hr		NA	NA	NA	NA					
Pneumatic air delivering alkaline sorbent	**HOLD**	m^3/min		0	0	0	0	0.0	0.0	0.0		
Ash load in inlet gas	25	tonnes/hr		5.1	4.4	7.0	5.9	4.4	5.6	7.0		
Salt load in inlet gas	25	tonnes/hr		0.0	0.0	0.0	0.0	0.0	0.0	0.0		
Total particulate concentration in inlet gas	25	mg/Nm^3		106,708.0	103,898.0	145,089.0	138,764.0	103,898.0	123,614.8	145,089.0		
Air to cloth ratio	NA	am^3/min/m^2		1.1	1.0	1.2	1.0	1.0	1.1	1.2		
Required particulate removal efficiency	NA	%		99.97	99.97	99.98	99.98	99.97	99.98	99.98		
Required regulated metals removal efficiency	NA	%		98.32	98.29	98.77	98.72	98.29	98.53	98.77		
Required Hg removal efficiency	NA	%		79.78	78.83	84.80	84.10	78.83	81.88	84.80		
SO2 removal efficiency	NA	%		0.00	0.00	0.00	0.00	0.00	0.00	0.00		
SO3 removal efficiency	NA	%		0.00	0.00	0.00	0.00	0.00	0.00	0.00		
HCl removal efficiency	NA	%		0.00	0.00	0.00	0.00	0.00	0.00	0.00		
Pressure Drop (design)	25-26	kPa		2.0	2.0	2.0	2.0	2.0	2.0	2.0		
Heat loss	NA	GJ/hr		4.3	4.1	4.3	4.1	4.1	4.2	4.3		
Outlet total gas flow rate	26	am3/min		2,238	2,001	2,301	1,990	1,990.2	2,132.4	2,300.8		
Outlet total gas flow rate	26	Nm3/min		772	694	783	684	684.4	733.1	782.7		
ID Fan												
Inlet total gas flow rate	26	am3/min		2,238	2,001	2,301	1,990	1,990.2	2,132.4	2,300.8		
Inlet total gas flow rate	26	Nm3/min		772	694	783	684	684.4	733.1	782.7		
Exit gas flow rate	27	am^3/min		2,125	1,899	2,184	1,889	1,889.2	2,024.2	2,184.0		
Exit gas flow rate	27	Nm^3/min		772	694	783	684	684.4	733.1	782.7		
Exit gas temperature	27	^{o}C		179	175	179	174	173.9	176.9	179.4		
Pressure drop	26-27	kPa		-7.3	-7.3	-7.3	-7.3	-7.3	-7.3	-7.3		
Heat loss	NA	GJ/hr		0.0	0.0	0.0	0.0	0.0	0.0	0.0		
Quench and Scrubber												
Inlet total gas flow rate	27	am3/min		2,125	1,899	2,184	1,889	1,889.2	2,024.2	2,184.0		
Inlet total gas flow rate	27	Nm3/min		772	694	783	684	684.4	733.1	782.7		
Quench fresh water	25	kg/hr		10,443	9,631	13,158	11,657	9,630.8	11,222.1	13,158.0		
Quench fresh water	25	l/min		174	160	219	194	160.3	186.9	219.2		
Quench recycle water	29	kg/hr		57,975	57,880	57,515	57,454	57,454.3	57,705.9	57,974.6		
Quench recycle water	29	l/min		945	945	945	945	945.0	945.0	945.0		
Emergency water (e)	**HOLD**	kg/hr		0	0	0	0	0.0	0.0	0.0		
Emergency water (e)	**HOLD**	l/min		0	0	0	0	0.0	0.0	0.0		

Orica Carpark Site - Mass & Energy Balance Case Summary - Metric Units

Case No. >			**Maximum**	**Orica TS1-350**	**Orica TS1-420**	**Orica TS2-350**	**Orica TS2-420**	**Minimum**	**Average**	**Maximum**	**Maximum**	**Minimum**
File Name >			**Design**	MEB2-Orica TS1-350	MEB2-Orica TS1-420	MEB2-Orica TS2-350	MEB2-Orica TS2-420				**as a %**	**as a %**
PTU Temperature >			**Limit**	**350**	**420**	**350**	**420**				**of Design**	**of Design**
Wt % Free Water in Feed Solids >				**15**	**15**	**10**	**10**				**Maximum**	**Maximum**
Wt % Salts in Feed Solids >				**0**	**0**	**0**	**0**				**(g)**	**(g)**
Parameter	Stream No.	Units										
Quench exit gas temperature	30	^{o}C		83	83	83	83	82.8	82.8	82.8		
Pressure drop	27-30	kPa		0.3	0.3	0.3	0.3	0.3	0.3	0.3		
Heat loss	NA	GJ/hr		0.0	0.0	0.0	0.0	0.0	0.0	0.0		
Fresh water to demister (f)	31	kg/hr		0	0	0	0	0.0	0.0	0.0		
Fresh water to demister (f)	31	l/min		0	0	0	0	0.0	0.0	0.0		
Scrubber recycle water	32	kg/hr		231,898	231,519	230,059	229,817	229,817.3	230,823.4	231,898.5		
Scrubber recycle water	32	l/min		3,780	3,780	3,780	3,780	3,780.0	3,780.0	3,780.0		
Blowdown flowrate	33	l/min		121	113	166	155	113.4	138.9	166.3		
NaOH usage (100%)	NA	kg/hr		103	92	91	76	76.2	90.5	103.4		
NaOH usage (40%)	34	kg/hr		258	229	227	191	190.5	226.0	258.1		
NaOH usage (40%)	34	l/min		3.52	3.14	3.10	2.61	2.61	3.09	3.52		
Stack exit gas flow rate	35	am^{3}/min		1,781	1,602	1,825	1,590	1,590.2	1,699.5	1,824.9		
Stack exit gas flow rate	35	Nm^{3}/min		771	693	782	684	683.7	732.3	781.9		
Stack exit gas temperature	35	^{o}C		82	82	83	83	82.2	82.5	82.8		
HCl removal efficiency (b)	NA	%		93.10	92.90	92.40	92.10	92.10	92.63	93.10		
SO_2 removal efficiency (b)	NA	%		85.00	84.60	81.30	80.40	80.40	82.83	85.00		
SO_3 removal efficiency	NA	%		0.00	0.00	0.00	0.00	0.00	0.00	0.00		
Hg removal efficiency	NA	%		0.00	0.00	0.00	0.00	0.00	0.00	0.00		
Particulate removal efficiency	NA	%		0.00	0.00	0.00	0.00	0.00	0.00	0.00		
Pressure drop	30-35	kPa		1.0	1.0	1.0	1.0	1.0	1.0	1.0		
Heat loss	NA	GJ/hr		0.0	0.0	0.0	0.0	0.0	0.0	0.0		
Stack												
Offgas exit gas flow rate	35	am^{3}/min		1,786	1,605	1,829	1,594	1,594.1	1,703.7	1,829.4		
Offgas exit gas flow rate	35	Nm^{3}/min		771	693	782	684	683.7	732.3	781.9		
Exit gas temperature	35	^{o}C		82	82	83	83	82.4	82.5	82.7		
Pressure Drop	35-amb	kPa		0.25	0.25	0.25	0.25	0.25	0.25	0.25		
Concentrations (g)												
Dioxins and Furans	35	ng/Ncm	0.1									
VOCs	35	mg/Ncm	10									
O2	35	vol% dry	11	9.30	9.10	9.10	9.00	9.00	9.13	9.30		
CO	35	mg/Ncm	125	91	90	124	120	90	106	124	99	72
NOx	35	mg/Ncm	350	153	153	156	156	153	155	156	45	44
HCl	35	mg/Ncm	100	100	100	100	100	100	100	100	100	100
Cl2	35	mg/Ncm	200	0	0	0	0	0	0	0	0	0
Any fluorine compound (HF)	35	mg/Ncm	50	0	0	0	0	0	0	0	0	0
SO2	35	mg/Ncm	100	100	100	100	100	100	100	100	100	100
H2SO4 mist or/and SO3, as SO3	35	mg/Ncm	100	44	43	35	34	34	39	44	44	34
Solid Particles	35	mg/Ncm	50	27	27	27	27	27	27	27	54	54
Hg	35	mg/Ncm	0.2	0.20	0.20	0.20	0.20	0.20	0.20	0.20	100	100
Cd	35	mg/Ncm	0.2	0.01	0.01	0.01	0.01	0.01	0.01	0.01	5	5
Regulated Metals	35	mg/Ncm	1.0	1.00	1.00	1.00	1.00	1.00	1.00	1.00	100	100

(a) Includes those constituents removed in thermal desorber; constituents that are not removed are included in ash fraction.
(b) Assumes all acid absorption occurs in packed column, although the quench should remove a significant fraction of the HCl.
(c) Excess air for burner only, does not include excess air for organics in soil.
(d) Estimate provided by Astec. Emergency use only, not a continuous flow.
(e) Estimate to be provided by scrubber vendor. Emergency use only.
(f) Normal flow is 0.00 gpm. Demister washed intermittently at 100 gpm for 1.0 minute per wash, every two hours. Average flow calculated based on total water used in two hour period.
(g) Stack concentrations limits are reported at 11% O2

Appendix B

Cost Estimate

Appendix C

Emissions Estimate

Appendix C

Emissions Estimate

Revised 04/10/07

Table 1. Stack Emissions Estimate

			Stack Gas Concentration (a)				Estimated Emissions		
				Estimated Concentration					
Parameters	Formula	Molecular Weight (lb/lb-mole)	Clean Air Reg 2005 Group 6 Plant	Corrected to 11% O_2 (b)	@ Actual O_2 Content	Units	(g/sec)	(kg/hr)	(tonnes) (b)
Carbon Monoxide	CO	28	125	40	48	mg/Nm^3	0.48	1.71	3.54
Hydrogen fluoride	HF	20	50	(c)	(c)	mg/Nm^3			
Particulates (d)		NA	50	30	36	mg/Nm^3	0.36	1.28	2.66
Dioxins/furans TEQ	I-TEQ	NA	0.1	0.05	0.060	ng/Nm^3	5.94E-10	2.14E-09	4.43E-09
Maximum Estimated Emissions									
Sulfuric acid mist (max) (e)	H_2SO_4	98		69	83	mg/Nm^3	0.82	2.95	6.11
Sulfur trioxide (max) (f)	SO_3	80	100	56	68	mg/Nm^3	0.67	2.41	4.98
Sulfur dioxide (max)	SO_2	64	100	86	103	mg/Nm^3	1.02	3.66	7.58
Nitrogen oxides (NO_2/NO) (max)	as NO_2	46	350	206	247	mg/Nm^3	2.4	8.8	18.2
Hydrogen chloride (max)	HCl	36.45	100	36	43	mg/Nm^3	0.43	1.54	3.18
Chlorine (max)	Cl_2	70.9	200	7.0	8.4	mg/Nm^3	0.08	0.30	0.62
Average Estimated Emissions									
Sulfuric acid mist (avg) (e)	H_2SO_4	98		24	29	mg/Nm^3	0.29	1.03	2.13
Sulfur trioxide (avg) (f)	SO_3	80	100	20	24	mg/Nm^3	0.23	0.84	1.74
Sulfur dioxide (avg)	SO_2	64	100	30	36	mg/Nm^3	0.36	1.28	2.65
Nitrogen oxides (NO_2/NO) (avg)	as NO_2	46	350	187	224	mg/Nm^3	2.2	8.0	16.5
Hydrogen chloride (avg)	HCl	36.45	100	10	12	mg/Nm^3	0.12	0.44	0.90
Chlorine (avg)	Cl_2	70.9	200	2.0	2.4	mg/Nm^3	0.02	0.09	0.18
Hazardous Metals									
Antimony				(c)	(c)	µg/Nm^3			
Arsenic				8.26	9.91	µg/Nm^3	9.81E-05	3.53E-04	7.31E-04
Barium				(c)	(c)	µg/Nm^3			
Beryllium				(c)	(c)	µg/Nm^3			
Cadmium	Cd	NA	200	3.14	3.77	µg/Nm^3	3.73E-05	1.34E-04	2.78E-04
Chromium				7.62	9.14	µg/Nm^3	9.05E-05	3.26E-04	6.74E-04
Cobalt				(c)	(c)	µg/Nm^3			
Lead				7.53	9.04	µg/Nm^3	8.95E-05	3.22E-04	6.67E-04
Manganese				(c)	(c)	µg/Nm^3			
Mercury	Hg	NA	200	189	226	µg/Nm^3	2.24E-03	8.07E-03	1.67E-02
Nickel				6.05	7.26	µg/Nm^3	7.18E-05	2.59E-04	5.35E-04
Selenium				(c)	(c)	µg/Nm^3			
Vanadium				(c)	(c)	µg/Nm^3			
Total Hazardous Metals		NA	1,000	221	266	µg/Nm^3	2.63E-03	9.46E-03	1.96E-02

a) Standard reference conditions: dry, 0°C, 101.3 Kpa and corrected to 11% O_2.

b) Mass emission from project based on:

Soil Mass Treated	72,889	tons	66,263	tonnes	Operations Duration	2,071	operating hr
Soil Treatment Rate	35.2	tons/hr	32.0	tonnes/hr			
Soil Moisture Content	10.0	wt%					

c) Not estimated, inadequate waste characteriazation data to serve as basis for emission estimate.

d) The estimated emissions of particulate is based on historical data (see Table 13)

e) Includes both H_2SO_4 and SO_3 as H_2SO_4.

f) Includes both H_2SO_4 and SO_3 as SO_3.

Stack gas conditions (from mass and energy balance)

Flow (actual)	56,288	acfm	1,595	am^3/min
Flow (standard, wet)	46,541	scfm (wet) @ 20°C	1,229	Nm^3/min (wet) @ 0°C
Flow (standard, dry)	22,493	scfm (dry) @ 20°C	594	Nm^3/min (dry) @ 0°C
Flow (molar, wet)	7,244.0	lb moles/hr (wet)	3,293	kg moles/hr (wet)
Flow (molar, dry)	3,501.0	lb moles/hr (dry)	1,591	kg moles/hr (dry)
Molar Water Flow	3,743.0	lb moles/hr (water)	1,701	kg moles/hr (water)
Actual O_2 Content	9.0	vol %		

Table 2. Sulfur Removal Summary (a)

Sample No.	Analyses	Concentration in Soil (wt%, dry basis)					Removal Efficiency (%)			
		Feed Soil	Treated Soil							
			350°C	450°C	550°C	Average	350°C	450°C	550°C	Average
TS1	Total Sulfur	0.099	0.038	0.041	0.034	0.038	61.5	58.4	65.6	61.8
TS2	Total Sulfur	0.057	0.047	0.059	0.046	0.051	17.9	X	19.5	11.5
TS3	Total Sulfur	0.030	0.029	0.039	0.032	0.033	X	X	X	X
	Average	0.063	0.039	0.047	0.038	0.041	38.1	25.4	39.7	35.4

Average from Other Sites (b)	38.3

(a) Based on data from Focus Environmental, Inc., Thermal Treatability Test Report - Orica Car Park Waste Encapsulation Site, February 2007, Tables 5-14, 5-15, 5-16.
(b) Average from historical data compiled by Focus Environmental from other sites. Includes treatability and full-scale data.
(c) X - Concentration of sulfur in treated soil exceeds concentration in feed soil. Likely due to non-homogeneity of soil sampled.

