

THERMAL DESORPTION TREATMENT OF PAH CONTAMINATED SOILS – A CASE STUDY

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EXECUTIVE SUMMARY

Innova Soil Technology Ltd has recently completed the remediation of a 6000 tonne hydrocarbon (PAH) contaminated soil stockpile that was located at the client's, primary chemicals refining facility in Newcastle NSW. Remediation approvals and licensing were granted by the NSW Government to undertake the project. This case study briefly describes Innova's thermal desorption process, the development approvals and operating licence granted by the NSW government to undertake the project, insights provided by the initial laboratory soil treatability studies, results of a 150 tonne treatment trial of the PAH contaminated soils and a summary of the final thermal desorption treatment and remediation of the 6000 tonne stockpile.

INNOVA'S THERMAL DESORPTION PROCESS DESCRIPTION

Thermal desorption is well-known as a high throughput remediation technology for removing hydrocarbon contaminants from soils. Hydrocarbon contaminants are volatilised in a thermal desorber (rotary dryer) and swept into an off-gas stream. The contaminant laden off-gas is then treated in an emissions control system in which the hydrocarbons are either collected as a liquid concentrate or converted in a heated chamber. Thermal desorption treatment systems have been successfully providing permanent treatment solutions to hydrocarbon contaminated land problems in the USA for the last 15 - 20 years. The Innova **D**irect **H**eated **F**ast **Q**uenched **T**hermal **D**esorption (**DFTD**) system is built on the proven and robust engineering design of the US systems, but with its unique arrangement and features, allows distinct operational advantages and superior emission control capability for the effective treatment of all types of hydrocarbon contaminated soils. Innova's DFTD plant consists of a series of integrated components designed to achieve successful contaminant separation and subsequent conversion, energy recovery, fines reconstitution and product soil cooling. Specifically, the Innova DFTD system consists of:

- Material Feed System – providing a regulated flow of blended and screened contaminated soil into the rotary dryer (Capable for clay, sand, silt and sediment)
- Direct Heated Rotary Desorption Unit – gently heats the soil separating hydrocarbon contaminants from the solid matrix into the gas phase, (importantly, this is NOT incineration as the soil geotechnical properties are retained and not destroyed – the soil is beneficially reused on-site).
- Product Soil Discharge Hopper – controlled removal of soil from the rotary dryer.
- Soil Cooler – using water for both cooling and dust reconstitution.
- Conversion Chamber –where hydrocarbon gas phase contaminants are converted into carbon dioxide and water at >950°C within 3 to 4 seconds residence time.

- Grit removal system for dust and fines removal from the converter chamber
- Energy Recovery Heat Exchangers – preheat the incoming combustion air.
- Dry Rapid Gas Quencher – eliminates contaminant (dioxin) reformation potential.
- Filter Baghouse – for fines collection and controlled removal to the soil cooler
- PLC and Citect System – process control and monitoring of operations
- CEMS – continuous monitoring of gaseous stack emissions.

Innova's DFTD plant flow-sheet is illustrated below in figure 1.

