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THERMAL DESORPTION TREATMENT OF PCB CONTAMINATED SOIL – A CASE STUDY

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EXECUTIVE SUMMARY

This case study describes the recently completed remediation of ~21,000 tonnes of Polychlorinated Biphenyl (PCB) contaminated soil on a disused industrial site in Springvale, Victoria using a relocatable thermal desorption process. The industrial site was formerly an Iron Foundary come Car Assembly Plant and then a telecommunication company's Material Supply Branch. The site's most recent owner, Harvey Norman, purchased the land as a development site to enable construction of a retail outlet – the largest of its type in the southern hemisphere. Although Harvey Norman was not responsible for the contamination, they chose to remediate the contaminated soil on-site to permanently remove the problem, rather than leaving it onsite and having to monitor and manage it indefinitely.

This case study describes the relocatable thermal desorption process, the development approvals and operating licence granted by the Victorian EPA to undertake the project, details of the EPA Proof of Performance (POP) Test and a summary of the thermal desorption treatment operations and remediation of ~ 21,000 Tonnes of PCB impacted soil. The onsite thermal desorption of the PCB impacted soil was the largest project of its type ever undertaken in Australia.

Results are presented for feed and treated product soil analysis and stack emissions testing. Residual PCB levels were reduced from 11 - 227 mg/kg in the feed soil to <0.1 mg/kg (non-detectable) in the treated product soil, significantly less than the treatment goal of <2 mg/kg total PCB. Similarly Dioxin levels of 0.3 - 0.5 μg/kg WHO TEQ in the feed soil, were reduced to <0.1 μg/kg WHO TEQ in the treated product soil. To monitor process emissions compliance, nine individual stack emissions tests were conducted over the 3 month treatment program. The process emissions were compliant with Victorian EPA requirements for each atmospheric contaminant for all 9 tests. Of note was that Dioxin levels were significantly below the regulatory limit of 0.1 ng/m^3 TCCD I-TEQ and fine particulate emissions (PM10) were typically an order of magnitude less the regulatory limit of 35 mg/m^3.

SITE LOCATION AND HISTORY

The remediation site was located on the south-east corner of the 917 Princes Highway and Westall Road intersection at Springvale, Victoria. The site was generally flat and had a total site area of ~80,000 m^2. The properties to the south, east and west were within an Industrial zone (allowing 24/7 treatment operations), and the properties to the North were within a commercial / business use zone. The nearest residential properties were located over 500 m away from the site which meant that any operational noise associated with the 24/7 operations were not an issue.

The site was originally Crown Land (prior to 1912) and had various private landlords as proprietors between 1912 and 1952. In 1952 the site was purchased for a large iron foundary operator. A European car manufacturer began operations on the site in 1954,

assembling imported motor vehicle parts, before manufacturing engines and complete motor vehicles up until 1968. The site continued to be operated by a motor vehicle company until 1976. The Australian Government purchased the site in 1970 and used the site for telecommunication purposes, as a Material Supply Branch after 1977 and through until 1997. In 2004, the property was purchased by a developer, who undertook demolition of the buildings and improvements on the site before selling to Harvey Norman whom purchased the site for construction of a large retail complex.

PCB SOIL CONTAMINATION

During site investigations conducted by Harvey Norman's environmental consultant; and prior to undertaking development works, Polychlorinated biphenyl (PCB) contamination was detected within some of the soil on the site. The particular PCB mixture discovered on the site had a similar composition and chlorine content to Aroclor1260®. Although Harvey Norman was not responsible for the PCB contamination, they chose to remediate the contaminated soil on-site, to permanently remove the problem, rather than leaving it onsite and having to monitor and manage it indefinitely.