Table 3a. Sulfur Dioxide/Sulfur Trioxide Emissions Estimate Average Case of All Treataility Test Data

Parameter	Value	Units	
Soil feed rate	70,400	lb/hr, wet basis	
Soil feed rate	63,360	lb/hr, dry basis	
Sulfur in soil from Hypalon liner	0.003	%, dry basis	(a)
Sulfur concentration in soil (Average)	0.063	%, dry basis	(b)
Soil feed sulfur concentration	0.066	%, dry basis	Includes liner
Sulfur to off-gas (Average)	35.4	% of total sulfur	(b)
Sulfur removed from soil	0.023	% of dry soil	
Sulfur to off-gas	14.81	lb/hr	
Sulfur conversion efficiency to SO_2	**95**	%	
SO_2 produced	28.15	lb/hr	
SO_2 produced	0.44	lb-moles/hr	
SO_2 scrubbing efficiency	**90.00**	%	
SO_2 emissions	2.81	lb/hr	
SO_2 emissions	0.04	lb-moles/hr	
SO_2 stack gas concentration	12.56	ppmv, dry, actual	
SO_2 stack gas concentration	36	mg/Nm^3, actual	
SO_2 stack gas concentration	30	mg/Nm^3, corrected to 11% O_2	
Conversion efficiency to H_2SO_4	5	%	
H_2SO_4 produced	2.27	lb/hr	
H_2SO_4 produced	0.02	lb-moles/hr	
H_2SO_4 scrubbing efficiency	**0.00**	%	
H_2SO_4 emissions	2.27	lb/hr	
H_2SO_4 emissions	0.02	lb-moles/hr	
H_2SO_4 stack gas concentration	6.61	ppmv, dry, actual	
H_2SO_4 stack gas concentration	29	mg/Nm^3, dry, actual	
H_2SO_4 stack gas concentration	24	mg/Nm^3, dry, corrected to 11% O_2	

(a) See calculations in Attachment A for estimated concentrations of sulfur from Hypalon liner.
(b) Average sulfur concentration and sulfur removed from soil are documented in Table 2.

Stack gas flow	3,501.0	lb-moles/hr (dry)
Stack gas O_2 concentration (actual)	9.0	vol%

Table 3b. Sulfur Dioxide/Sulfur Trioxide Emissions Estimate
Worst Case (TS1 Soil Treated at 550°C)

Parameter	Value	Units	
Soil feed rate	70,400	lb/hr, wet basis	
Soil feed rate	63,360	lb/hr, dry basis	
Sulfur in soil from Hypalon liner	0.003	%, dry basis	(a)
Sulfur concentration in soil (Maximum)	0.099	%, dry basis	(b)
Soil feed sulfur concentration	0.102	%, dry basis	Includes liner
Sulfur to off-gas (Maximum)	65.6	% of total sulfur	(b)
Sulfur removed from soil	0.067	% of dry soil	
Sulfur to off-gas	42.38	lb/hr	
Sulfur conversion efficiency to SO_2	**95**	%	
SO_2 produced	80.52	lb/hr	
SO_2 produced	1.26	lb-moles/hr	
SO_2 scrubbing efficiency	**90.00**	%	
SO_2 emissions	8.05	lb/hr	
SO_2 emissions	0.13	lb-moles/hr	
SO_2 stack gas concentration	35.94	ppmv, dry, actual	
SO_2 stack gas concentration	102.7	mg/Nm^3, dry, actual	
SO_2 stack gas concentration	85.6	mg/Nm^3, dry, corrected to 11% O_2	
Conversion efficiency to H_2SO_4	5	%	
H_2SO_4 produced	6.49	lb/hr	
H_2SO_4 produced	0.07	lb-moles/hr	
H_2SO_4 scrubbing efficiency	**0.00**	%	
H_2SO_4 emissions	6.49	lb/hr	
H_2SO_4 emissions	0.07	lb-moles/hr	
H_2SO_4 stack gas concentration	18.9	ppmv, dry, actual	
H_2SO_4 stack gas concentration	83	mg/Nm^3, dry, actual	
H_2SO_4 stack gas concentration	69	mg/Nm^3, dry, corrected to 11% O_2	

(a) See calculations in Attachment A for estimated concentrations of sulfur from Hypalon liner.
(b) Average sulfur concentration and sulfur removed from soil are documented in Table 2.

Stack gas flow	3,501.0	lb-moles/hr (dry)
Stack gas O_2 concentration (actual)	9.0	vol %

Table 4. Chlorine Removal Summary (a)

Sample No.	Analyses	Concentration in Soil (wt%, dry basis)					Removal Efficiency (%)			
		Feed Soil	Treated Soil							
			350°C	450°C	550°C	Average	350°C	450°C	550°C	Average
TS1	Total Chlorine/Chloride	0.311	0.118	0.119	0.111	0.116	62.1	61.7	64.3	62.7
TS2	Total Chlorine/Chloride	0.171	0.108	0.093	0.086	0.096	36.8	45.6	49.7	44.1
TS3	Total Chlorine/Chloride	0.064	0.05	0.038	0.038	0.042	21.9	40.6	40.6	34.4
	Average	0.182	0.092	0.083	0.078	0.085	49.5	54.2	57.0	53.5

Average from Other Sites (b) 55.5

(a) Based on data from Focus Environmental, Inc., Thermal Treatability Test Report - Orica Car Park Waste Encapsulation Site, February 2007, Tables 5-14, 5-15, 5-16.
(b) Average from historical data compiled by Focus Environmental from other sites. Includes treatability and full-scale data.

Table 5a. HCl & Cl_2 Emissions Estimate - Average

Parameter	Value	Units	
Soil feed rate	70,400	lb/hr, wet basis	
Soil feed rate	63,360	lb/hr, dry basis	
Chlorine in soil from Hypalon liner	0.094	%, dry basis	(a)
Chlorine concentration in soil (Average)	0.182	%, dry basis	(b)
Soil feed Chlorine concentration	0.276	%, dry basis	Includes liner
Chlorine to off-gas (Average)	53.5	% of total chlorine	(b)
Chlorine removed from soil	0.148	% of dry soil	
Chlorine to off-gas	93.63	lb/hr	
Conversion efficiency to HCl in Oxidizer	**99.8**	%	
HCl produced	96.1	lb/hr	
HCl produced	2.63	lb-moles/hr	
HCl scrubbing efficiency	**99.00**	%	
HCl emissions	0.96	lb/hr	
HCl emissions	0.03	lb-moles/hr	
HCl stack gas concentration	8	ppmv, dry, actual	
HCl stack gas concentration	12	mg/Nm^3, dry, actual	
HCl stack gas concentration	10	mg/Nm^3, dry, corrected to 11% O_2	
Conversion efficiency to Cl_2 in Oxidizer	0.2	%	
Cl_2 produced	0.2	lb/hr	
Cl_2 produced	0.00	lb-moles/hr	
Cl_2 scrubbing efficiency	**0.00**	%	
Cl_2 emissions	0.19	lb/hr	
Cl_2 emissions	0.003	lb-moles/hr	
Cl_2 stack gas concentration	0.8	ppmv, dry, actual	
Cl_2 stack gas concentration	2.4	mg/Nm^3, dry, actual	
Cl_2 stack gas concentration	2.0	mg/Nm^3, dry, corrected to 11% O_2	
	HCl	**Cl_2**	
Stack Gas Cl Distribution (Calculated)	83.7	16.3	%
Stack Gas Cl Distribution (Historical) (c)	85.9	14.1	%

(a) See calculations in Attachment A for estimated concentrations of chlorine from Hypalon liner.
(b) Average chlorine concentration and chlorine removed from soil are documented in Table 4.
(c) See historical HCl and Cl_2 stack data in Table 6.

Stack gas flow	3,501.0	lb-moles/hr (dry)
Stack gas O_2 concentration (actual)	9.0	vol%

Table 5b. HCl & Cl_2 Emissions Estimate - Worst Case

Parameter	Value	Units	
Soil feed rate	70,400	lb/hr, wet basis	
Soil feed rate	63,360	lb/hr, dry basis	
Chlorine in soil from Hypalon liner	0.094	%, dry basis	(a)
Chlorine concentration in soil (Maximum)	0.311	%, dry basis	(b)
Soil feed Chlorine concentration	0.405	%, dry basis	Includes liner
Chlorine to off-gas (Maximum)	64.3	% of total chlorine	(b)
Chlorine removed from soil	0.260	% of dry soil	
Chlorine to off-gas	165.02	lb/hr	
Conversion efficiency to HCl in Oxidizer	**99.6**	%	
HCl produced	169.0	lb/hr	
HCl produced	4.63	lb-moles/hr	
HCl scrubbing efficiency	**98.00**	%	
HCl emissions	3.38	lb/hr	
HCl emissions	0.09	lb-moles/hr	
HCl stack gas concentration	26	ppmv, dry, actual	
HCl stack gas concentration	43	mg/Nm^3, dry, actual	
HCl stack gas concentration	36	mg/Nm^3, dry, corrected to 11% O_2	
Conversion efficiency to Cl_2 in Oxidizer	0.4	%	
Cl_2 produced	0.7	lb/hr	
Cl_2 produced	0.01	lb-moles/hr	
Cl_2 scrubbing efficiency	**0.00**	%	
Cl_2 emissions	0.66	lb/hr	
Cl_2 emissions	0.009	lb-moles/hr	
Cl_2 stack gas concentration	3	ppmv, dry, actual	
Cl_2 stack gas concentration	8	mg/Nm^3, dry, actual	
Cl_2 stack gas concentration	7	mg/Nm^3, dry, corrected to 11% O_2	
	HCl	**Cl_2**	
Stack Gas Cl Distribution (Calculated)	83.7	16.3 %	
Stack Gas Cl Distribution (Historical) (c)	85.9	14.1 %	

(a) See calculations in Attachment A for estimated concentrations of chlorine from Hypalon liner.
(b) Maximum chlorine values are from TS1 at 550°C in Table 4.
(c) See historical data in Table 6.

Stack gas flow	3,501.0	lb-moles/hr (dry)
Stack gas O_2 concentration (actual)	9.0	vol%

Table 6. Full-Scale HCl/Cl_2 Stack Data

Site	HCl Corrected Conc. @ 11% O_2, 0^oC (mg/Nm^3)	Cl_2 Corrected Conc. @ 11% O_2, 0^oC (mg/Nm^3)	Split of Cl Between HCl and Cl_2		Wet Scrubber
			HCl (%)	Cl_2 (%)	
Aberdeen	47.5	24.18	66.3	33.7	Yes
Woods	3.97	0.22	94.7	5.3	Yes
Missouri Electric	7.12	0.04	99.4	0.6	Yes
Lipari	0.98	0.20	83.1	16.9	Yes
Average	14.89	6.16	85.9	14.1	

Table 7. Metals Emissions Estimate

Metal	Feed Soil Concentration (Dry Basis) (a) (mg/kg)	Metal Feed Rate in Soil (g/sec)	Minimum SRE (b) (%)	Metal Emission Rate		Stack Metal Concentration (dry basis)	
				(g/sec)	(µg/min)	(Actual) (µg/Nm^3)	(@ 11% O_2) (µg/Nm^3)
Antimony							
Arsenic	5.65	0.0451	99.783	9.81E-05	5,886	9.91	8.26
Barium							
Beryllium							
Cadmium	1.04	0.0083	99.551	3.73E-05	2,239	3.77	3.14
Chromium	13.14	0.1050	99.914	9.05E-05	5,428	9.14	7.62
Cobalt							
Lead	21.55	0.1722	99.948	8.95E-05	5,370	9.04	7.53
Manganese							
Mercury	1.87	0.0149	**85**	2.24E-03	134,478	226	189
Nickel	8.96	0.0716	99.900	7.18E-05	4,310	7.26	6.05
Selenium							
Vanadium							

a) Metals data for feed soil provided by URS in memo to John Hunt (Thiess) dated March 16, 2007.
b) SRE - System Removal Efficiency (based on minimum historical data in Table 8) except for mercury which is based on carbon injection to the baghouse for mercury removal.

Soil Feed Rate	35.2	tons/hr (wet basis)
Soil Feed Rate	31.68	tons/hr (dry basis)
Gas flow	594	Nm3/min (dry) @ 0°C
Stack gas O_2 concentration (actual)	9.0	%

Table 8. Full-scale Metals System Removal Efficiency (SRE) Data

Parameter	Units	Average Test Values						Historical Data Summary				
		Aberdeen	Woods Industries	Madisonville Creosote	Lipari Landfill	Savannah Army Depot	Fulton Terminals	No. of Samples	Minimum	Average	Median	Maximum
Antimony	%SRE		99.952	99.999	99.999	99.658		4	99.658	99.902	99.975	99.999
Arsenic	%SRE	99.966	99.984	99.810	99.991	99.783	99.974	6	99.783	99.918	99.970	99.991
Barium	%SRE		99.994	99.990	99.996	99.940		4	99.940	99.980	99.992	99.996
Berylium	%SRE		99.893	99.998	99.939	99.836		4	99.836	99.916	99.916	99.998
Cadmium	%SRE		99.730	99.990	99.841	99.551		4	99.551	99.778	99.785	99.990
Chromium	%SRE		99.943	99.970	99.968	99.942	99.914	5	99.914	99.947	99.943	99.970
Cobalt	%SRE											
Copper	%SRE											
Lead	%SRE	99.956	99.953	99.990	99.991	99.948	99.953	6	99.948	99.965	99.955	99.991
Manganese	%SRE											
Mercury	%SRE		49.773	37.470	92.256	27.403		4	27.403	51.726	43.622	92.256
Nickel	%SRE		99.920	99.930	99.900			3	99.900	99.917	99.920	99.930
Selenium	%SRE		99.956	99.950				2	99.950	99.953	99.953	99.956
Silver	%SRE		99.891	99.997	99.592	99.486		4	99.486	99.742	99.742	99.997
Thallium	%SRE		99.999	99.993	99.790	99.415		4	99.415	99.799	99.892	99.999
Vanadium	%SRE											

a) Data taken from historical data on full-scale systems compiled by Focus Environmental.