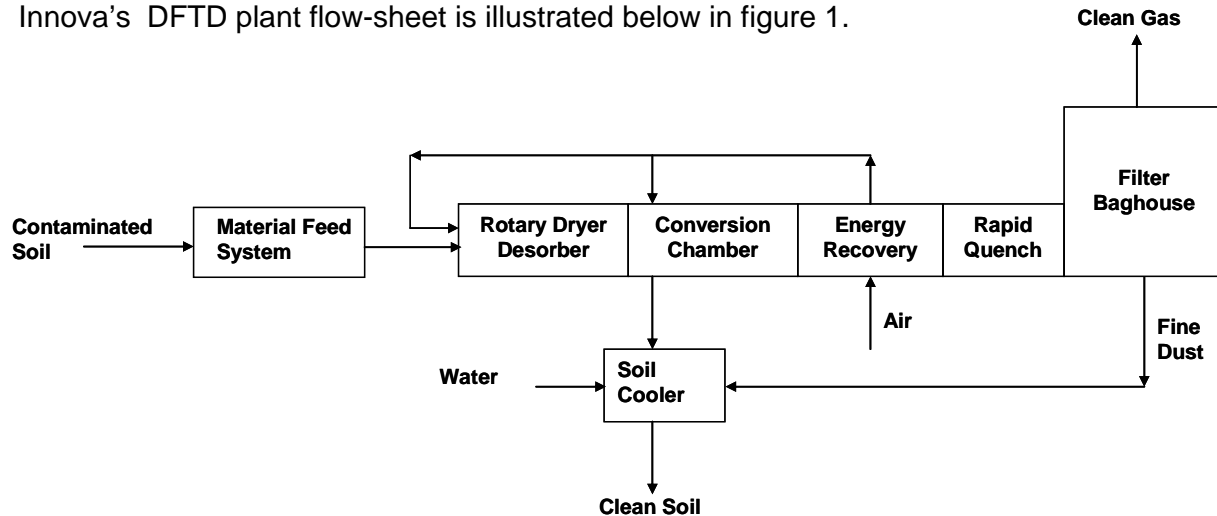


Figure 1 Flow-sheet of Innova DFTD Process

THE REMEDIATION PROJECT

The remediation project involved: transportation of stockpiled PAH contaminated soil from the client's chemicals processing facility to the Innova plant on the former Newcastle steelworks site – a distance along private industrial roads of approximately 2.5 kms, treatment of the contaminated soil at the Innova plant, post-treatment validation of the cleaned soil and transport of the treated soil back to the chemicals manufacturing facility. The purpose of the project was to remediate the PAH contaminated soil to allow its beneficial reuse as clean industrial fill within the grounds of the chemicals manufacturing facility – see table 1 for validation criteria.

Table 1 - Remediation/ Validation Criteria

Hydrocarbon Contaminant	Validation Criteria (mgkg ⁻¹)
Benzo(a)pyrene	5
Total polycyclic aromatic hydrocarbons (PAH)	100
Benzene	1
Toluene	1.4
Ethylbenzene	3.1
Total xylenes	14
Total petroleum hydrocarbons (TPH) C6 to C9	65
Total petroleum hydrocarbons (TPH) C10 to C36	1000

Before the project could be undertaken: approvals had to be granted by the NSW state government, laboratory studies undertaken and a treatment trial completed. Figure 2 shows a flow-sheet illustrating the various activities undertaken as part of the total remediation project, from the approvals process through to the final treatment operations.