The approximate surface area of the Springvale site containing PCB contamination, at a concentration greater than 2 mg/kg (< 2 mg/kg is classed as PCB free), was 15,000 m^2 with a corresponding in-situ volume of approximately 10,000 m^3. The maximum concentration of PCB found on site was 8,400 mg/kg with the average PCB contaminant concentration base on in-ground sampling being ~135 mg/kg. The overall depth of contamination on the site was quiet shallow, with the majority of the areas, requiring excavation to a depth of only 0.3 m to 0.6 m. The deepest excavations being in the 1.0 to 2.0 m range. The overall shallowness of the PCB contamination was indicative of the relatively low mobility of PCB's within the dense natural clay soils found on the Springvale site. Given the extensive soil sampling and analysis that had occurred on the Springvale site (over 800 samples at greater than 200 sampling points); good quality information existed as to the extent of PCB contamination against soil volume.

REGULATORY GUIDELINES AND APPROVALS

In accordance with Victorian state legislation, the EPA was notified of the extent, location and nature of the PCB contamination on the Springvale site as soon as it was discovered by Harvey Norman. As a result of the notification, the EPA issued a "cleanup notice" which required, amongst other things, that a "risk of harm" audit and an Environmental Improvement Plan (EIP) be prepared. The EIP stipulated that the scope of works would involve onsite thermal desorption of all soils onsite with PCB levels greater than 2 mg/kg.

A "Works Approval Exemption" was prepared and submitted to the Victorian EPA to undertake the works as outlined in the EIP. An exemption was granted to undertake onsite thermal remediation of the PCB impacted soil on the basis that: the soil treatment works were temporary in nature, the duration of the operations was less than six months, that only soil from the Springvale site would be treated, and the expected thermal desorption plant discharges and emissions were compliant with Victorian EPA statutory guidelines (assessed by an independent auditor).

A pollution abatement notice (PAN) was issued by the Victorian EPA on 7th August 2007 to control the proposed thermal desorption remediation of the site, as specified during the works approval exemption process. The PAN required, amongst other things: (1) that community consultation be undertaken before and during the project and (2) that a stringent Proof of Performance (POP) Test be undertaken to critically appraise the thermal desorption process prior to full scale 24/7 operations being allowed to commence.

THERMAL DESORPTION SYSTEM

Thermal desorption is an internationally proven and accepted technology for the efficient removal and destruction of all hydrocarbon contaminants from soil. Despite this, thermal desorption had been used on a limited number of sites around the world, when treating PCB contaminated soils – the majority of PCB impacted soil had been treated in the USA in the 1980's using expensive incineration type technologies. As such, the Springvale project was the first time "direct heated" thermal desorption had been used to treat PCB impacted soils in Australia; additionally the project was significantly larger (10x) than any previous thermal desorption of PCB impacted soil projects undertaken in Australia.

Innova's **D**irect-Heated **F**ast-Quenched **T**hermal **D**esorption (**DFTD**) system consists of a series of integrated components designed to efficiently remediate contaminated soil and treat the resultant contaminant laden gas stream. Figure 1 shows an overview of the process in operation. Thermal Desorption involves gently heating soil to a treatment temperature in a thermal desorber; typically a rotary dryer; such that the hydrocarbon contaminants evaporate into the gas stream. The soil treatment temperature is usually below 500^{o}C ensuring that the mechanical integrity of the soil is maintained whilst at the same time ensuring all hydrocarbon contaminants are desorbed. After a sufficient residence time within the desorber (typically 10 to 20 minutes), clean product soil drops out, and undergoes a cooling and rehydration step prior to being stockpiled for validation and beneficial reuse.

Hydrocarbon laden off-gas produced in the thermal desorber is ducted to the conversion stage of the plant where it is heated to between 900ºC and 1000°C, converting the hydrocarbon contaminants into carbon dioxide, water vapour and in the case of PCB remediation - some hydrochloric acid gas. Further off-gas treatment is required following conversion including unit operations such as hot gas energy recovery, rapid gas quench (a key operation for sound emission control), dust filtration and acid gas scrubbing to meet guidelines set by the local environmental agency for stack emissions. An acid gas scrubber was a new edition to the DFTD process and was installed and commissioned specifically for the Springvale PCB remediation project to remove any HCl formed.