Table 9. Nitrogen Removal Summary (a)

Sample No.	Analyses	Concentration in Soil (wt%, dry basis)					Removal Efficiency (%)			
		Feed Soil	Treated Soil							
			350°C	450°C	550°C	Average	350°C	450°C	550°C	Average
TS1	Nitrogen	0.068	0.05	0.03	0.02	0.033	26.5	55.9	70.6	51.0
TS2	Nitrogen	0.071	0.04	0.06	0.03	0.043	43.7	15.5	57.7	39.0
TS3	Nitrogen	0.039	0.01	0.01	0.01	0.010	74.4	74.4	74.4	74.4
	Average	0.059	0.033	0.033	0.020	0.029	43.8	43.8	66.3	51.3

Average from Other Sites (b)	44.5

(a) Based on data from Focus Environmental, Inc., Thermal Treatability Test Report - Orica Car Park Waste Encapsulation Site, February 2007, Tables 5-14, 5-15, 5-16.
(b) Average from historical data compiled by Focus Environmental from other sites. Includes treatability and full-scale data.

Table 10a. NOx Emissions Estimate - Average

Parameter	Value	Units	Notes
Soil feed rate	70,400	lb/hr, wet basis	
Soil feed rate	63,360	lb/hr, dry basis	
Nitrogen concentration in soil	0.059	%, dry basis	(a)
Nitrogen to off-gas	51.3	% of total nitrogen	(a)
Nitrogen removed from soil	0.031	% of dry soil	
Nitrogen to off-gas	19.29	lb/hr	
Nitrogen to off-gas	1.38	lb-mole/hr	
Nitrogen to NOx conversion efficiency	**4**	%	Assumption based on data from liquid fuel application
NOx produced	0.06	lb-mole/hr	
NOx produced	2.54	lb/hr	as NO_2

a) Based on average Treatability Data (See Table 9).

Table 10b. NOx Emission Estimate - Worst Case

Parameter	Value	Units	Notes
Soil feed rate	70,400	lb/hr, wet basis	
Soil feed rate	63,360	lb/hr, dry basis	
Nitrogen concentration in soil	0.068	%, dry basis	(a)
Nitrogen to off-gas	51.0	% of total nitrogen	(a)
Nitrogen removed from soil	0.035	% of dry soil	
Nitrogen to off-gas	21.96	lb/hr	
Nitrogen to off-gas	1.57	lb-mole/hr	
Nitrogen to NOx conversion efficiency	**6**	%	Assumption based on data from liquid fuel application
NOx produced	0.09	lb-mole/hr	
NOx produced	4.33	lb/hr	as NO_2

a) Based on Treatability Data - TS1 (See Table 9).

Table 11. Astec NOx Estimate

Burner Type	Estimated NOx at 3% O_2 (ppmv)	Estimated NOx at 11% O_2		Estimated NOx at Actual O_2		NOx Emissions (lb/hr)	NOx Emissions (lb-mole/hr)
		(ppmv)	(mg/Nm^3)	(ppmv)	(mg/Nm^3)		
Whisper Jet	**140**	78	160	93	192	15.0	0.33
Phoenix	**80**	44	91	53	109	8.6	0.19

Stack Conditions (max design case)

O_2 Concentration	9.0	vol%
Volume Flow	22,493	scfm (dry) @ 20°C
Volume Flow	594	Nm3/min (dry) @ 0°C
Molar Flow	3,501.0	lb-mole/hr

$$Cg = \frac{\text{ppmv} \times \text{MW}}{22.41}$$

where

Cg	concentration in mg/Nm^3 at 0^{o}C		
ppmv	concentration in ppmv		
MW	Molecular weight	46	lb/lbmole (for NO_2)

Table 12. Summary of NO_x Emission Calculations

Parameter	NO_x Rate Emissions (lb/hr)	NO_x Rate Emissions (lbmole/hr)	NO_x Concentration (dry basis) Actual (ppmv)	NO_x Concentration (dry basis) @11% O_2 (ppmv)	NO_x Concentration (dry basis) @11% O_2 (mg/Nm^3)
Average NOx Emissions					
NO_x from Soil (a)	2.54	0.06	16	13	27
Whisper Jet Burner NO_x (b)	15.04	0.33	93	78	160
Total Estimated NO_x Emissions	17.57	0.38	109	91	187
Worst Case NOx Emissions					
NO_x from Soil (c)	4.33	0.09	27	22	46
Whisper Jet Burner NO_x (b)	15.04	0.33	93	78	160
Total Estimated NO_x Emissions	19.37	0.42	120	100	206

NO_x - as NO_2 Equivalents

Molecular weight	46	lb/lbmole (for NO_2)
Stack Gas Flow	3,501	lbmoles/hr (dry basis)
Stack gas O_2 concentration (actual)	9.0	vol%

a) See Table 10a.
b) Thermal NO_x. See Astec estimate in Table 11 and benchmark calculation from AP-42 in Attachment B.
c) See Table 10b.

Table 13. Full-scale Particulate Emissions
Thermal Desorption Systems with Baghouse and Scrubber

Site Name	Particulates (mg/Nm^3 @ 11% O_2)
Woods	58.88
Aberdeen	29.03
Lipari Landfill	13.95
Sanders Aviation	13.74
Missouri Electric Works	13.5
Union Carbide	1.46
Average (a)	30

a) Rounded up to nearest 10.

Attachment A. Hypalon Composition Data (wt%)

Hypalon - Chlorosulfonated Polyethylene
Source: http://www.dupontelastomers.com/Products/Hypalon/techInfo.asp

	Chlorine	Sulfur	
H-20	29	1.4	CoatingsAdhesives
H-30	43	1.1	CoatingsAdhesives
H-40	34.5	1	GasketsSealsHydraulic HosesAutomotive Hoses
H-40 S	34.5	1	Automotive HosesWire and Cable JacketingsRollersGasketsSealsO-rings
H-4085	36	1	Flexible Magnetic CompoundsAdhesivesAutomotive HosesRollersCoated Fabrics
H-48	43	1	Misc AutomotiveCoatingsHydraulic Hoses
HPG 6525	26.5	1	Industrial Hose
HPR 6983	26.5	1	Timing Belts
CPR 6140	40		Roofing
CP 337	35		Coatings and Adhesives
Average	34.8	1.07	

Calculation of Liner Impacts on Soil Composition

Mass of Hypalon Liner	**16**	tonnes	
Mass of Soil	66,263	tonnes	
Moisture Content of Soil	10.0	wt%	
Mass of Dry Soil	59,637	tonnes	
Concentration of Liner in Soil	0.027	%, Dry Basis	16 x 66263 / 66263
Contingency Factor	10		
Concentration of Liner in Soil	0.270	%, Dry Basis	
Sulfur from Liner (in Soil)	0.003	%, Dry Basis	0.27 x 1.07 / 100
Chlorine from Liner (in Soil)	0.094	%, Dry Basis	0.27 x 34.8 / 100

Attachment B. AP-42 NOx Factors

(Used for Benchmarking Astec Burner NOx Estimate, Not Actually Used to Estimate NOx Emissions for Orica)

Fuel Type	**Emission Factor**		**Thermal Desorber Mass Emission Rate**		**Thermal Desorber Unit Emission Rate**	
#6 Residual Oil, normal fire	47	lb NOx/1000 gallon of fuel	**28.40**	lb/hr	0.34	lb/MM Btu
#6 Residual Oil, tangential fire	32	lb NOx/1000 gallon of fuel	**19.34**	lb/hr	0.23	lb/MM Btu
#1 & # 2 Distillate oil	24	lb NOx/1000 gallon of fuel	14.50	lb/hr	0.17	lb/MM Btu
Natural Gas	190	lb/MM ft^3	15.17	lb/hr	0.18	lb/MM Btu
Waste Oil Fuel Properties						
Reclaimed Oil Heat Content	18,802	Btu/lb				
Reclaimed Oil Density	0.8848					
Reclaimed Oil Bulk Density	7.38	lb/gallon				
Natural Gas Propertites						
Heat Content	1,050	Btu/ft^3				
	1,050,000,000	Btu/MM ft^3				
Gas Usage	0.08	MM ft^3/hr				
Fuel Usage						
Dryer Burner	40.61	MM Btu/hr	Feasibility Study Report			
Thermal Oxidizer Burner	43.24	MM Btu/hr	Feasibility Study Report			
Subtotal	83.85	MM Btu/hr	Feasibility Study Report			
RFO Rate	4,460	lb/hr				
RFO Rate	604	gallon/hr				

Source: U.S. EPA, AP-42 NOx Emission Factors
External Combustion Boilers, > 100 MM Btu/hr - Utility

Removal Efficiency Data (% of starting)

	Other Sites		
	Avg	**95% CI**	**Orica**
Nitrogen	44.5	54.6	44.6
Sulfur	38.3	48.1	62.1
Chlorine	55.5	76.7	47.0
Carbon	38.8	46.0	24.1
Heat Content	57.6	67.2	44.1

CPWE Analytical Data

Chemical	95% UCL	Mean	Median	Minimum	Maximum
Hexachlorobutadiene	1,848.5	1,367.8	682.0	0.5	8,680.0
Hexachlorobutadiene	1,520.4	1,056.9	347.0	0.5	11,700.0
Tetrachloroethene	251.7	89.4	30.5	0.5	1,010.0
Hexachlorobenzene (HCB)	106.6	76.4	28.3	1.0	641.0
1.1.2-Trichloroethane	48.0	24.1	10.0	0.5	313.0
Trichloroethene	38.1	19.5	10.0	0.5	176.0
1.1.2.2-Tetrachloroethane	33.3	18.3	10.0	0.5	158.0
cis-1.2-Dichloroethene	28.8	17.8	10.0	0.5	100.0
1.2.4-Trichlorobenzene	28.5	16.9	10.0	0.5	100.0
cis-1.2-Dichloroethene	27.8	16.6	10.0	0.5	100.0
1.2-Dibromo-3-chloropropane	27.8	16.6	10.0	0.5	100.0
Hexachloroethane	19.2	6.1	0.5	0.5	131.0
PCBs	10.4	5.1	2.5	0.1	20.0
Pentachlorobenzene	14.9	3.4	0.5	0.5	130.0
Hexachlorocyclopentadiene	2.6	2.5	2.5	2.5	4.5
1.2.4.5-Tetrachlorobenzene	9.6	2.3	0.5	0.5	82.1
1.2.4-Trichlorobenzene	9.3	2.2	0.5	0.5	80.8
1.4-Dichlorobenzene	1.3	0.8	0.5	0.5	14.9
Naphthalene	1.3	0.8	0.5	0.5	13.5
1.2-Dichlorobenzene	1.0	0.7	0.5	0.5	9.7
1.3-Dichlorobenzene	0.9	0.6	0.5	0.5	7.4
2-Chloronaphthalene	0.8	0.6	0.5	0.5	6.2
Bis(2-chloroethyl) ether	0.8	0.6	0.5	0.5	6.1
Acetophenone	0.8	0.6	0.5	0.5	4.9
Fluorene	0.6	0.5	0.5	0.5	2.4
2-Methylnaphthalene	0.5	0.5	0.5	0.5	0.8
Phenanthrene	0.5	0.5	0.5	0.5	1.0
N-Nitrosomorpholine	0.5	0.5	0.5	0.5	0.8
Total Organic Carbon	1.4	1.3	1.2	0.5	2.9
Zinc	118.7	51.2	27.0	6.0	764.0
Lead	24.4	21.6	19.0	6.0	59.0
Chromium	26.1	13.1	8.0	3.0	138.0
Copper	19.8	12.6	9.0	5.0	63.0
Nickel	20.9	9.0	5.0	2.0	130.0
Arsenic	6.3	5.7	5.0	5.0	18.0
Mercury	2.9	1.9	1.0	0.1	14.7
Cadmium	1.1	1.0	1.0	1.0	3.0

Source: Memo from Mulholland (URS) to Biddles (Orica) dated March 16, 2007

Attachment B Thermal Oxidiser Operating Conditions

Emma M
Biddles/AU/TCG/ORICA
14/02/2007 12:32 PM

To James.Goodwin@environment.nsw.gov.au
cc Bala Kathiravelu/AU/TCG/ORICA, jwhunt@thiess-services.com.au
bcc
Subject CPWE - Environmental Assessment and Clean Air Regulation

Dear James,

Re Clean Air Regulation, Oxygen Correction Basis

Orica Australia Pty Ltd (Orica) is seeking clarification of the oxygen correction basis for reporting stack emission concentrations for the thermal plant proposed for the Car Park Waste Encapsulation (CPWE) remediation.

I understand that the purpose of correcting stack concentrations based on stack oxygen is to eliminate concentration variations due to the addition of air, above that which is properly required for efficient combustion. I also understand that different classes of thermal process, when operated efficiently have different inherent stack oxygen concentrations, reflecting the particular nature of the processes.

The Protection of the Environment Operations (Clean Air) Regulation (2002) gives an oxygen basis of 3% in Schedule 5, part 3 for reporting stack concentrations for Group 6 plant. This is the typical oxygen concentration in a well managed furnace or boiler combusting liquid or gaseous fuel. The Regulation in Section 28(2)(c) refers to other “relevant reference conditions” that the Department of Environment and Conservation (DEC) may specify in a licence. Orica assume that this provision was designed to allow for the use of other reference conditions where the default reference conditions (correction to 3% oxygen) is not applicable.

The plant proposed for the CPWE remediation is a Stockholm compliant Directly-heated Thermal Desorption (DTD) plant that will classified as Group 6 plant under the Regulation. The DTD plant includes a continuous rotary soil dryer and treated soil pugmill. Emissions from both unit operations are directed to a thermal oxidiser to destroy organic compounds present. Because both operations unavoidably capture associated non-combustion air, the typical stack gas oxygen concentration for the process is 11%, based on stack test data from previous projects in the United States using similar plants. A letter from out consultant documenting this position is attached (see the last section titled Oxygen Correction Factors).

On this basis, Orica consider that 11% O2 is the relevant reference condition for this technology and seek clarification from the DEC on this issue.

For clarity the following example, based on the Regulation is provided. The standard for Solid Particles for afterburners treating air impurities from material containing PTAPS for Group 6 plant is 50 mg/m3 (Schedule 2). Thus the standard for the DTD plant would be would 50 mg/m 3 at the relevant reference conditions of 11% O2 (dry, 273K and 101.3 kPa).

Your timely attention to this matter is requested, to enable finalisation of the Environmental Assessment (EA).