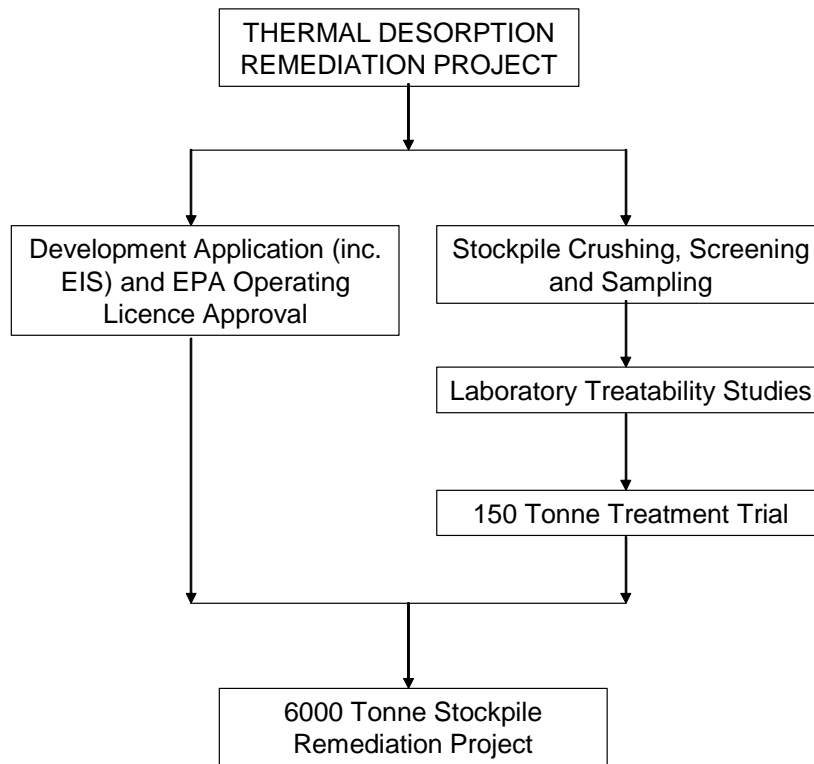


Figure 2 Flow-sheet illustrating the various activities within the total remediation project from approvals through to final treatment operations

CONTAMINATED SOIL STOCKPILE BACKGROUND

The client for the project operates a primary chemicals refining process, in Newcastle, which was opened in 1968 at a time when environmental management requirements were less stringent than nowadays. Over time, the facility undertook a number of improvement works to reduce the environmental impact of its operations and to control the potential for the contamination of soil and groundwater within the site. In carrying out these works the facility recognised that the dumping of any removed soil or fill, that was contaminated with hydrocarbons, was not desirable and so this soil was stockpiled on the facilities grounds. Since the stockpiling of contaminated soil began in the early 1980's, the facility had been trying to identify an acceptable process to remove the hydrocarbons from the soil so that the remediated soil minimised the potential for any future environmental impacts – Innova's DFTD process provided the best solution.

DEVELOPMENT APPROVALS

To undertake the remediation project, various NSW Government approvals were sought and detailed community consultation undertaken. In line with this, an Environmental Impact Statement (EIS) was prepared to accompany a Development Application (DA) submitted under the requirements of Part IV of the *NSW Environmental Planning and Assessment Act 1979*. The EIS provided an assessment of the potential environmental impacts of the proposed remedial activity and recommended safeguards to minimise any potential impacts on the environment. The proposed remediation activity was classed as a "designated development" as it involved "contaminated soil treatment works treating more than 1,000 cubic metres per year of contaminated soil not originating from the site on which the development is located" and therefore met the definition under Schedule 3 of the *NSW Environmental Planning and Assessment Regulation 2000*. Further, the proposed activity was an integrated development due to the requirements of the *Protection of the Environment Operations Act 1997* (s. 5). An Environment Protection Licence (EPL) was

required from the NSW Department of Environment and Conservation (DEC) as the Innova plant was undertaking “contaminated soil treatment works” and would “handle more than 1,000 cubic metres per year of contaminated soil not originating from the site on which the works are located”. Innova was awarded approval to undertake the remediation works by the NSW Department of Industry Planning and Natural Resources (DIPNR) – DA Approval No DA-294-11-2004-i. An environmental protection licence (EPL No. 11866) was issued the NSW DEC to undertake the contaminated soil treatment works.

STOCKPILE PREPARATION AND SAMPLING

The soil from the client’s site had been crushed and screened to less than 50 mm and stockpiled on the client’s site by an earthworks contractor previously. Due to the previous screening operations, the stockpile had been well blended, somewhat into a homogenous mix. Soil samples taken throughout the screening operations showed relatively constant PAH levels through the stockpile. Indeed PAH contaminant levels were generally high and ranged from 3290 to 6210 mg/kg. Total hydrocarbon (or TPH) levels ranged from 5972 mg/kg to 16390 mg/kg – well within Innova’s processing capability of up to 25,000 ppm TPH in soil. Please see tables 3 and 4, in the following pages, for summaries of all feed and product soil samples treated during the trial and main remediation projects.