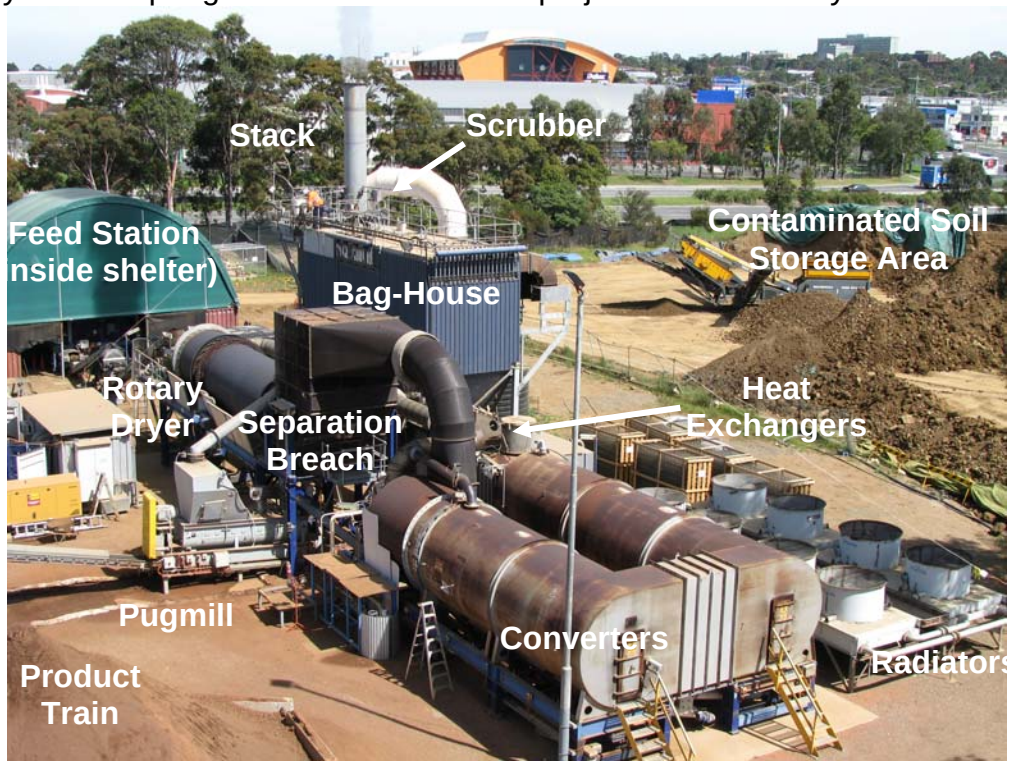

Figure 1: DFTD Process Overview

PROJECT STAGES

There were several stages involved in undertaking the PCB thermal desorption remediation project at Springvale, these included:

- contaminated soil earthworks, screening, crushing and stockpiling
- site preparation and services installation for the temporary project,
- plant mobilisation and set-up,
- plant commissioning and shakedown,
- proof of Performance (POP) Testing,
- production Treatment Operations, and
- plant Decommissioning and Removal.

A critical aspect of the remediation project was the timely execution and completion of each of the project phases since the remediation project was only a small phase of Harvey Norman's overall development project – the construction of a large retail outlet. Figure 2 shows the schedule for the remediation project and the planned duration of each project stages. The actual thermal desorption treatment operations of ~21,000 Tonnes occurred over a 12 week window and the project was finished a little over one week ahead of schedule.