Regards,
Emma

Table 8. DRE vs Conc Calcs.pdf Figure 1 - VOC DRE.pdf Figure 2 - SVOC DRE.pdf FocusLetterRT- Rev 9.pdf
Table 1. Temp & Oxygen Data.pdf Table 2. Reynolds No..pdf Table 3. Arrhenius Equation.pdf Table 4. DRE - HCB.pdf

Table 5. DRE - Toluene.pdf Table 6. DRE - DDT.pdf Table 7. MCB DRE Calc.pdf

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Focus Environmental, Inc.
ENGINEERING SOLUTIONS TO ENVIRONMENTAL PROBLEMS

9050 Executive Park Drive
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January 6, 2006

Mr. John Hunt
Thiess Services Pty Ltd
43 Fourth Avenue
Blacktown NSW 2148
Australia

Subject: Thermal Desorber Thermal Oxidiser Operating Conditions

In response to your E-mail dated October 23, 2006, Focus Environmental, Inc. has prepared this report on issues arising from requirements for thermal oxidizer operating conditions for Group 6 plant treating Principal Toxic Air Pollutants (PTAPS) as set out in the NSW *Protection of the Environment Operations (Clean Air) Regulation (2002)* (the Clean Air Regulation). Specifically, we address operating conditions for thermal oxidizer exit gas temperature, gas residence time, destruction efficiency and oxygen correction factors applicable to thermal desorption plant treating contaminated soils.

Background

The new Clean Air Regulation specifies the following conditions for Group 6 (post September 2005) thermal oxidisers treating material containing PTAPs:

- Thermal oxidizer gas residence time of more than 2 seconds;
- Thermal oxidizer combustion temperature of more than 980°C;
- Operation of the plant in such a way that the destruction efficiency (DE) for a PTAP in the waste feedstream is more than 99.9999%; and
- Correction of stack gas emission concentrations for solid particles, nitrogen oxides, volatile organic compounds, hydrogen chloride, Type 1 and Type 2 substances (metals), sulfuric acid mist, sulfur trioxide, fluorine, and chlorine to an oxygen basis of 3%.

It should be noted that the NSW Department of Environment and Conservation (DEC) has proposed modifying the oxygen correction applied to stack gas emission concentration limits from a basis of 11% used in several recent licences for DTD plants to 3%, but has not proposed to modify the actual concentration limit values themselves.

We understand that the following sources were used to develop the thermal oxidiser limits in the Clean Air Regulation:

- *Reference 1: Guidance on Best Available Techniques and Provisional Guidelines on Best Environmental Practices Relevant to Article 5 and Annex C of the Stockholm Convention on Persistent Organic Pollutants, December 2004.*
- *Reference 2: Directive 2000/76/EC of the European Parliament and of the Council of 4 December 2000 on the Incineration of Waste (EU Waste Incineration Directive).*
- *Reference 3: US EPA Resource Conservation and Recovery Act (RCRA) regulations for hazardous waste incinerators, 40 Code of Federal Regulations, Part 60, Subpart O, Section 264.343.*

The requirements in the Clean Air Regulation contain aspects from each of the three cited regulatory sources. All three of the regulated operating parameters (residence time, temperature, and destruction efficiency) are highly interrelated, rather than being independent of each other. Considering the US, EU and Hong Kong, we have not previously seen requirements for specific minimum temperatures, gas residence times and DE combined in the same regulations. None of the cited regulatory sources specify numerical values for minimum temperatures, gas residence times, and destruction efficiency combined in the same regulation. These three regulatory frameworks specify either a minimum temperature and residence time or specify a minimum destruction and removal efficiency, however, none of them include both as discussed below:

- The Stockholm Convention incineration guidance documents discuss typical operating parameters of temperature and gas residence time and present some information concerning destruction efficiency. The general principals of the "Three T's" (time, temperature, and turbulence) are stressed as a guide for proper incinerator design. Recommendations are made for temperature and residence time deemed to provide high destruction efficiency, thus no specific destruction efficiency values are specified.

- The EU Waste Incineration Directive, in Article 6, Paragraph 1, specifically requires incinerators to operate at a fixed minimum temperature and gas residence time in order to ensure proper destruction of organic contaminants. Since these prescribed minimum operating conditions are deemed to provide adequate organic destruction, no numerical value or measurement requirement is placed on destruction efficiency.

- US Environmental Protection Agency hazardous waste incineration regulations (which are broadly applied to the thermal decontamination of soils) require a minimum destruction and removal efficiency for selected organic contaminants in the waste feed. Under this regulatory program, no specific minimum temperature or gas residence time is mandated. Rather, the incinerator operator is required to measure the destruction efficiency during a performance test and then develop a site-specific minimum operating temperature based on the process conditions demonstrated during the performance test.

The design and operation of the DTD plants used to treat contaminated soil typically do not meet all of the specifications in the Clean Air Regulation related to thermal oxidiser exit gas temperature and residence time. Designs for these types of plants are based on a well-established technology with a long history of application to the treatment of hazardous wastes in the US. It should also be noted that while the Clean Air Regulation stipulates that the plant must be operated to achieve a DE of >99.9999%, measurement of the DE is not required. Demonstration of 99.9999% DE for native organic compounds in any type of thermal treatment system is very difficult, and in many cases impossible because of sampling and analytical issues, as discussed in detail later in this report. Therefore, we have developed analyses for the following factors:

- Review of the three key process operating parameters (gas residence time, temperature, and turbulence) affecting combustion efficiency
- Interrelationship of gas residence time, temperature and turbulence
- Discussion of DE calculation methods, measurement issues, theoretical DE calculations, and actual destruction and removal efficiency test results
- Basis for use of oxygen correction factors
- Differences in thermal desorption plants used for soil decontamination and typical hazardous waste incinerators
- How the design and operation of the proposed DTD plant can address the intent of the Clean Air Regulation.

Gas Residence Time

Many guidance documents for hazardous waste incineration design recommend a minimum gas residence time of 2 seconds at a temperature of about 850°C or higher. The basis for this recommendation is to provide adequate time and temperature for organic destruction, given the wide array of waste materials and physical characteristics of the wastes that may be treated in a hazardous waste incinerator. The recommendation for a 2 second residence time originates with the requirement to treat liquid wastes injected into a single combustion chamber incinerator or into the thermal oxidiser of a rotary kiln or other multiple chamber incinerators. Adequate time must be provided first for the liquid droplet to evaporate and then for the resulting organic vapor to be oxidized. The rate-limiting step in the process is the evaporation of the liquid droplet.

Conversely, fume incinerator design guidelines typically recommend a minimum gas residence time in the range of 0.5 to 1.0 seconds, with a typical value being 0.75 seconds. In fume incineration plants, organics entering the combustion chamber are already present as a vapor. Therefore, no time is required for evaporation of liquid droplets in a fume incinerator.

In a DTD plant equipped with a thermal oxidiser, the organics entering the thermal oxidiser are already in the vapor phase, having been desorbed from the soil in the rotary dryer. No liquid wastes are injected into the thermal oxidiser. No residence time is required in the thermal oxidiser for evaporation of liquid droplets, and a relatively short gas residence time is capable of achieving adequate organic destruction efficiency. Therefore, DTD plants are much more similar in design and function to fume incinerators rather than to hazardous waste incinerators that inject liquid wastes into the thermal oxidiser.

DTD plants in the US are typically designed for gas residence times in the thermal oxidiser in the range of 1.0 to 2.0 seconds. Therefore, we believe that a thermal desorption plant equipped with an afterburner having at least a 1 second gas residence time should be capable of organic destruction comparable to a more traditional hazardous waste incinerator burning a variety of liquid and solid waste with an afterburner gas residence time of 2 seconds or greater. To design an afterburner on a DTD plant with a gas residence time of >2 seconds would increase the physical size of the equipment for a marginal environmental benefit.

In a wider context, the gas residence time in the rotary dryer is also relevant when compared to the "2 second residence time rule of thumb" since the evaporation of organic compounds occurs in the rotary dryer. A typical rotary dryer has a gas velocity of 3.6-4.6 m/sec (12-15 ft/sec) and a length of 9.8-12.2 m (32-40 ft). Based on these parameters, the typical gas residence time in a rotary dryer alone is in the range of 2-3 seconds.

Astec, the largest US manufacturer of mobile DTD plants, has manufactured approximately 40 soil remediation plants. Thermal oxidisers have been manufactured with a range of residence times but Astec's "standard" design for the gas residence time in the thermal oxidiser combustion chamber of these mobile plants is approximately 1.6 seconds. However, plants have been constructed with residence times ranging from 1.0 to 2.0 seconds, depending on the type of waste applications the plant was to be used on. Residence time values have been chosen to ensure good combustion but also recognizing equipment size limitations imposed by the requirement to make the plants portable (*personal communication, Wendell Feltman of Astec to William Troxler of Focus, 03/01/07*).

A small amount of additional residence time is available in the burner chamber and in the ductwork between the thermal oxidiser chamber and downstream equipment. However, thermal oxidisers for mobile DTD plants must be designed with weights and dimensions so that the equipment can be transported over the road as one unit. Fixed based incinerators may be field erected and do not have this limitation, hence they may utilize larger equipment that may provide additional gas residence time.

Gas residence time in DTD plants can be determined only by mass and energy balance calculations and cannot generally be measured directly for two reasons:

1) Reliable measurement of gas velocity with a pitot tube requires a minimum length of straight ductwork. Since DTD plants are typically designed with a "tight" layout, sufficient straight ductwork to measure a gas velocity directly downstream of a thermal oxidiser rarely exists.
2) Stack gas parameters (velocity, temperature) measured at the stack include not only the gas exiting the thermal oxidiser, but any other process streams that were added to the gas

downstream of the thermal oxidiser. These process streams would include water added to a scrubber, and steam and air drawn from or through a treated soil cooling pugmill.

Another gas residence time consideration specific to a DTD plant treating contaminated soils is the potential for entrained fine particles to contain absorbed contaminants. Some residence time is required for desorption of any surface adsorbed contaminants, however it is difficult to quantify how much residence time may be required. Since a cyclone is used to remove large particles upstream of the thermal oxidiser, only very small particles will enter into the thermal oxidizer. Therefore, minimal residence time should be required for desorption of the contaminants from these small particles.

However, any contaminants associated with particles emitted through the stack would be quantitatively determined through the sampling and analysis of the stack gases. With the exception of the sampling for volatile organic compounds (which are appropriately assumed to be confined to the gas phase) all applicable stack gas sampling methods include the collection of particulate matter as a part of the overall stack gas sample. Prior to analysis, the analytical methodology includes sample preparation procedures that incorporate an extraction step for recovery of organic contaminants from the collected particulate matter. Therefore, any organics contained in entrained particles would be quantified in the stack gas analysis.

In summary, the best practice thermal oxidizer residence time for a mobile DTD plant to achieve a high destruction efficiency for gaseous contaminants in a thermal oxidiser based on US experience ranges from 1 to 2 seconds, with a typical value of approximately 1.6 seconds.

Gas Temperature

Design recommendations for hazardous waste incinerator thermal oxidizer temperatures typically range from 800°C to 1200°C. The Stockholm Convention Incineration Guidance Document recommends a minimum thermal oxidiser temperature of 900°C, while the EU Waste Incineration Directive specifies a minimum temperature of 850°C for any incinerator, and a minimum of 1,100°C when burning wastes containing more than 1% organic chlorine. Table 1 summarizes thermal oxidizer operating temperature values for eight different DTD systems treating chlorinated organic compounds. The average temperature for these applications was 991^{o}C, with a range of 934^{o}C to 1,037^{o}C and a standard deviation of 31^{o}C. For comparison, the DTD plant at the Allied Feeds site, which is a similar design to that proposed for the Lednez site, has been licensed to operate with a temperature set-point of 950°C ±30°C for the thermal oxidiser.

It is generally recognized that virtually all organic compounds are destroyed at temperatures above 800^{o}C. This assertion is supported by theoretical calculations presented later in this report. In full-scale practice, somewhat higher operating temperatures are used to account for non-ideal mixing, "cold spots" in oxidizer chambers, allowances for temperature fluctutations, etc.

It should also be recognized that there is a tradeoff between very slight improvements in organic destruction efficiency and the consumption of a non-renewable resource (natural gas) as operating temperatures are increased. Fuel usage in a thermal oxidizer (with all other factors being constant), is roughly proportional to the change in temperature for the gas between the inlet and outlet of the thermal oxidizer. Consider the following hypothetical example based on the following assumptions for a DTD system:

- Soil feed rate - 27 tonnes/hr
- Thermal oxidizer inlet gas temperature of 600^{o}C
- Thermal oxidizer outlet gas temperature of 900^{o}C
- Natural gas usage rate of 40 GJ/hr
- Monochlorobenzene feed concentration - 1,000 mg/kg
- Monochlorobenzene feed rate - 27 kg/hr
- Monochlorobenzene DE - 99.99%
- Monochlorobenzene stack emission rate - 0.0027 kg/hr

The energy consumption required to remove chlorobenzene at DE of 99.99% is 1.48 GJ/kg (40 GJ/hr/26.9973 kg/hr). If the thermal oxidizer outlet gas temperature was raised to 1,000^{o}C and a monochlorobenzene DE value of 99.9999% was obtained, the incremental fuel usage would be about 13 GJ/hr and the monochlorobenzene stack emission rate would be 0.000027 kg/hr (a reduction of 0.002673 kg/hr compared to the base case). Therefore, the incremental energy consumption for the additional emission reduction would be 4,863 GJ/kg (13 GJ/hr/0.002673 kg/hr) of additional monochlorobenzene destroyed compared with 1.48 GJ/kg .

While a DTD plant thermal oxidiser operating temperature can be set to operate higher than 950^{o}C, there is a significant concern that this could result in a slagging problem in the thermal oxidiser. Melting of entrained particles in the thermal oxidiser and accumulation of slag on the walls of the thermal oxidiser chamber can result in significant operational problems and require frequent shutdowns and cooling down of the DTD plant to remove the accumulated slag. Removal of slag from the walls of the thermal oxidizer also poses safety issues for personnel who will be responsible for removing the slag.

The EU Reference Document on the Best Available Techniques for Waste Incineration states that ash fusion can become a problem in incinerators operated at 980°C or above. Because this is the same temperature specified as the minimum in the new Clean Air Regulation, it bears close observation when operating within the requirements of the new regulation. The potential for slagging depends on: (1) the operating temperature in the thermal oxidiser, (2) the mixing of the gas within the thermal oxidiser flame envelope, (3) chemical composition of the particulates in the process gas, and (4) the mass of particulates in the process gas.