SOIL TREATABILITY STUDIES

Given that the hydrocarbons and their level of contamination within the soil stockpile appeared suitable for Innova’s thermal desorption process, basic soil treatability studies were undertaken at Innova’s in house laboratory. Treatability studies help with determining suitable operating temperatures for the removal of volatile organic species from the soil matrix. Experiments were undertaken in a muffle furnace using 500 gram soil samples spread thinly on stainless steel trays. Treatment temperatures ranging between 300°C and 600°C were studied and residence times of ~20 minutes were selected, to somewhat simulate the conditions within the larger scale thermal desorption unit. See table 2 below for a summary of some of the soil treatability studies results. Results showed that there was partial removal of hydrocarbon contaminants at a treatment temperature of 350°C, with PAH levels being reduced from 4800 mg/kg to 1405 mg/kg. At treatment temperatures of 450 and 550°C all the contaminant hydrocarbon levels (TPH, PAH, BaP and BTEX) were reduced to below laboratory detection limits (nd).

Table 2 Summary of lab treatability studies

Parameter	Units	FEED	350C	450C	550C
Metals					
Arsenic	mg/kg	10.00	9.00	11.50	9.00
Cadmium	mg/kg	1.67	2.00	2.00	6.00
Chromium	mg/kg	157.67	133.00	171.00	150.00
Copper	mg/kg	101.67	131.00	125.00	97.00
Nickel	mg/kg	69.67	45.00	56.50	42.00
Lead	mg/kg	216.67	220.00	284.50	167.00
Zinc	mg/kg	1401.00	1880.00	1230.00	1060.00
Mercury	mg/kg	163.33	16.30	1.35	5.80
Sum TPH's	mg/kg	15080.76	4,143	nd	nd
Sum BTEXs	mg/kg	1.84	1.60	nd	nd
BaP	mg/kg	452.86	174	nd	nd
Sum PAHs	mg/kg	4806.30	1405.00	nd	nd

150T TREATMENT TRIAL

Following on from the positive laboratory treatability studies results, Innova Soil Technology (Innova) undertook a 150 T treatment trial of the PAH contaminated soils. The aim was to prove the commercial capability of the full-scale thermal desorption technology and assess the suitability of using the the chemicals facility by-product **N**aphthalene **S**till

Residue (NSR) fuel, instead of conventional burner fuel (diesel), as an energy source for Innova's process. If successful, this would result in a significant cost saving to the project. Innova's trial treatment operations were undertaken on two separate days; the first trial using commercial burner fuel (diesel) as an energy source and the second trial treatment operations using the by-product NSR fuel. Of note, was that the chemical composition of the NSR fuel contained many of the PAH contaminants of concern within the soil being treated. During the trial operations, Innova's DFTD process burners were successfully operated using both the conventional burner fuel (diesel) as well as the by-product NSR fuel – the latter requiring some minor burner re-tuning. The trial confirmed that the fuels were almost interchangeable resulting in little to no operability issues, no detrimental effect on ability to treat the soils and no change to process emissions.

The Innova DFTD process successfully processed and treated the chemical facilities contaminated soil despite the very high hydrocarbon levels in the feed soil of 1.18 to 3.1 wt% (see table 3 below). The NSW auditor product soil clean-up level for TPH of 1000 ppm was easily met. Similarly the clean-up level for PAH's of 100 ppm was easily met as product samples showed PAH levels to be non-detectable to 5.5 ppm. Independent stockpile sampling results showed some samples had BaP hydrocarbon levels slightly above the soil clean-up criteria of 5 ppm– this was attributed to lower than required treatment temperatures within the rotary dryer (BaP has a high boiling point of ~495°C).

Table 3 Summary of 150T treatment trial soil results

ANALYTE	UNITS	Trial 1 - Burner Fuel		Trial 2 - NSR Fuel		Validation Criteria
Feed TPH	mg/kg	16630	31000	11795	26106	1000
Product TPH	mg/kg	ND	2	5	7	1000
Feed Total PAH	mg/kg	6045	13368	2835	6198	100
Product Total PAH	mg/kg	ND	5.5	ND	3.6	100
Feed BaP	mg/kg	508	1000	221	463	5
Product BaP	mg/kg	ND	0.6	ND	ND	5

The Innova DFTD process has a nominal soil treatment rate of 30 TPH (~700 T/day) but the treatment rate was limited to 15 – 16 TPH during the trial operations (equiv. to 350 T/day) due to the high contaminant / calorific value of the feed soil. Increasing the soil throughput beyond ~16TPH resulted in process difficulties, namely increased and uncontrolled temperatures within the rotary dryer and conversion chambers as well as lower oxygen levels in the conversion chambers.