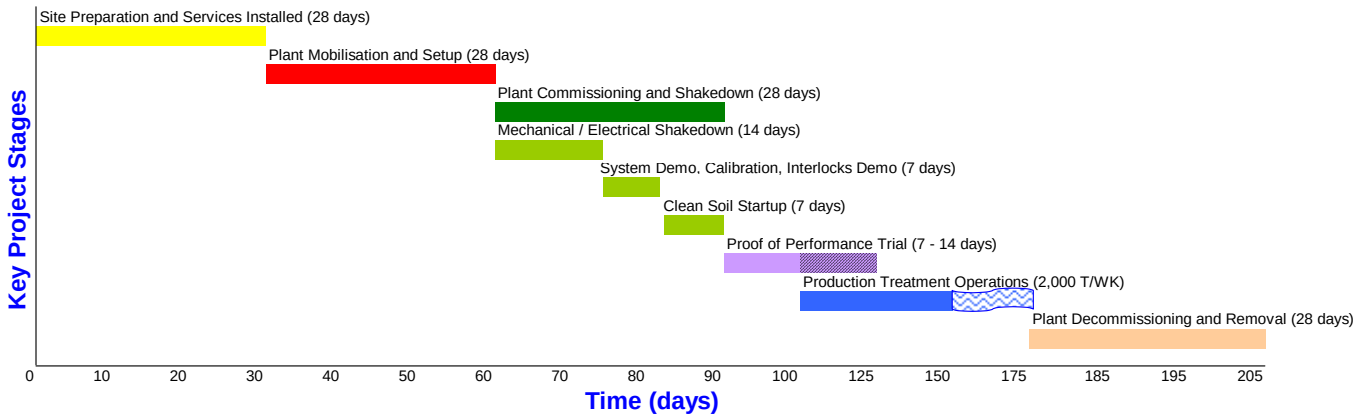

Figure 2: Key Thermal Remediation Project Stages and Timelines

A brief description of each of the project stages and their execution is presented below:

Earthworks

Remediation earthworks were undertaken on the Springvale site from February 2008 through to April 2008, by an experienced civil subcontractor. The excavations were staged such that both the highly contaminated and lowly contaminated PCB impacted soils (also high and low moisture areas) were excavated alternately to enable soil blending and homogenisation. Once excavated the contaminated soil was transported on a temporary haul road to the north-western end of the Springvale site (~ 300m) and stockpiled on an impermeable asphalt surface in the contaminated soil compound. Once in the compound, the contaminated soil was screened and crushed to less than 50mm, and blended (by both contaminant level and moisture content) in order to create as homogenous as possible soil feed stream for the plant. Tarpaulins were used to cover the soil stockpiles to keep the stockpiles dry and to minimise dust emissions.

Site Preparation and Services Installation

The thermal desorption plant area was prepared by laying a concrete pad to support the main components of the DFTD Plant (feed station, rotary dryer, converters, heat exchangers, baghouse and acid gas scrubber). A Natural gas meter set, electrical

transformer and mains water supply was installed and connected from the existing street services to the edge of the plant compound.

The thermal desorption soil treatment operation was self-contained within an approximate 50m × 40m fenced in compound at the North-Western end of the Springvale site (to the south of the contaminated soil storage area). See Figure 3 for an aerial photograph of the site showing an overview of the main soil excavation areas and the location of the thermal desorption plant and soil stockpile areas. The overall area of the Thermal Desorption compound and Soil Storage area was approximately 20,000m^2. Contaminated soil stockpiles were located in close vicinity, to the north of the treatment plant and clean treated soil stockpiled east of the plant (on an old carpark) ensuring there was little opportunity for "cross-contamination".

Figure 3 – The Thermal Desorption Treatment Layout at Springvale

1 – Plant Compound (5,000m^2); 2 – Innova DFTD System Pad (20 x 50m); 3 – Contaminated Soil Storage Area (3,500 m^2); 4 - Treated Soil Storage Area (3,000m^2); 5 – Nth Section of Contaminated Excavation Area

Plant Mobilisation and Set-up

The plant was mobilised in Newcastle and transported on a mix of semi-trailer, B-Double trailers and low loaders (33 in total) to the Springvale site in Melbourne, Victoria. Innova's personnel, along with skilled tradesmen and electricians, erected and set-up the plant in readiness for operation over a 3 to 4 week period. Once the plant was assembled, the main services (gas, electricity and water) were connected and power was supplied to the plant.