The fourth factor listed above is a much more important factor in a soil treatment plant than in a typical hazardous waste incinerator. In a DTD plant, 70-90% of the feed materials are inert solids that can potentially be entrained as particulates in the gas stream. In hazardous waste incinerators, the ash content of the feed material is typically 5-20%. Therefore, the mass of entrained particles contained in the gases entering the thermal oxidiser from a DTD plant would be much greater than from a hazardous waste incinerator. Slagging is also a particular concern when processing materials containing low melting point materials, such as sodium chloride, that may be present in marine sediments, which are present at the Allied Feeds and Lednez sites.

In summary, we believe that a best practice thermal oxidiser temperature for a mobile DTD plant to achieve a high destruction efficiency of gaseous contaminants should be based on US and EU experience and recognize the unique characteristics of DTD plants treating contaminated soils. We believe that the current operating set-point of the DTD plant at the Allied Feed site (950°C ±30°C) is sufficient to ensure a high destruction efficiency for gaseous contaminants and meets the intent of the new regulation, in that the value of 980°C is at the upper limit of the specified operating range.

We would propose that a mechanism to meet the intent of the new regulations on future projects would be to specify an operating range of 980°C ±50°C. This would allow for the incorporation of the 980°C value into the operating consent, but would provide some latitude to allow the operators to maintain the unit below the temperature where slagging could become a problem or to increase temperature if necessary to meet destruction and removal efficiency requirements. The consent conditions should also include establishing the operating temperature set-point as a 60 minute rolling average, rather than as an instantaneous value. This will allow some operational flexibility to account for normal variations in temperature due to differences in the soil feed rate and chemical composition.

Gas Turbulence

Good combustion requires not only adequate gas residence time and temperature, but also good turbulence (mixing). Turbulence cannot be measured directly; however, the Reynolds number can be calculated as an indicator of turbulence. The Reynolds number is a function of the diameter of the thermal oxidiser and the combustion gas velocity, temperature, density, and viscosity. Example calculations showing the relationship of these parameters to the Reynolds numbers are presented in Table 2. As shown in the formula at the bottom of Table 2, Reynolds number is a direct function of gas velocity.

From an equipment design standpoint, design velocity is controlled through the selection of the optimum length to diameter ratio for the thermal oxidiser chamber. Astec recommends a design gas velocity in the range of 9.1-20.7 m/sec (30-35 ft/sec). Lower gas velocities will result in less turbulence and potentially poorer organic destruction efficiencies. Higher gas velocities will result in an increased pressure drop. Attempts to increase gas residence time by reducing the gas flow rate and velocity may reduce turbulence below acceptable levels and result in poorer combustion performance than would be achieved at a lower gas residence time.

Inter-relationship of Gas Temperature, Residence Time, and Turbulence

The three critical thermal oxidizer operating parameters of residence time, temperature and turbulence are highly interrelated for a given DTD plant design and soil feed conditions. In simple terms for a DTD plant, if the volume of gas passing through the thermal oxidiser increases due to either increased thermal oxidiser operating temperature or soil treatment temperature, then the residence time in the thermal oxidizer decreases and the turbulence increases. For a given thermal oxidizer operating temperature and soil treatment temperature, the only effective operational solution to increase residence time is to decrease the soil feed rate so that less fuel is used in the rotary dryer and thermal oxidiser. This would, however, have the effect of decreasing turbulence in the thermal oxidizer and potentially reducing combustion efficiency. It would also negatively impact project economics.

Theoretical Calculation of Destruction Efficiency
A theoretical calculation of destruction efficiency can be developed as a first order rate equation using the Arrhenius equation (*J.J. Cudahy and W.L. Troxler, Autoignition as an Indicator of Thermal Oxidation Stability, Journal of Hazardous Materials, Volume 8, pp. 59-68, 1983*). It should be noted that destruction efficiency in the NSW Clean Air Regulation is defined differently to destruction efficiency discussed here (see section on DRE below). These calculations are based on combustion of a single compound under ideal mixing conditions. These calculations also do not consider the formation of products of incomplete combustion from other precursor compounds.

Since none of these conditions exist in real applications, the calculated destruction efficiencies are somewhat higher than those that can be achieved in full-scale thermal treatment plants. However, the calculations do illustrate the relationships between combustion temperature, residence time, and thermal stability of the compound. The Arrhenius equations are presented in Table 3 and example calculations for hexachlorobenzene (high thermal stability), toluene (moderate thermal stability) and DDT (low thermal stability) are presented in Tables 4, 5 and 6 respectively. Conditions that theoretically result in 99.9999% destruction efficiency are shaded in yellow.

This analysis indicates that there is a threshold temperature for each compound at which destruction is initiated, and once it is initiated, proceeds very rapidly with slight increases in temperature. This analysis also indicates that temperature is a much more important parameter than residence time in terms of its effect on destruction efficiency. Slight increases in temperature (20-40^{o}C) can have the same effect on increase in destruction efficiency as large increases in gas residence time (0.5 to 2.0 seconds).

Destruction and Removal Efficiency
The term "destruction and removal efficiency" (DRE) was developed as part of the hazardous waste incineration regulations in the United States. The DRE concept is not contained in the EU Waste Incineration Directive, nor is it included in the recommendations for best practices in the Stockholm Convention guidance document, which focus on thermal oxidizer temperature, residence time and turbulence, the main factors that control DRE.

The DRE performance standards were developed around 1980 as part of the US EPA Resource Conservation and Recovery Act (RCRA) regulations for hazardous waste incinerators. They are described in 40 Code of Federal Regulations (CFR), Part 60, Subpart O, Section 264.343. The same requirements for DRE have been kept in the new US Hazardous Waste Combustor Maximum Achievable Control Technology (HWC MACT) regulations described in 40 CFR, Part 63, Subpart EEE. DRE is an indicator of a thermal treatment device's organic compound control efficiency and is assessed for one or more principal organic hazardous constituents (POHCs).

Demonstration of DRE requires that sufficient analyte be present in the feed material so that a detectable quantity is present in the stack gas after the required DRE is achieved. In order to demonstrate >99.9999% DRE, a very high concentration of the analyte in the feed material is required. The key factors that affect the capability to demonstrate a given level of DRE include:

- Concentration of analyte in the feed soil
- Soil feed rate
- Stack gas flow rate (dry basis)
- Stack gas sample volume
- Lower analytical quantitation limit for analyte
- Analyte background concentration in stack gas.

Table 7 presents an example calculation for the measurable DRE value for monochlorobenzene at a soil feed concentration of 1,000 mg/kg. As shown in this calculation, the estimated DRE value that can be measured at this feed condition is 99.99982%.

Table 8 presents a summary of DRE calculations for monochlorobenzene and hexachlorobenzene at a range of concentrations in the feed soil ranging from 1 mg/kg to 10,000 mg/kg. Two different sets of calculations are presented for hexachlorobenzene based on using analytical techniques with different detection limits. Table 8 shows that the concentration of monochlorobenzene in the feed soil would have to be between 1,000 and 10,000 mg/kg in order to demonstrate 99.9999% DRE. For hexachlorobenzene (using a standard GC/MS analytical method), 99.9999% DRE could not be demonstrated, even at a feed soil concentration of 10,000 mg/kg. For hexachlorobenzene (using a GC/MS analytical method coupled with scanning ion microscopy or SIM), demonstration of 99.9999% DRE would require a feed soil concentration of close to 1,000 mg/kg.

Native concentrations of individual contaminants in the environmental samples are generally far less than 1,000 mg/kg. Therefore, DRE could not be demonstrated on feed soil without spiking the soil with a surrogate compound. In some cases, the mass of surrogate compound required for spiking may exceed the mass of contaminant at the site. Since this approach is illogical, a best practice would be to design and operate a plant to achieve a 99.9999% DRE and rely on engineering calculations rather than direct measurement of DRE.

Destruction Efficiency

The definition of DE in the letter from Mr. John Coffey of the NSW DEC to Mr. Scott Jeffries of the Department of Planning on the proposed modification to thermal treatment technology for the Lednez project, appears to be significantly different than the definition of DE in the Clean Air Regulation and the definition of DRE in the US EPA hazardous waste incineration regulations. The US EPA regulations define DRE based on the mass of the analyte in the feed material and the mass of the analyte in the stack gas. Therefore, destruction and *removal* efficiency includes not only any destruction or decomposition that occurs in the thermal oxidizer, as well as any removal that occurs based on residual concentrations in the treated soil, or any analytes removed in any other part of the emission control system, such as scrubber water. For most compounds, contributions to removal by these two mechanisms would be very small.

However, the term *removal* would also include any destruction of organic compounds in the gas stream before the gas stream enters the thermal oxidizer. For thermally stable compounds, such as chlorobenzene or hexachlorobenzene, this removal mechanism would be relatively small as shown by theoretical destruction calculations previously presented in Tables 4 and 5. However, for thermally unstable compounds, such as DDT, this removal mechanism could be substantial as shown by calculations presented in Table 6.

The definition of DE in the letter from Mr. John Coffey appears to be based on measurement of the mass of specific compounds at the entrance and exit of the thermal oxidizer. Destruction efficiency measured in this manner is very different from destruction and removal efficiency as defined in the US hazardous waste regulations (and the NSW Clean Air Regulation). This definition ignores other removal mechanisms, as discussed above, which were considered by US EPA when they established the technology-based DRE standards. Destruction efficiency measured across the thermal oxidizer of a DTD plant is more conservative than destruction efficiency (or DRE) measured across the whole DTD plant. This is because the DRE calculation considers contaminant decomposition and destruction in the rotary dryer in advance of the thermal oxidizer, as well as low levels of contaminant that are not removed from the treated soil. The impact of these other removal mechanisms, as discussed above, may vary from very minor to very significant (as presented in Tables 4,5 and 6), depending on the chemical and physical properties of the compound being measured. For example, a DE of 99.9999% for DDT across the thermal oxidizer may be equivalent to a DE (or DRE) of 99.999999% across the entire plant.

However a second, and much more significant, issue related to collecting stack gas samples at the entrance and exit of the thermal oxidizer is that that it may be difficult, dangerous, or impossible to collect representative samples of the process gas in order to calculate DE. Thermal oxidizers on DTD plants are not designed with sampling ports at the inlet and exit of the thermal oxidizer for several reasons:

- Sampling of a potentially organic-rich gas at the inlet of the thermal oxidizer may exposure stack sampling personnel to toxic fumes. While the gas at this point should be under negative pressure and any leakage should be into the stack, the possibility exists that a positive pressure event could occur during which organic-rich gas could be discharged from the sampling port.

- Sampling methods for organic compounds (except for VOCs) require isokinetic sampling techniques. Isokinetic sampling requires straight runs of ductwork upstream and downstream of the sampling point. Because DTD plants are built for compactness and portability, suitable straight lengths of sampling duct runs upsteam and downstream of the thermal oxidizer do not exist on most plants.

- Organic compound gas sampling methods are based on collecting trace concentrations of contaminants. The concentration of organics in the gas at the inlet to the thermal oxidizer will be very high compared to the concentration at the outlet of the thermal oxidizer. Therefore, the organics would quickly saturate the XAD sampling resin.

- Thermal oxidizer is upstream of the baghouse in many DTD plants; therefore, the process gas will contain high concentrations of particulates that will quickly blind sample filters before a sampling run can be completed.

- The temperature of the gas at the outlet of a thermal oxidizer will be >900^{o}C, which will damage standard metal or glass stack sampling probes. Therefore, special air-cooled sampling probes are required. The use of air-cooled sampling probes is not common and this type of sampling equipment may or may not be readily available.

Oxygen Correction Factors

Where environmental regulations contain limitations on emission concentrations, it is common to "normalize" the concentration limits to a common basis in an effort to prevent a regulated entity from complying with the emission standard simply by diluting their emissions with ambient air. A common normalization basis for combustion plants is to use a "baseline" oxygen concentration, since this quantity is related to amount of "excess air" used in the combustion process. In the US, emission concentrations from thermal treatment plants processing hazardous wastes are normalized to 7% oxygen, dry basis, while the EU and many other countries normalize to 11% oxygen, dry basis. These values are both well above the minimum excess oxygen content of about 3% required for efficient combustion of typical boiler fuels, such as fuel oil or natural gas.

Since ambient air contains about 21% oxygen by volume, the proportional change in concentration with change in oxygen correction can be expressed as follows:

$$C_{new} = C_{old} \times \frac{21 - Y_{new}}{21 - Y_{old}}$$

where:

C = Stack gas concentration (mg/m^3)
Y = Oxygen correction basis (volume %)

Subscripts “old” and “new” denote values corresponding to the “old” oxygen correction and to the “new” value. Base on the equation presented above, the three following examples all represent the same actual concentration of a contaminant in a stack gas:

Oxygen Correction Factor	Concentration (mg/Nm^3)
3%	90
7%	70
11%	50

The NSW DEC has changed the current oxygen correction basis for DTD plants from 10 or 11% in the previous Clean Air Regulation and recent licenses to 3% in the new Clean Air Regulation. However, there has been no proposed corresponding change in the value of the emission standards. This amounts to establishing a regulatory standard at 3% oxygen that is only 55% of he value compared a standard corrected to 11% oxygen. Therefore, if a regulatory agency modifies an oxygen correction factor, the emission concentration value should also be changed in proportion to the change in oxygen correction factor.

An oxygen correction value is typically chosen that is similar to the normal stack gas oxygen concentration in the regulated processes. All combustion plants must operate with some level of excess oxygen to ensure good combustion. The required concentration of excess oxygen depends on the uniformity of the feed material and/or fuel. For example, boilers firing natural gas or fuel oil typically run at about 3% excess oxygen because these fuels have consistent compositions and are easily metered. Conversely, DTD plants that feed contaminated soil that may have a variable feed composition that is difficult to feed at a consistent rate. DTD plants must operate at a higher average excess oxygen concentration in order to assure that sufficient oxygen is always available to combust all organics, even under variable organic loading conditions.

Measured excess oxygen levels in DTD plants, as previously shown in Table 1, range from 4% to 14%. DTD plants that vent the pugmill steam to the atmosphere operate with oxygen contents at the lower end of this range. DTD plants that vent the pugmill steam (and any air drawn in through the pugmill discharge) back into the baghouse operate with oxygen contents at the higher end of this range. However, venting the steam back into the baghouse is a best practice emission control technique since any particulates in the steam stream will be captured in the baghouse. Measured stack gas oxygen concentrations from a number of full-scale DTD plants for both of these designs were previously presented in Table 1.

As shown in Table 1, the average concentration of oxygen in the stack gas from DTD plants that vent the pugmill steam back into the baghouse (the preferred design for the DTD plant to be used as the Lednez site) is 11.5%. Therefore, we would recommend that an appropriate oxygen correction basis for this type of DTD plant would be 11%.