6000 T TREATMENT OPERATIONS SUMMARY

Prior to undertaking the full scale stockpile remediation, Innova Soil Technology undertook some process modifications to improve the operation of the DFTD plant. Most notably, the wet scrubber was replaced with a new high efficiency filter baghouse to ensure that there would be no particulate emissions associated with conducting the project. Additionally the converter energy source was replaced with a new burner system allowing soils with higher contaminant loadings to be treated at higher production rates. Also, a permanent water injection system was installed into the converter chamber to control process temperatures.

Operations

Prior to conducting the soil treatment operations, extensive site controls were installed to manage dust and storm water within the treatment compound. Soil and water management controls used included: storing all contaminated soils on sealed concrete pads, covering the feed soil stockpiles with tarpaulins and installing sumps to capture any run-off water. The run-off water was stored and later used within the process. Concrete road barriers were used to contain the feed soil to the plant as well as to disseminate

between treated soil stockpile batches awaiting validation. Figure 3 shows a photograph of the Innova DFTD process and site setup during soil treatment operations.



Figure 3 Innova DFTD process operations and site set-up

Remedial treatment operations were conducted in January and February 2006 with over 5000 T of the 6000 T of soil being treated within a 4 week period. Operations were conducted on a 24 hours per day, Monday to Friday basis with preventative maintenance occurring on Saturday mornings. Innova staff operated on a 12 hr shift basis with 1 supervisor and 3 team members per shift. Soil treatment rates averaged 16 to 18 TPH with an average production rate of 1300 T per week– this was below the Innova DFTD plant capability of ~ 2500T / week, but higher than rates achieved during the 150 T trial. Slower treatment rates were due to the very high contaminant loading within the hydrocarbon impacted soil. In total, 6130 T of PAH contaminated soil was successfully treated to meet the auditor's remediation criteria for beneficial re-use on an industrial site, see table 1 for criteria. Figure 4 shows some key process temperatures over a one week operating period in the middle of the project. Of note is the relatively stable and constant temperatures during the entire weeks operations. There were two shutdown periods in this particular weeks operations; one due to a front-end loader flat tyre and the other due to failure of a key component related to the burner function. Soil treatment temperatures were controlled at approximately 500 °C throughout the operation, this was critical to ensure the high boiling point compounds like BaP (495°C) were removed from the soil. The conversion chamber temperature was maintained at 980°C, on average, to ensure complete conversion of the hydrocarbon contaminants into carbon dioxide and water – the efficiency of conversion was evinced by very low CO emissions.

Soil Analysis

An extensive soil sampling campaign was undertaken as part of Innova's internal QA / QC processes, throughout the stockpile remediation program. Soil was sampled by Innova personnel directly off the feed and product conveyors at 1 hour intervals and respective samples combined after 6 hour periods to provide a composite or average sample twice per 12 hour shift. In total 48 feed samples and 60 product soil samples were sent for laboratory analysis for TPH, BTEX, PAH and many for heavy metals. Independent to Innova's analysis an environmental consultant took 53 samples from the treated soil stockpiles. Table 4 shows a summary of all the feed and product soil samples taken during the 6130 T treatment operations. Total petroleum hydrocarbon (TPH) levels

ranging from 6410 to 28,900 mg/kg in the feed soil were treated to non-detectable levels in the product soil. Similarly, PAH levels ranging from 2454 to 13,361 mg/kg in the feed soil were treated back to levels suitable for beneficial re-use on an industrial site (< 100mg/kg). Only one sample analysed by both Innova and the consultant was outside the PAH acceptance criteria. The 80 tonne soil stockpile associated with this sample was re-treated through Innova's process as it also had measured BaP levels in the product soil, slightly above the 5 mg/kg criteria. In addition to NATA accredited laboratory soil analysis, Innova utilised an onsite soil analyser to screen the treated soil samples. The analyser was a "siteLAB" ultraviolet fluorescence instrument capable of analysing both PAH and TPH contaminated soils. Measurements were quick and simple and took only about 15 mins to complete, compared to the best laboratory "turn-around" times of > 4 days. Most importantly the results were reasonably accurate with only a ~30 mg/kg offset being measured between lab results and the on-site analyser, allowing Innova to successfully screen and assess whether the treated soils met the 100 mg/kg PAH cleanup criteria level.