Thermal Desorption Treatment Operations

The thermal desorption treatment operations occurred in three distinct stages:

(1) Plant Commissioning and Shakedown,
(2) Proof of Performance Testing (POP Test), and
(3) Continuous Treatment Operations

A brief description of each of the three soil treatment stages is presented below:

(1) Plant Commissioning and Shakedown
The objectives of the Commissioning and Shakedown program were to:

- ensure the satisfactory mechanical operation of each individual unit operation,
- ensure the integrated operation of the DFTD process,
- calibrate and test all relevant equipment and instruments,
- check on the operation of all instrumentation and controls,
- conduct a control interlocks demonstration for both burner and feed systems, and
- to prove the operational readiness of the thermal plant

(2) Proof of Performance (POP) Testing

The POP test incorporated two distinct parts:
(i) a "contaminated soil shakedown test", and
(ii) a "proof of performance test".

(i) The purpose of the *contaminated soil shakedown test* was to perform sensitivity analysis on key process variables such as soil feed rate and treated soil temperature to find the optimal process conditions. It was during this time period that the plant operator determined suitable target operating parameters for the Proof of Performance Test phase.

The contaminated soil shakedown test was performed on various days between the 14th and 19th August 2008. The test was performed on a total of 166 tonnes of contaminated soil and was used to refine the Innova DFTD system to suit the contaminated feed material excavated from the Springvale Site. The treated soil temperature was purposely varied between 300 deg^{o}C and 500 deg^{o}C during the contaminated soil shakedown period. This test temperature range was determined by considering the boiling point range of the Arochlor1260® PCB mixture (ranges between 340 deg^{o}C to 415 deg^{o}C) – it was key to ensure that the lowest treatment temperature was such that some soil samples failed the treatment goal of 2 mg/kg PCB and at the other extreme, high enough that PCB levels significantly less (non-detectable) than the treatment goal were achieved. Treated soil results showed that a soil treatment temperature > 400 deg^{o}C was necessary to reduce residual PCB levels to below the treatment goal of 2 mg/kg PCB – see Figure 4.

In addition to PCB in soil analysis it was even more important to analyse feed and product soil samples for residual Dioxin levels. Dioxins and Furans are known as potential breakdown products when PCB mixtures are heated and as such Dioxins can form at low levels during thermal desorption treatment. Feed soil samples from the Springvale site had initial Dioxin in soil levels of 0.3 – 0.5 μg/kg WHO TEQ. As anticipated, Dioxin formation was prevalent at low soil treatment temperatures as evinced by the 7 μg/kg WHO TEQ Dioxin level measured in the soil treated at 300 deg^{o}C. The treated soil results showed that a soil treatment temperature of > 465 deg^{o}C was necessary to reduce the residual Dioxin levels below the goal level of <0.1 μg/kg WHO TEQ Dioxin. This influence of soil treatment temperature on Dioxin generation and then removal, was a key and unique finding of the contaminated soil shakedown testing phase.

Given the shakedown test findings, a soil treatment temperature of >465 deg^{o}C was selected as the "set-point" soil treatment temperature for the subsequent POP Test and Continuous Treatment Operations phases to ensure that both PCB and Dioxin treatment goals were met.