Conclusions and Recommendations

The new Clean Air Regulation contains requirements for minimum gas residence time, minimum temperature, and minimum destruction efficiency. These requirements were developed based primarily on regulatory standards for hazardous waste incinerators in the US and EU. Operation of DTD plants must address these requirements in the future, even though DTD plants differ significantly from a typical hazardous waste incinerator. NSW EPA has also proposed changes to the oxygen correction factors used for specific emission concentration limits, without proposing corresponding changes to the actual emission concentration values themselves. A summary of conclusions regarding these requirements follows.

Typical thermal oxidiser gas residence times in DTD plants range from 1.0 to 2.0 seconds. Residence time in these systems is limited by the requirement to optimize the dimensions and weight of the thermal oxidiser chamber so that the unit can be transportable. The thermal oxidiser on a DTD plant is combusting vapors removed from the contaminated soils, and therefore does not require the same amount of gas residence time for good combustion as a typical hazardous waste incinerator which is injecting liquid wastes into the thermal oxidiser. It should also be noted that attempts to increase gas residence time by reducing the gas flow though the plant will result in lower gas velocities, poorer mixing, and may actually result in a reduction in destruction efficiency. Therefore, a residence time of 1.6 second is suggested as a best practice for DTD plants based on US experience.

The new Clean Air Regulation requires a minimum thermal oxidiser temperature of 980°C. However, there is a concern that operating at this temperature may result in excessive slagging in the thermal oxidiser chamber because of the high particulate loading. A mechanism to meet the intent of the new regulations on future projects would be to specify an operating range of 980°C ±50°C. This would allow for the incorporation of the 980°C value into the operating consent, but would provide latitude to allow the operators to maintain the unit below the temperature where slagging could become a problem or to increase temperature if necessary to meet destruction and removal efficiency requirements. This value should be based on a 60-minute rolling average to allow normal fluctuations in operating parameters.

A DTD plant is expected to treat materials with relatively low concentrations of contaminants compared to a traditional hazardous waste incinerator. Direct measurement of DE values in the range of 99.9999% for native contaminants in the soil may be impossible in most cases because of analytical detection limit issues. Spiking the feed with a surrogate organic compound and measuring the stack gas for that same compound may provide a means for direct measurement of DE, but the overall amount of additional contaminants to be brought to the site, only for the purpose of testing, should be considered in assessing the efficacy of such an approach.

However the Clean Air Regulation actually says "…………must be operated in such a way the destruction efficiency is ………> 99.9999%". Therefore, given the above issues and considering the relationship between thermal oxidizer temperature, residence time and DE, it is reasonable to conclude that a DTD plant thermal oxidizer treating chlorinated compounds and operating with a residence time of >1.6 second, a temperature of 980^{o}C $+50^{o}$C and adequate turbulence will have an acceptable DE in terms of the Stockholm Convention.

The use of oxygen correction factors is common for the regulation of combustion processes to avoid unwarranted dilution as a means of achieving compliance. However, when concentration limits are expressed in terms of a modified oxygen correction factor, the concentration limit value itself should be changed proportionally to maintain an equivalent standard. The average concentration of oxygen in the stack gas from DTD plants that vent the pugmill steam back into the baghouse (the preferred design for the DTD plant to be used as the Lednez site) is 11.5%. Therefore, we would recommend that an appropriate oxygen correction basis for this type of DTD plant would be 11%.

Please call me at (865) 694-7517 if you would like to discuss this report further.

Sincerely,

William L. Troxler

William L. Troxler, P.E.

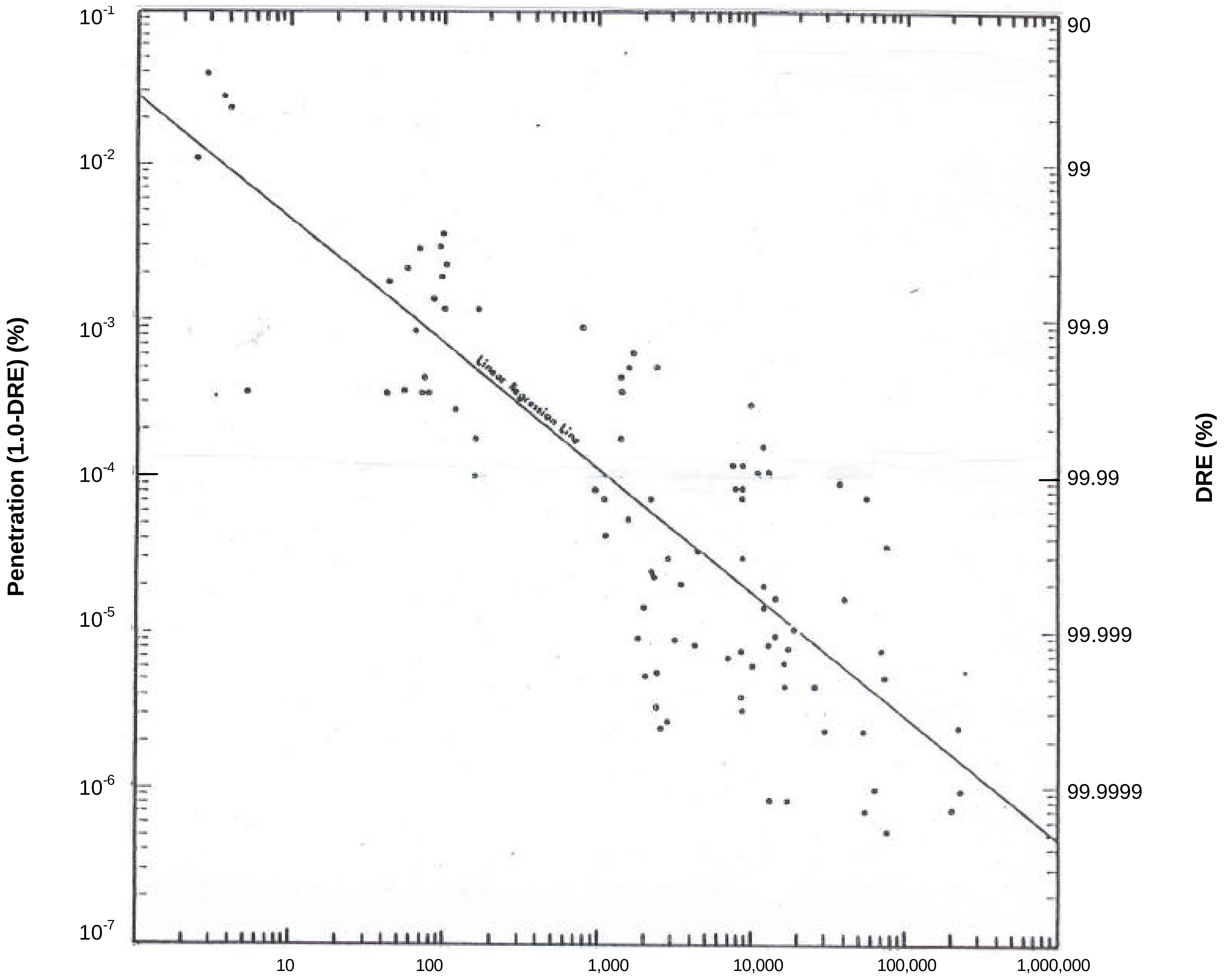

Figure 1. DRE versus POHC Concentrations for VOC Compounds

Adapted from U.S. EPA-600/2-84-181 Performance Evaluation of Full-Scale Hazardous Waste Incinerators

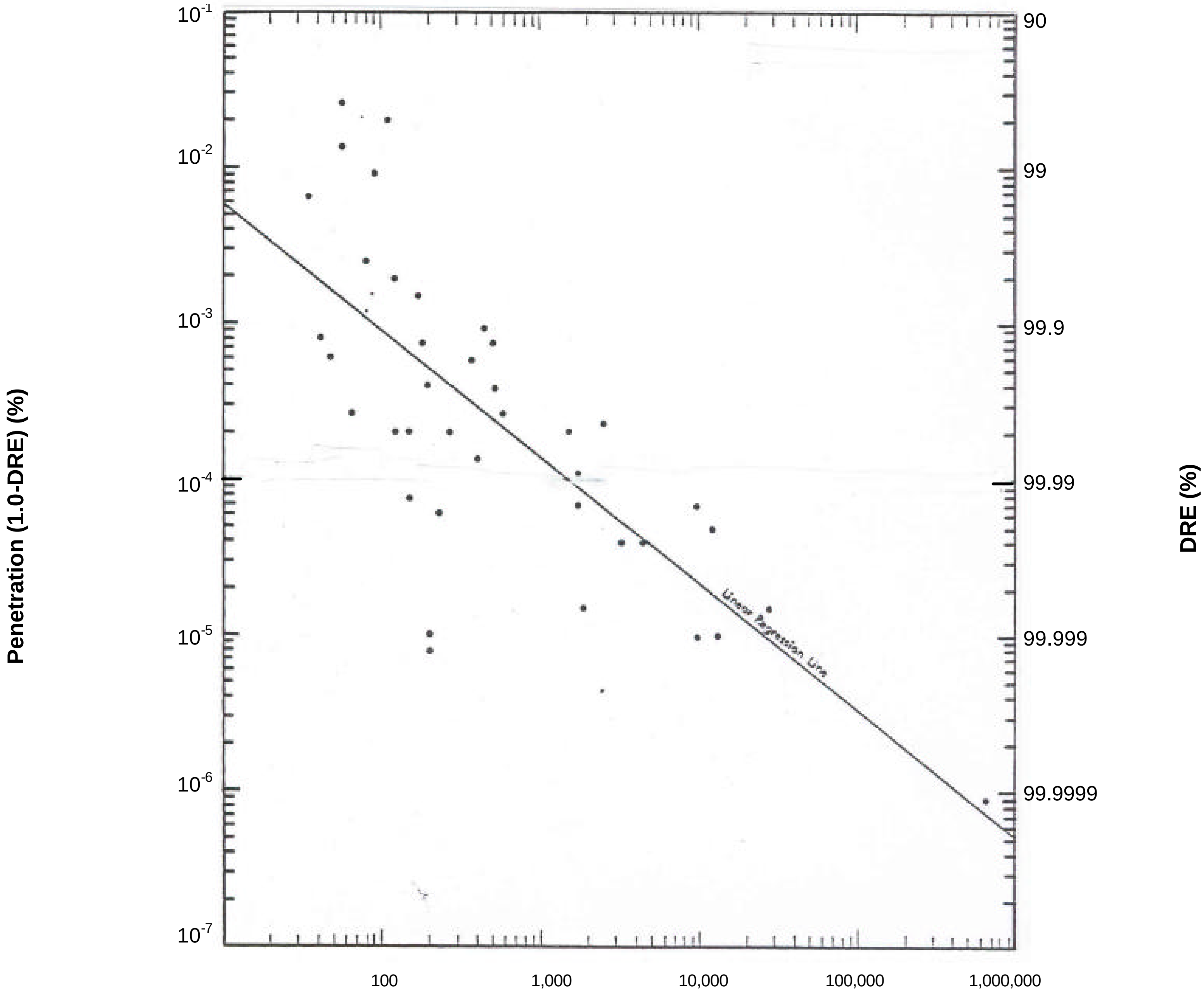

Figure 2. DRE versus POHC Concentrations for SVOC Compounds

Adapted from U.S. EPA-600/2-84-181 Performance Evaluation of Full-Scale Hazardous Waste Incinerators

Table 1. Stack Gas Oxygen - Directly-heated Thermal Desorption Plants

Pugmill Steam Routed to Emission Control System				**Pugmill Steam Vented to Atmosphere**			
Site	**Run No.**	**Thermal Oxidiser Temperature (°C)**	**Oxygen (%)**	**Site**	**Run No.**	**Thermal Oxidiser Temperature (°C)**	**Oxygen (%)**
Aberdeen	Run 1	994	14.0	Woods	Run 1B	988	4.9
Aberdeen	Run 2	989	14.4	Woods	Run 2B	988	9.2
Aberdeen	Run 3	988	14.4	Woods	Run 3	988	6.5
Aberdeen	Run 4	1,016	14.3	Woods	Run 4	988	7.5
Average		**997**	**14.3**	**Average**		**988**	**7.0**
Union Carbide	Run 1a	937	10.9	Del-Cook Lumber	Run 1	1,018	7.1
Union Carbide	Run 2a	937	10.0	Del-Cook Lumber	Run 3	1,013	7.7
Union Carbide	Run 3a	934	9.8	Del-Cook Lumber	Run 4	1,001	9.4
Union Carbide	Run 4b	935	9.5	**Average**		**1,011**	**8.1**
Union Carbide	Run 5b	934	9.2				
Average		**935**	**9.9**	Sanders Aviation	Run 1	1,005	6.2
				Sanders Aviation	Run 2	1,022	4.4
Savannah Army Depot	Run 4	972	10.4	Sanders Aviation	Run 3	1,037	4.8
Savannah Army Depot	Run 5	981	9.6	**Average**		**1,021**	**5.1**
Savannah Army Depot	Run 6	981	10.6				
Average		**978**	**10.2**	Missouri Electric Works	Run 2	1,027	4.8
				Missouri Electric Works	Run 3	1,026	3.9
				Missouri Electric Works	Run 4	1,026	4.4
				Average		**1,026**	**4.4**
				Lipari Landfill	Run 1	1,012	4.7
				Lipari Landfill	Run 2	1,010	7.0
				Lipari Landfill	Run 3	1,010	7.4
				Average		**1,011**	**6.3**
Overall Average		**970.0**	**11.5**			**1,011**	**6.2**

Statistical Summary for of All Data

Temperature (°C)		**Oxygen Content (%)**	
Minimum	934	**Minimum**	3.9
Average	991	**Average**	8.5
Maximum	1,037	**Maximum**	14.4
Std Dev	31	**Std Dev**	3.2

Table 2. Calculation of Combustion Parameters and Reynolds Number

	English System		Metric System	
Parameter	**Units**	**Value**	**Units**	**Value**
Oxidiser Inside Diameter (D)	ft	**9.0**	m	2.7
Oxidiser Length (L)	ft	**50.0**	m	15.2
Chamber Cross-sectional Area	ft^2	63.59	m^2	5.91
Chamber Volume	ft^3	3,179	m^3	90.10
Offgas Temperature	°F	**1,800**	°C	982
Oxidizer Offgas Flow Rate	acfm	**116,064**	acmm	3,285
Gas Viscosity (μ)	lb/ft-sec	2.83E-05	g/cm-sec	4.22E-04
Density of Gas (ρ)	lb/ft^3	0.0180	kg/m^3	0.2886
Average Gas Velocity (V)	ft/sec	30.4	m/sec	9.3
Residence Time	sec	1.6	sec	1.6
Reynolds Number (N_{RE})		**173,778**		

$$N_{RE} = D\ V\ \rho / \mu$$

Where:

D = Chamber Inside Diameter (ft)
V = Average Gas Velocity in Chamber (ft/sec)
ρ = Gas Density (lb/ft^3)
μ = Gas Viscosity (lb/ft-sec)

a) Gas temperature, flow rate and composition are typical values from a large DFTD system.

acfm = actual cubic feet per minute
acmm = actual cubic meters per minute

Table 3. Example Calculation of Destruction Efficiency (a)

First Order Rate Equation

$C = C_o e^{-kt}$ **Equation 1**

where:

C_o	initial concentration or reactant at time 0	mass/volume
C	concentration of reactant at time t	mass/volume
t	time (seconds)	seconds
k	reaction rate constant	1/seconds

Estimation of Reaction Constant (k)

k can be estimated by the Arrhenius equation

$k = A \exp(-E_a/RT)$ **Equation 2**

where:

A	collisional frequency factor		1/seconds
E_a	activation energy		kJ/g-mole
R	universal gas constant	0.008314	kJ/g-mole ^oK
T	absolute temperature		^oK

Destruction Efficiency Calculation

$DE = ((C_o-C)/C_o)*100$ **Equation 3**

where:

DE	destruction efficiency	%

(a) Reference: James J. Cudahy and William L. Troxler, Autoignition Temperature as and Indicator of Thermal Oxidation Stability, Journal of Hazardous Materials, Vol. 8, 1983, pp. 59-68.