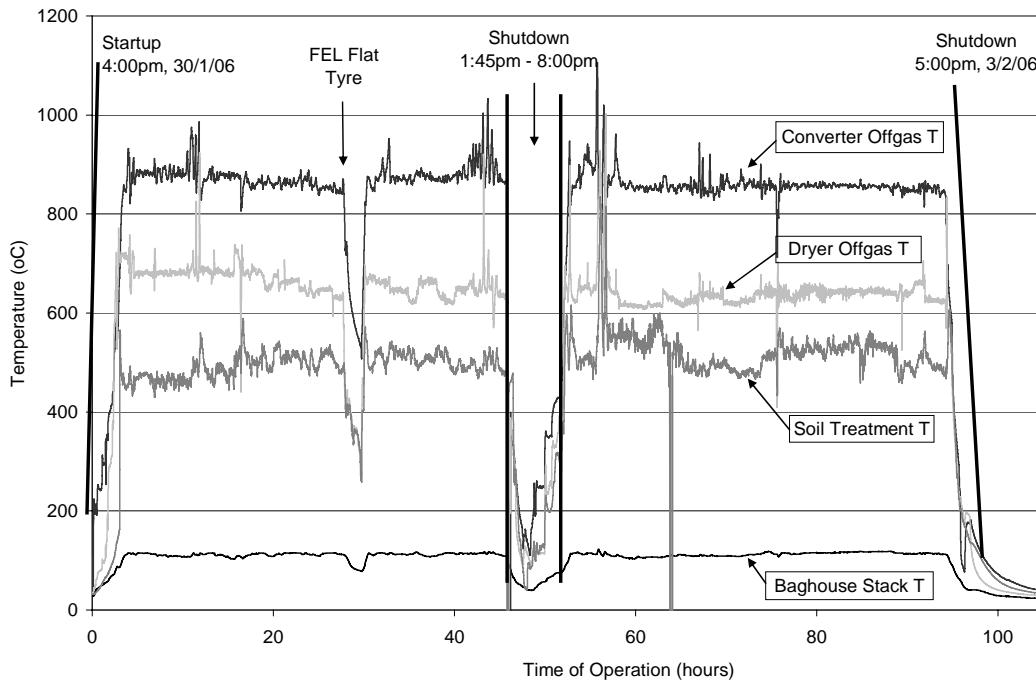


Figure 4 Key process temperatures over a one week period of operations

Stack Testing

Stack emissions were monitored continuously using Innova's Infra-Red continuous emissions monitoring system (CEMS). Emissions were in general very low: sulfur dioxide (SO₂) emissions were very low and averaged 101.5 ppm, carbon monoxide (CO) emissions were also low at < 5 ppm on average. Low CO levels are indicative of high hydrocarbon conversion efficiency within the conversion chambers. NO_x emissions were compliant yet slightly higher than measured previously - at approx 165 ppm average, this was most likely due to the high operating temperatures within the conversion chambers and the Nitrogen loss from the NSR by-product fuel being used. In addition to Innova's CEMS, a local consultancy was engaged to undertake extensive stack emissions testing of the Innova process as part of compliance requirements with the NSW EPA. Table 5 provides a summary of some of the key emissions data measured. All stack emissions were compliant and within regulatory limits, many significantly below acceptable limits. Of note was the very low particulate emission of 32 mg/m³ – this was despite the high fines content of the material being treated! Further Dioxin and Furan emissions were two orders of magnitude below the 0.1 ng/m³ world's best practice limit.