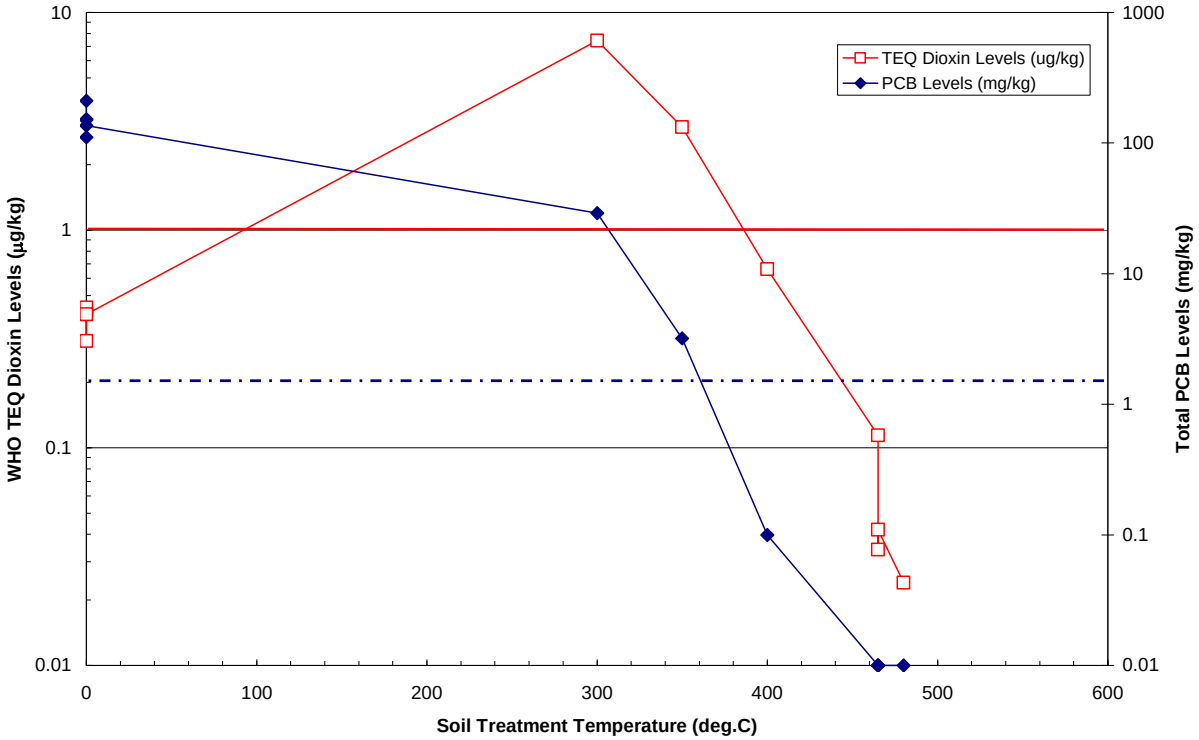

Figure 4: Effect of Soil Treatment Temperature on Residual PCB and Dioxin levels

(ii) The *POP Test* was a quality assurance/quality control test to verify and demonstrate the safe and reliable operation of the DFTD process, at the process conditions determined during the shakedown test. The POP test was undertaken in accordance with requirements specified within the PAN issued by the Victorian EPA. The POP Test involved the processing of a fixed amount of contaminated soil (with site representative contaminant levels) to:

- monitor process streams to ensure the safe and efficient operation of the plant,
- demonstrate that any process discharges meet Victorian EPA regulations, and
- to ensure that the contaminated soil is treated to a standard acceptable to the client (< 2mg/kg PCB) by establishing the appropriate operating conditions.

The POP test was conducted on the 21st and 22nd of August and the 2nd of September 2008. In total, 351 tonnes of contaminated soil was treated over the three days for the proof of performance (POP) test. The soil used in the POP test was selected from a "hot spot" area of the site and accordingly sampled and pre-analysed to ensure that the average contaminant level was greater than the expected average PCB level to be found in the sites bulk soil. All soil was processed as per the treatment parameters determined in the shakedown test (>465 deg^{o}C treatment temperature), whilst a NATA accredited organisation conducted stack testing concurrently. The average plant parameters attained during the POP Test and shakedown test are displayed in Table 1.

Twenty Feed and Twenty Product soil samples were taken over the course of the POP Test. PCB levels ranging from 130 to 227 mg/kg in the feed soil were reduced to between to 0.35 mg/kg and <0.1 mg/kg (non-detectable) PCB in the Product soil samples – 16 out of 20 product samples showed non-detectable (<0.1 mg/kg) PCB remaining in the soil.