Table 4. Destruction Efficiency as a Function of Temperature and Residence Time (a)
Hexachlorobenzene (HCB)

Temperature			k	Gas Residence Time at Temperature (seconds)						
(°F)	(°C)	(°K)	(1/sec)	0.50	0.75	1.00	1.25	1.50	1.75	2.00
932	500	773	3.41E-04	0.017030	0.025544	0.034057	0.042570	0.051082	0.059593	0.068103
968	520	793	8.67E-04	0.043331	0.064990	0.086644	0.108293	0.129938	0.151578	0.173213
1,004	540	813	2.11E-03	0.105283	0.157883	0.210455	0.262999	0.315516	0.368005	0.420467
1,040	560	833	4.91E-03	0.245034	0.367326	0.489467	0.611459	0.733302	0.854995	0.976539
1,076	580	853	1.10E-02	0.547676	0.820389	1.092353	1.363572	1.634047	1.903781	2.172774
1,112	600	873	2.37E-02	1.177799	1.761486	2.341726	2.918539	3.491945	4.061963	4.628616
1,148	620	893	4.94E-02	2.439273	3.636505	4.819046	5.987074	7.140769	8.280306	9.405859
1,184	640	913	9.97E-02	4.862186	7.203893	9.487963	11.715812	13.888826	16.008353	18.075711
1,220	660	933	1.95E-01	9.300556	13.621246	17.736109	21.654951	25.387109	28.941476	32.326522
1,256	680	953	3.72E-01	16.961781	24.331166	31.046542	37.165948	42.742276	47.823722	52.454206
1,292	700	973	6.89E-01	29.153559	40.368318	49.807817	57.753075	64.440625	70.069557	74.807448
1,328	720	993	1.25E+00	46.387758	60.744912	71.257275	78.954467	84.590381	88.717018	91.738557
1,364	740	1,013	2.20E+00	66.762144	80.837617	88.952449	93.630835	96.328031	97.883026	98.779516
1,400	760	1,033	3.81E+00	85.099828	94.248423	97.779849	99.143005	99.669194	99.872306	99.950709
1,436	780	1,053	6.45E+00	96.015819	99.204741	99.841263	99.968315	99.993676	99.998738	99.999748
1,472	800	1,073	1.07E+01	99.525075	99.967271	99.997744	99.999845	99.999989	99.999999	100.000000
1,508	820	1,093	1.74E+01	99.983626	99.999790	99.999997	100.000000	100.000000	100.000000	100.000000
1,544	840	1,113	2.79E+01	99.999913	100.000000	100.000000	100.000000	100.000000	100.000000	100.000000
1,580	860	1,133	4.40E+01	100.000000	100.000000	100.000000	100.000000	100.000000	100.000000	100.000000
1,616	880	1,153	6.81E+01	100.000000	100.000000	100.000000	100.000000	100.000000	100.000000	100.000000
1,652	900	1,173	1.04E+02	100.000000	100.000000	100.000000	100.000000	100.000000	100.000000	100.000000
1,688	920	1,193	1.57E+02	100.000000	100.000000	100.000000	100.000000	100.000000	100.000000	100.000000
1,724	940	1,213	2.33E+02	100.000000	100.000000	100.000000	100.000000	100.000000	100.000000	100.000000
1,760	960	1,233	3.41E+02	100.000000	100.000000	100.000000	100.000000	100.000000	100.000000	100.000000
1,796	980	1,253	4.94E+02	100.000000	100.000000	100.000000	100.000000	100.000000	100.000000	100.000000
1,832	1,000	1,273	7.08E+02	100.000000	100.000000	100.000000	100.000000	100.000000	100.000000	100.000000
1,868	1,020	1,293	1.00E+03	100.000000	100.000000	100.000000	100.000000	100.000000	100.000000	100.000000
1,904	1,040	1,313	1.40E+03	100.000000	100.000000	100.000000	100.000000	100.000000	100.000000	100.000000
1,940	1,060	1,333	1.95E+03	100.000000	100.000000	100.000000	100.000000	100.000000	100.000000	100.000000
1,976	1,080	1,353	2.68E+03	100.000000	100.000000	100.000000	100.000000	100.000000	100.000000	100.000000
2,012	1,100	1,373	3.64E+03	100.000000	100.000000	100.000000	100.000000	100.000000	100.000000	100.000000

(a) Yellow shading indicates theoretical conditions to achieve >99.9999% destruction efficiency.

Table 5. Destruction Efficiency as a Function of Temperature and Residence Time (a)
Toluene

Temperature			k	Gas Residence Time at Temperature (seconds)						
(°F)	(°C)	(°K)	(1/sec)	0.50	0.75	1.00	1.25	1.50	1.75	2.00
932	500	773	2.43E-03	0.121531	0.182242	0.242915	0.303552	0.364151	0.424714	0.485240
968	520	793	6.15E-03	0.306925	0.460034	0.612908	0.765548	0.917953	1.070123	1.222060
1,004	540	813	1.48E-02	0.739647	1.107416	1.473823	1.838872	2.202569	2.564918	2.925925
1,040	560	833	3.44E-02	1.703961	2.545022	3.378887	4.205616	5.025272	5.837915	6.643604
1,076	580	853	7.65E-02	3.752885	5.576177	7.364928	9.119794	10.841416	12.530423	14.187435
1,112	600	873	1.64E-01	7.879282	11.582960	15.137733	18.549587	21.824270	24.967295	27.983956
1,148	620	893	3.40E-01	15.647731	22.527931	28.846948	34.650553	39.980786	44.876258	49.372431
1,184	640	913	6.83E-01	28.946919	40.107234	49.514597	57.444345	64.128566	69.762896	74.512241
1,220	660	933	1.33E+00	48.629191	63.180778	73.610400	81.085668	86.443449	90.283555	93.035890
1,256	680	953	2.52E+00	71.704152	84.948352	91.993450	95.741008	97.734479	98.794882	99.358952
1,292	700	973	4.66E+00	90.276843	96.968127	99.054602	99.705206	99.908077	99.971337	99.991062
1,328	720	993	8.40E+00	98.497083	99.815752	99.977412	99.997231	99.999661	99.999958	99.999995
1,364	740	1,013	1.48E+01	99.938075	99.998459	99.999962	99.999999	100.000000	100.000000	100.000000
1,400	760	1,033	2.54E+01	99.999700	99.999999	100.000000	100.000000	100.000000	100.000000	100.000000
1,436	780	1,053	4.29E+01	100.000000	100.000000	100.000000	100.000000	100.000000	100.000000	100.000000
1,472	800	1,073	7.10E+01	100.000000	100.000000	100.000000	100.000000	100.000000	100.000000	100.000000
1,508	820	1,093	1.15E+02	100.000000	100.000000	100.000000	100.000000	100.000000	100.000000	100.000000
1,544	840	1,113	1.84E+02	100.000000	100.000000	100.000000	100.000000	100.000000	100.000000	100.000000
1,580	860	1,133	2.89E+02	100.000000	100.000000	100.000000	100.000000	100.000000	100.000000	100.000000
1,616	880	1,153	4.46E+02	100.000000	100.000000	100.000000	100.000000	100.000000	100.000000	100.000000
1,652	900	1,173	6.79E+02	100.000000	100.000000	100.000000	100.000000	100.000000	100.000000	100.000000
1,688	920	1,193	1.02E+03	100.000000	100.000000	100.000000	100.000000	100.000000	100.000000	100.000000
1,724	940	1,213	1.51E+03	100.000000	100.000000	100.000000	100.000000	100.000000	100.000000	100.000000
1,760	960	1,233	2.21E+03	100.000000	100.000000	100.000000	100.000000	100.000000	100.000000	100.000000
1,796	980	1,253	3.19E+03	100.000000	100.000000	100.000000	100.000000	100.000000	100.000000	100.000000
1,832	1,000	1,273	4.56E+03	100.000000	100.000000	100.000000	100.000000	100.000000	100.000000	100.000000
1,868	1,020	1,293	6.44E+03	100.000000	100.000000	100.000000	100.000000	100.000000	100.000000	100.000000
1,904	1,040	1,313	9.00E+03	100.000000	100.000000	100.000000	100.000000	100.000000	100.000000	100.000000
1,940	1,060	1,333	1.24E+04	100.000000	100.000000	100.000000	100.000000	100.000000	100.000000	100.000000
1,976	1,080	1,353	1.71E+04	100.000000	100.000000	100.000000	100.000000	100.000000	100.000000	100.000000
2,012	1,100	1,373	2.32E+04	100.000000	100.000000	100.000000	100.000000	100.000000	100.000000	100.000000

(a) Yellow shading indicates theoretical conditions to achieve >99.9999% destruction efficiency.

Table 6. Destruction Efficiency as a Function of Temperature and Residence Time (a)
DDT

Temperature			k	Gas Residence Time at Temperature (seconds)						
(°F)	(°C)	(°K)	(1/sec)	0.50	0.75	1.00	1.25	1.50	1.75	2.00
932	500	773	1.36E+01	99.888759	99.996290	99.999876	99.999996	100.000000	100.000000	100.000000
968	520	793	1.96E+01	99.994591	99.999960	100.000000	100.000000	100.000000	100.000000	100.000000
1,004	540	813	2.79E+01	99.999912	100.000000	100.000000	100.000000	100.000000	100.000000	100.000000
1,040	560	833	3.89E+01	100.000000	100.000000	100.000000	100.000000	100.000000	100.000000	100.000000
1,076	580	853	5.34E+01	100.000000	100.000000	100.000000	100.000000	100.000000	100.000000	100.000000
1,112	600	873	7.23E+01	100.000000	100.000000	100.000000	100.000000	100.000000	100.000000	100.000000
1,148	620	893	9.65E+01	100.000000	100.000000	100.000000	100.000000	100.000000	100.000000	100.000000
1,184	640	913	1.27E+02	100.000000	100.000000	100.000000	100.000000	100.000000	100.000000	100.000000
1,220	660	933	1.66E+02	100.000000	100.000000	100.000000	100.000000	100.000000	100.000000	100.000000
1,256	680	953	2.14E+02	100.000000	100.000000	100.000000	100.000000	100.000000	100.000000	100.000000
1,292	700	973	2.73E+02	100.000000	100.000000	100.000000	100.000000	100.000000	100.000000	100.000000
1,328	720	993	3.44E+02	100.000000	100.000000	100.000000	100.000000	100.000000	100.000000	100.000000
1,364	740	1,013	4.31E+02	100.000000	100.000000	100.000000	100.000000	100.000000	100.000000	100.000000
1,400	760	1,033	5.34E+02	100.000000	100.000000	100.000000	100.000000	100.000000	100.000000	100.000000
1,436	780	1,053	6.57E+02	100.000000	100.000000	100.000000	100.000000	100.000000	100.000000	100.000000
1,472	800	1,073	8.03E+02	100.000000	100.000000	100.000000	100.000000	100.000000	100.000000	100.000000
1,508	820	1,093	9.73E+02	100.000000	100.000000	100.000000	100.000000	100.000000	100.000000	100.000000
1,544	840	1,113	1.17E+03	100.000000	100.000000	100.000000	100.000000	100.000000	100.000000	100.000000
1,580	860	1,133	1.40E+03	100.000000	100.000000	100.000000	100.000000	100.000000	100.000000	100.000000
1,616	880	1,153	1.66E+03	100.000000	100.000000	100.000000	100.000000	100.000000	100.000000	100.000000
1,652	900	1,173	1.97E+03	100.000000	100.000000	100.000000	100.000000	100.000000	100.000000	100.000000
1,688	920	1,193	2.31E+03	100.000000	100.000000	100.000000	100.000000	100.000000	100.000000	100.000000
1,724	940	1,213	2.70E+03	100.000000	100.000000	100.000000	100.000000	100.000000	100.000000	100.000000
1,760	960	1,233	3.14E+03	100.000000	100.000000	100.000000	100.000000	100.000000	100.000000	100.000000
1,796	980	1,253	3.63E+03	100.000000	100.000000	100.000000	100.000000	100.000000	100.000000	100.000000
1,832	1,000	1,273	4.18E+03	100.000000	100.000000	100.000000	100.000000	100.000000	100.000000	100.000000
1,868	1,020	1,293	4.80E+03	100.000000	100.000000	100.000000	100.000000	100.000000	100.000000	100.000000
1,904	1,040	1,313	5.48E+03	100.000000	100.000000	100.000000	100.000000	100.000000	100.000000	100.000000
1,940	1,060	1,333	6.23E+03	100.000000	100.000000	100.000000	100.000000	100.000000	100.000000	100.000000
1,976	1,080	1,353	7.06E+03	100.000000	100.000000	100.000000	100.000000	100.000000	100.000000	100.000000
2,012	1,100	1,373	7.97E+03	100.000000	100.000000	100.000000	100.000000	100.000000	100.000000	100.000000

(a) Yellow shading indicates theoretical conditions to achieve >99.9999% destruction efficiency.