Table 4 Summary of 6130T Project - Soil Analytical Results

Analyte	Units	REMIEDIATION PROJECT										Clean Up Criteria
		Innova QA / QC Sampling					Independent Sampling by RCA					
		No. samples	Min.	Max.	Average	No. above criteria	No. samples	Min.	Max.	Average	No. above criteria	
TPH												
Feed C6-C9	mg/kg	48	<2	60	8.75	0/48	0					65
Product C6-C9	mg/kg	60	<2	<2	<2	0/48	53	<2	5	<2	0/53	65
Feed C10-C36	mg/kg	48	6410	28900	17485	48/48	0					1000
Product C10-C36	mg/kg	60	<250	710	<250	0/60	53	<250	450	<250	0/53	1000
Feed SUM TPH	mg/kg	48	6410	28944	17494	48/48	0					1000
Product SUM TPH	mg/kg	60	<250	710	<250	0/48	53	<252	450	<252	0/53	1000
PAH												
Feed Total PAH	mg/kg	48	2454	13361	6150	48/48	0					100
Product Total PAH	mg/kg	60	<8	311	27.4	1/60	53	<8	111	22.5	1/53	100
Feed BaP	mg/kg	48	178	811	451	48/48	0					5
Product BaP	mg/kg	60	<0.5	10.2	2.3	9/60	53	<0.5	8.5	2.3	4/53	5
BTEX												
Feed Benzene	mg/kg	48	<0.2	1	0.32	0/48	0				0/48	1
Product Benzene	mg/kg	60	<0.2	0.3	<0.2	0/60	53	<0.2	0.8	0.28	0/60	1
Feed Toluene	mg/kg	48	<0.2	1.1	0.36	0/48	0				0/48	1.4
Product Toluene	mg/kg	60	<0.2	<0.2	<0.2	0/60	53	<0.2	<0.2	<0.2	0/60	1.4
Feed Ethyl Benzene	mg/kg	48	<0.2	1.1	0.36	0/48	0				0/48	3.1
Product Ethyl Benzene	mg/kg	60	<0.2	<0.2	<0.2	0/60	53	<0.2	<0.2	<0.2	0/60	3.1
Feed o-Xylene	mg/kg	48	<0.2	1	0.21	0/48	0				0/48	14
Product o-Xylene	mg/kg	60	<0.2	<0.2	<0.2	0/60	53	<0.2	<0.2	<0.2	0/60	14
Selected Metals												
Feed Arsenic	mg/kg	4	7	11	8.5	0/4	0					500
Product Arsenic	mg/kg	10	8	39	12	0/10	0					500
Feed Cadmium	mg/kg	4	2	2	2	0/4	0					100
Product Cadmium	mg/kg	10	1	3	1.6	0/10	0					100
Feed Lead	mg/kg	4	157	244	190	0/4	0					1500
Product Lead	mg/kg	10	99	221	168	0/10	0					1500
Feed Mercury	mg/kg	4	16.2	26.8	21.9	0/4	0					75
Product Mercury	mg/kg	10	<0.1	4.6	0.6	0/10	0					75

Table 5 Independent Stack Emissions Testing Results Summary

Test Parameter	Units	Result	Regulatory Limit
Total Particulate (TP)	mg/m ³	32	100
Sulfuric Acid Mist (as SO ₃)	mg/m ³	20.2	100
Sulfur Dioxide (as SO ₃)	mg/m ³	221.6	Not Listed
Hydrogen Sulfide (H ₂ S)	mg/m ³	<0.1	5
Hydrogen Chloride (HCl)	mg/m ³	5.7	100
Total Hazardous Substances (Metals)	mg/m ³	0.03	5
Mercury (as Hg)	mg/m ³	0.0183	1
Dioxins and Furans Lower & Middle Bound	ng/m ³	0.004	0.1
Total Volatile Organic Compounds (VOC)	mg/m ³	1.51	Not Listed
Total Oxides of Nitrogen (NOx)	mg/m ³	187.4	Not Listed