Stack emissions testing results for the entire remediation project, including the POP Test phase, are summarised in Table.2. It was a requirement of the EPA issued PAN that an individual stack emissions test was conducted during the POP test and that duplicate stack

tests were conducted during the continuous treatment operations. In summary all stack emission parameters measured during the POP test were compliant with Victorian EPA requirements. Notably, Dioxin emissions reported on a TCDD I-TEQ basis were 0.033 ng/m^3 which were less than the 0.1 ng/m^3 emission limit. Similarly, Fine Particulate (PM10) emissions were 6.6 mg/m^3, significantly less than 35 mg/m^3 EPA limit.

(3) Continuous Treatment Operations

Continuous Treatment operations commenced on Wednesday 17th September 2008 – almost 4 weeks after the POP Test was completed, as it was a requirement for operations to remain on hold until all findings of the POP test had been reported to the Victorian EPA. Continuous Treatment operations were undertaken on a 24 hour per day, 7 day per week basis with four operators working on each shift. Table 1 summarises average process temperatures and other key operational conditions recorded during all three soil treatment phases.

Table 1 – Operating Parameters throughout each of the Operational Phase

Project Phase	*Dates*	*Quantity Treated (T)*	*Average Feed Rate (T/hr)*	*Average Temperatures (°C)*			
				Treated Soil	*Dryer Off-Gas*	*Converter Off-Gas*	*Quench HEX Off-Gas*
Shakedown Test	14/08/08 - 19/08/08	166	5 to 24	300 to 490	350 to 700	952	195
POP Test	21/08/08	170	15.0	483	676	958	188
	22/08/08	135	14.8	477	675	952	187
	02/09/08	46	14.8	478	665	951	189
Continuous Treatment Operations	September 2008	2122	15.0	465	638	932	194
	October 2008	4475	14.6	471	665	931	197
	November 2008	7385	13.7	483	688	930	197
	December 2008	4370	12.4	484	681	926	197
	January 2009	1872	13.9	477	676	927	204
	TOTAL	20,741					

Over the duration of the Springvale remediation project, Innova Soil Technology treated a total of 20,741.2 tonnes of soil – of which 20,224 Tonnes was treated during the continuous operations phase. Plant uptime improved steadily throughout the project and was high for the majority of the project at greater than 85%. The remaining 15% of the time was accounted for by scheduled and breakdown plant maintenance. The soil treatment rate varied between 12 to 18 TPH during the project and averaged just under 15 Tonnes per hour. The treatment rate variance was, to a large extent, dependent of the moisture content in the feed soil which ranged from 10% up to 22% by weight.

The soil treatment temperature was maintained at >465 deg°C (up to 484 deg°C) throughout the continuous operation phase of the project. Following thermal desorption treatment, the cooled and rehydrated soil was stockpiled into batches with a maximum size of ~300 tonnes before being sampled by Harvey Norman's environmental consultant. Each batch was then moved to the treated soil storage area to await validation. In summary, residual PCB levels were reduced from 11 - 227 mg/kg in the feed soil to <0.1 mg/kg in the treated product soil, significantly less than the treatment goal of <2 mg/kg total PCB. Similarly Dioxin levels of 0.3 - 0.5 μg/kg WHO TEQ in the feed soil, were

reduced to <0.1 μg/kg WHO TEQ in the treated product soil. Once the soil was validated, a "PCB destruction certificate" was issued and the treated soil moved offsite for beneficial reuse as clean fill material.

A local consultancy was engaged to undertake extensive stack emissions testing of the Innova process as part of compliance requirements with the Victorian EPA. Four rounds of duplicate stack testing (8 x individual tests) were undertaken during the continuous treatment operations phase of the project. Table 2 provides a summary of some of the key stack emissions data measured. All stack emissions were compliant and within regulatory limits, many significantly below acceptable limits. Emissions were in general very low: Hydrogen Chloride (HCl) emissions were very low and were <0.1 mg/m^3, carbon monoxide (CO) emissions were also low at <2.5 ppm on average. Low CO levels are indicative of high hydrocarbon contaminant conversion efficiency within the conversion chambers. Of particular note was the very low average fine particulate (PM10) emission of 3.7 mg/m^3. Further, Dioxin and Furan emissions were significantly below the world's best practice and EPA emission limit of <0.1 ng/m^3 TCDD I-TEQ.