Table 7. Achieveable DRE Calculation for Monochlorobenzene

Evaluates POHC feed/spiking rate needed for desired DRE demonstration, and accounts for PICs/background

Client:	Thiess Services	Proj. No.:	100107
Facility:	Lednez Site	By:	CEM
Case:	Achievable DRE with MCB @ 1,000 mg/kg in the Soil Feed	Date:	05-Jan-07
		Worksheet:	

Input Data

POHC Name	Monochlorobenzene
POHC Molecular Weight	112.5
Dry Stack Gas Flow Rate (dscfm)	29000
DRE Requirement (%)	99.99
Expected DRE (%)	99.999
Lower Quantitation Limit (ng/tube set)	20
Upper Quantitation Limit (ng/tube set)	2000
Sample Volume (l, dry std./tube set)	20
POHC Concentration in Feed (mg/kg)	1000
Soil Feed Rate (tonnes/hr)	27.2
Soil Feed Rate (ton/hr)	30.0
Actual POHC Feed Rate (lb/hr)	60.0
Analytical Safety Factor	5.0
POHC Background Concentration in Stack Gas (ng/l)	3.0
POHC Contamination in Sample Train (ng/tube set)	0.0

Minimum Emissions and Feed/Spiking Required to Demonstrate Regulatory DRE

% DRE (Regulatory Limit)	99.99
Stack Emission Rate Required for Detection (lb/hr)	1.09E-04
Min. Stack Conc. to Demonstrate DRE (ng/l, dry std.)	1.00E+00
Min. Stack Conc. to Demonstrate DRE (ppbvds)	0.214
Min. Feed/Spiking Rate to Demonstrate DRE (lb/hr)	1.0862
Feed/Spiking Rate With Analytical Safety Factor Applied (lb/hr)	5.4

Minimum Emissions and Feed/Spiking Required to Demonstrate Expected DRE

% DRE (Expected Performance)	99.999
Stack Emission Rate Required for Detection (lb/hr)	1.09E-04
Min. Stack Conc. to Demonstrate DRE (ng/l, dry std.)	1.00E+00
Min. Stack Conc. to Demonstrate DRE (ppbvds)	0.214
Min. Feed/Spiking Rate to Demonstrate DRE (lb/hr)	10.8620
Feed/Spiking Rate With Analytical Safety Factor Applied (lb/hr)	54

Potential Emissions and DRE Demonstration Capability at Actual Feed/Spiking Rate

Feed/Spiking Rate (lb/hr)	60.000
POHC Emission at Regulatory DRE (lb/hr)	6.00E-03
POHC in Stack Gas at Regulatory DRE (ng/l, dry std.)	5.52E+01
POHC in Stack Gas at Regulatory DRE (ppbvds)	11.8132
POHC Emissions at Expected DRE (lb/hr)	6.00E-04
POHC in Stack Gas at Expected DRE (ng/l, dry std.)	5.52E+00
Train Loading at Regulatory DRE (ng/tube set)	1105
Train Loading at Expected DRE (ng/tube set)	110
Max. DRE Demonstrated at Feed/Spiking Rate (%)	**99.99982**

Impact of Sample/Combustion Gas PICs and Background POHC Concentration

Emissions at Regulatory DRE from Actual Feed/Spiking (lb/hr)	6.00E-03
Emissions Equivalent from PICs. Background (lb/hr)	3.26E-04
Apparent Total Emissions w/PICs & Background (lb/hr)	6.33E-03
Apparent DRE at Reg. DRE w/PICs & Background (%)	99.9895
Added Sample Train Loading from PICs/Background (ng)	60.00
DRE Required to Counter PICs/Background (%)	99.99

Table 8. DRE Values Versus Concentration of Compound in Feed Material

Compound Concentration in Feed Soil (mg/kg)	Maximum DRE (%) Based on Sampling and Analytical Limitations		
	Monochlorobenzene	Hexachlorobenzene	Hexachlorobenzene by SIM
1	99.81897	96.381152	99.963812
10	99.98190	99.638115	99.996381
100	99.99819	99.963812	99.999638
1,000	99.99982	99.996381	99.999964
10,000	99.99998	99.999638	99.999996

Attachment C NSW CAR and Mercury Emission Control

Focus Environmental,
ENGINEERING SOLUTIONS TO ENVIRONMENTAL PROBLEMS

9050 Executive Park Drive
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(865) 694-7517
Fax (865) 531-8854

January 11, 2007

Mr. John Hunt
Thiess Services
43 Fourth Avenue
Blacktown, NSW 2148
Australia

Subject: NSW Clean Air Regulation and Mercury Emission Control

Dear John:

Focus Environmental, Inc. has prepared this report to describe the state of the art in controlling mercury emissions from thermal desorption systems and to compare achievable emission levels with requirements in the NSW Clean Air Regulations.

Regulatory Basis for Mercury Emissions
The NSW POEO (Clean Air) Regulation) stack concentration for mercury emissions is 0.2 mg Nm^3 corrected to 3% $O_{2.}$

Mercury Concentration in Materials from Orica CPWE
Mercury concentrations were measured in 49 1-m depth interval contaminated soil samples at the Orica site and produced the following results:

Minimum	0.1 mg/kg
Maximum	14.7 mg/kg
Mean	1.9 mg/kg
95% UCL of mean	2.5 mg/kg.

Mercury Behaviour During Thermal Desorption
Mercury, unlike most metals, is volatile at thermal desorption system operating temperatures. The boiling point of elemental mercury is 357°C. This temperature is near the bottom of the range or well below typical soil treatment temperatures (350-550°C) in thermal desorption systems. Treatability results from a number of different sites have indicated that virtually 100% of the mercury is volatilised from the soil into the process gas at the high end of the typical soil treatment temperature range. Treatability tests for three groups of samples from the Orica CPWE site show that the mercury removal is proportional to the soil treatment temperature as shown in Table 1 and approaches 100% at 550°C.

Mercury Emission Controls
Mercury emission control technology typically consists of injecting powdered activated carbon (and sometimes other reagents, such as lime), adsorbing the mercury on the activated carbon

and other reagents, and then collecting the carbon and other reagents in a baghouse. Mercury absorbs onto the carbon and reagents both while the carbon and reagents are entrained in the gas stream and while they are present in the dust cake on the baghouse bags. The collection efficiency for mercury depends upon a number of parameters, including:

- The chemical speciation of the mercury, which may be either elemental or ionic, with elemental being much more difficult to collect. In addition, the chemical form of the mercury may change as it passes through the thermal oxidizer.
- The process gas temperature, with better removal efficiency obtained at lower process gas temperatures.
- The composition of the gas (moisture, sulphur dioxide, hydrogen chloride, etc.)
- The type of activated carbon (various compounds, such as sulphur compounds, can be used to impregnate the carbon to increase the adsorptive capacity for mercury)
- The stoichiometric ratio of carbon to mercury (may range from about 50:1 to 500:1).

Carbon injection technology has typically been used in industrial incineration, municipal waste incineration, or utility boiler applications. However, these applications are very different from thermal desorption applications because of the quantity and nature of the total amount of particulates that are collected in the baghouse. In a thermal desorption system, the concentration of particulates in the process gas at the entrance to the baghouse is much higher than for either industrial or municipal waste incineration or utility boiler applications. The concentration of activated carbon in the baghouse filter cake for a thermal desorption application will therefore be diluted by the large quantity of particulate carryover. Therefore, the design parameters for injection of activated carbon in other thermal treatment applications may not transfer directly to thermal desorption applications.

There have been very few applications of carbon injection for mercury emission controls on thermal desorption systems. To the best of my knowledge, there has been only one application in the US where activated carbon injection was used to control mercury emissions. This project was conducted by Merck & Company at their Rahway, New Jersey facility. However, there is very little information in the public domain regarding this project. Thus prediction of mercury removal efficiency by carbon injection is conjectural at this time.

Mass and Energy Balance Calculations

Mass and energy balance calculations were developed to estimate the concentration of mercury in the stack gas as a function of the concentration of mercury in the thermal desorber feed soil and the mercury removal efficiency by the emission control system. These concentrations were then compared to the NSW POEO (Clean Air) regulatory standards.

Mass and energy balance calculations were conducted for a direct thermal desorption system treating approximately 27 tonnes/hr of soil at a moisture content of 12% and a soil treatment temperature of 450°C. Two cases were evaluated. In Case 1, it was assumed that no emission controls were applied specifically for removing mercury from the process gas. In this case, a mercury control efficiency of 0% was assumed. In Case 2, it was assumed that activated carbon injection was used to control mercury emissions at a control efficiency of 90%.

The results of this analysis are presented in Table 2. These calculations show that at 0% mercury removal efficiency, the maximum allowable concentration of mercury in the feed soil would be about 0.2 mg/kg. At 90% mercury removal efficiency, the maximum allowable concentration of mercury in the feed soil would be about 2 mg/kg. This maximum value is close to the mean concentration measured in the Orica CPWE samples (1.9 mg/kg).

Based on these results and the lack of certainty regarding mercury removal efficiency, there is a significant risk that concentration of mercury in the stack may exceed the NSW limit.

Summary

The key conclusions from this analysis are as follows:

- Mercury control technologies for thermal desorption applications are in their infancy and there are very few published results. Best practices appear to include injection of powdered activated carbon in conjunction with lime based reagents. The optimum stoichiometric ratio of reagents must be determined either by pilot testing or full-scale field testing.
- Removal efficiency of mercury from soil primarily depends on the soil treatment temperature.
- Removal efficiency for mercury from the process gas depends on the chemical form of the mercury. However, speciation between the various forms of mercury is variable, may change as the mercury passes through the thermal process, and is generally poorly understood for thermal desorption applications.
- There are a number of process variables that can affect the performance of carbon injection systems for removal of mercury from the process gas, with key parameters including the gas temperature and moisture content.
- It is likely that treatment of soils containing more that 2 mg/kg of mercury could result in a stack emission concentration that exceeds the NSW POEO regulations, even if best control practices are applied which achieve a 90% mercury control efficiency.
- Because the average concentration of mercury in soil on the Orica site is about 2 mg/kg, there is a significant risk that mercury emissions on the Orica site may exceed the allowable stack concentration due to the current uncertainty about the effectiveness of mercury emission controls and lack of understanding of the controlling factors.

If you have any questions, please contact me at (865) 694-7517 x 3014.

Sincerely,

William L. Troxler

William L. Troxler
President

Table 1. CPWE - Mercury Treatment Results

			Feed Soil	Treated Soil		
			Field	350°C	450°C	550°C
Sample Group	**Units**	**LOR**	**TS1-FS**	**TS1-350**	**TS1-450**	**TS1-550**
Group 1	mg/kg	0.1	**1.4**	**0.7**	**0.2**	<0.1
Group 2	mg/kg	0.1	**2.4**	**1.2**	**0.4**	<0.1
Group 3	mg/kg	0.1	**1.5**	**0.3**	<0.1	<0.1

Table 2. Mercury Emissions Analysis

		0% Removal from Stack Gas (a)			90% Removal from Stack Gas (b)		
Mercury Concentration in Feed Soil (mg/kg)	Mercury Feed Rate (mg/hr)	Mercury Emission Rate (g/sec)	Mercury Stack Gas Concentration (mg/Nm^3, actual)	Mercury Stack Gas Concentration (mg/Nm^3, 3% O_2)	Mercury Emission Rate (g/sec)	Mercury Stack Gas Concentration (mg/Nm^3, actual)	Mercury Stack Gas Concentration (mg/Nm^3, 3% O_2)
0.1	2,700	0.0008	0.075	0.11	0.0001	0.007	0.01
0.2	5,400	0.0015	0.150	0.21	0.0002	0.015	0.02
0.3	8,100	0.0023	0.225	0.32	0.0002	0.022	0.03
0.4	10,800	0.0030	0.299	0.42	0.0003	0.030	0.04
0.5	13,500	0.0038	0.374	0.53	0.0004	0.037	0.05
0.6	16,200	0.0045	0.449	0.64	0.0005	0.045	0.06
0.7	18,900	0.0053	0.524	0.74	0.0005	0.052	0.07
0.8	21,600	0.0060	0.599	0.85	0.0006	0.060	0.08
0.9	24,300	0.0068	0.674	0.95	0.0007	0.067	0.10
1.0	27,000	0.0075	0.749	1.06	0.0008	0.075	0.11
2.0	54,000	0.0150	1.497	2.12	0.0015	0.150	0.21
3.0	81,000	0.0225	2.246	3.18	0.0023	0.225	0.32
4.0	108,000	0.0300	2.994	4.24	0.0030	0.299	0.42
5.0	135,000	0.0375	3.743	5.30	0.0038	0.374	0.53
6.0	162,000	0.0450	4.492	6.37	0.0045	0.449	0.64
7.0	189,000	0.0525	5.240	7.43	0.0053	0.524	0.74
8.0	216,000	0.0600	5.989	8.49	0.0060	0.599	0.85
9.0	243,000	0.0675	6.737	9.55	0.0068	0.674	0.95
10.0	270,000	0.0750	7.486	10.61	0.0075	0.749	1.06
11.0	297,000	0.0825	8.234	11.67	0.0083	0.823	1.17
12.0	324,000	0.0900	8.983	12.73	0.0090	0.898	1.27
13.0	351,000	0.0975	9.732	13.79	0.0098	0.973	1.38
14.0	378,000	0.1050	10.480	14.85	0.0105	1.048	1.49
15.0	405,000	0.1125	11.229	15.91	0.0113	1.123	1.59

(a) Worst case at 0% removal in emission control system.

(b) Best case at 90% removal in emission control system (powdered activated carbon injection).

			Benchmark Values (EDS, App D)	
Process Conditions	**Value**	**Units**	**Value**	**Units**
Stack Gas Flow	22,766	dscfm	26560	dscfm
Stack Gas Flow (actual)	601.13	Nm^3/min (dry)	701.32	Nm^3/min (dry)
Stack Gas Flow (actual)	36,068	Nm^3/hr (dry)	42,079	Nm^3/hr (dry)
Stack Gas Flow (@11% O2)	41,642	Nm3/hr (dry)	48,583	Nm3/hr (dry)
Stack gas oxygen content	8.30	%	8.30	%
Soil feed rate	29.7	tons/hr	35	tons/hr
Soil feed rate	27.0	tonnes/hr	31.8	tonnes/hr
Soil feed rate	27,000	kg/hr	31,818	kg/hr

Conversion Factors

35.29	ft3/m3
1.10	ton/tonne
1000	kg/tonne
1000	mg/g
60	min/hr
60	sec/min
3600	sec/hr

Temperature Basis	°C	°K
Standard conditions	20	293.15
Normal conditions	0	273.15

Mercury Removal Efficiency 90 % (PAC Injection)