Table 2 Stack Emission Test Results Summary

Atmospheric Contaminant	VIC EPA	POP Test	Test Week 1 Month 1		Test Week 2 Month 1		Test Week 1 Month 2		Test Week 1 Month 3	
	PAN	21/8, 22/8, 2/9	30/9, 01/10, 02/10		07/10, 08/10, 09/10		10/11, 12/11, 13/11		2/12, 3/12, 4/12	
	Aug '07	Run A	Run A	Duplicate	Run A	Duplicate	Run A	Duplicate	Run A	Duplicate
	mg/m^3	mg/m^3	mg/m^3	mg/m^3	mg/m^3	mg/m^3	mg/m^3	mg/m^3	mg/m^3	mg/m^3
PM_{10}	35	6.6	.<0.74	0.96	0.72	0.41	2.1	4.0	11	9.9
Total Particulate	n/a	19	3.1	2.3	2.7	2.9	6.4	8	11	12
Dioxin (TCDD1-TEQ)	0.1 ng/m3	0.033ng/m3	0.0073ng/m3	0.0092ng/m3	0.0065ng/m3	0.0061ng/m3	0.067 ng/m3	0.059 ng/m3	0.076 ng/m3	0.015 ng/m3
PCB (Total)	0.8 mg/m3	0.0016	0.000054	0.000037	0.000013	0.00003	0.00061	0.00038	0.00043	0.00043
CO	250	1.9	<2.5	<2.5	<2.5	<2.5	<2.5	<2.5	2.5	3.7
SO_2	130	<11	<0.21	<0.32	2	1.1	<0.25	<0.26	<0.37	<0.29
NO_x	640	160	290	290	280	280	250	300	290	340
Oxygen	n/a	10%	11%	11%	10.90%	10.90%	10.20%	11.00%	11.00%	12.00%
CO2	n/a	6%	6%	6%	6.30%	6.30%	6.40%	6.90%	5.30%	5.80%
HCL	100	<0.08	<0.007	<0.0063	<0.042	<0.048	<0.046	<0.018	0.059	0.1
Total Fluoride (HF)	11	4.2	0.01	0.012	0.082	0.054	<0.042	<0.038	<0.024	<0.021
Heavy Metals										
As (Arsenic)	0.17	0.0017	<0.0014	0.0013	<0.0023	<0.0013	<0.0011	<0.0011	<0.0015	<0.0016
Cd (Cadmium)	0.033	0.0002	<0.011	0.01	0.0054	0.0038	<0.0011	<0.0011	<0.0015	<0.0016
Cr (Chromium)	0.17	0.0004	<0.0029	<0.0026	<0.0023	<0.0013	<0.0029	<0.0030	0.002	0.0013
Pb (Lead)	0.17	0.0006	<0.0072	<0.0065	<0.012	<0.0063	<0.0055	<0.0055	<0.0073	<0.0078
Hg (Mercury)	1.8	0.04	0.039	0.017	0.00021	0.00053	0.00021	0.00013	0.001	0.0023

Conclusions

In summary, the onsite Thermal Desorption Treatment of PCB impacted soil on the Springvale site was successful:

- The majority of PCB contaminated soil was treated to <0.1 mg/kg (non-detectable) PCB levels – significantly less than the treatment goal of 2 mg/kg PCB,
- The soil geotechnical properties remained intact after processing, allowing beneficial re-use of all the treated soil on a local clean fill site,
- All stack emissions (9 individual tests in total) were compliant with Victorian EPA requirements,
- The strict project timeline was met, allowing the subsequent construction works to proceed as scheduled,
- No complaints or issues were received from the community or local businesses.

Acknowledgements

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