

**Madsen, Søren R. N.**

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**Fra:** Jakobsen, Dorte Skjøtt  
**Sendt:** 30. november 2009 14:10  
**Til:** Jakobsen, Dorte Skjøtt  
**Emne:** nr. 1 HCB waste

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**Fra:** Reville, Barry [mailto:Barry.Reville@environment.gov.au]  
**Sendt:** 30. januar 2009 07:38  
**Til:** Madsen, Søren R. N.  
**Cc:** Schou, Lone; Hall, Damien; Rothenfluh, Daniel  
**Emne:** Updated Report [SEC=UNCLASSIFIED]

<<SIA IAR Final Draft 290109.pdf>>

Dear Søren

As promised yesterday, please find attached the updated report from SIA. The changes are minor. The biggest change is the addition of a preamble on page 10. This addition is to make it clear to the reader in the public domain that SIA has assessed the technologies for their ability to deal with the Orica HCB waste stockpile with its unique characteristics, not to judge whether the technologies are able to deal with other waste streams.

Otherwise, a potential customer might wrongly conclude that a technology could not deal with a waste stream such as PCBs when it can deal with it effectively, but not the Orica HCB wastes.

Small editorial changes have been made where sentences were not clear, to correct minor errors, to improve descriptions of processes and to include events since the previous version was written, such as the closure of the Ausmelt Whyalla facility. SIA has not provided us with a marked-up copy of these minor changes but they are mostly in the Hydrodec and Ausmelt sections.

As you will see, none of the conclusions has changed:

"This independent assessment has concluded that there are no technologies available in Australia at the present time or the foreseeable future capable of destruction or acceptable treatment of the Orica HCB Botany Stockpile in an environmentally sound manner." (page 11)

We would be grateful if you could let us know when you anticipate releasing the Duly Reasoned Request and the SIA Report, and whether there will be any conditions placed on the distribution of the documents by the recipients.

This will assist us with dealing with enquiries from the media and others in Australia about the availability and contents of the documents.

Please let me know if you have any questions about the updated SIA report.

Best regards

Barry

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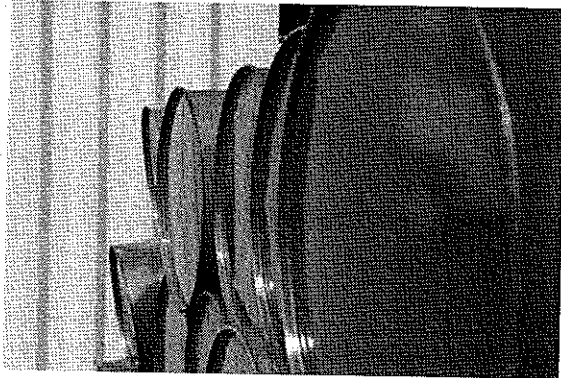
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SUSTAINABLE  
INFRASTRUCTURE  
AUSTRALIA

# ORICA HEXACHLOROBENZENE WASTE STOCKPILE

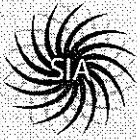
Independent Assessment Report



DEPARTMENT OF THE ENVIRONMENT, WATER,  
HERITAGE AND THE ARTS  
Australian Government

FINAL DRAFT  
JANUARY 2009

Report prepared by:  
Sustainable Infrastructure Australia Pty Ltd



### **LIMITATIONS STATEMENT**

This report has been prepared in accordance with the scope of services agreed upon by the Australian Government – The Department of Environment, Water, Heritage and the Arts (DEWHA) and Sustainable Infrastructure Australia Pty Ltd (SIA). In preparing this report, SIA has relied upon data, surveys, analyses, plans and other information provided by the Australian Government, industry, and other individuals and organizations. No monitoring or testing of technology has been undertaken by SIA during the course of this study. Except as otherwise stated in this report, SIA has not verified the accuracy or completeness of such data, surveys, analyses, plans and other information.



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## Abbreviations and Acronyms

Term	Definition
AMEC	A Managerial and Engineering Company
ANZECC	Australia and New Zealand Environment and Conservation Council
BCD	Base Catalyzed Dechlorination
BD	Butadiene
BDAT	Best Demonstrated Available Technology
BGC	Sodium Dechlorination Plasma arc thermal destruction
Bioaccumalates	Accumulates within the tissues of living organisms (i.e., wildlife such as birds and fish)
BMW	Biomedical Waste
C	Catalytic hydrogenation dechlorination Thermal desorption (and vapor phase destruction)
CFC's	Chlorofluro Carbons
CHC	Chlorinated Hydrocarbons
COD	Chemical Oxygen Demand
Contaminated	A state that presets an adverse health or environmental impact due to presence of potentially hazardous substances
DA	Development Authority
DAF	Dissolved Air Floatation
DDT	Dichloro – Diphenyl - Trichloroethane
DEP	Department of Environmental Protection
DEWHA	Department of the Environment, Water, Heritage and the Arts
Dioxins PCDD's and furans PCDF's	A range of dioxin and furan congeners with varying carcinogenic toxic strengths
DRE	Destruction and Removal Efficiency





Term	Definition
EDC	Ethylene Dichloride
EIS	Environment Impact Statement
Emission controls	Wet scrubbing – producing wastewater for disposal Dry scrubbing – ash and chemical residues for disposal Particulates removal Acid gas removal Dioxins removal Activated carbon Alkali scrubbing
EMP	Environmental Management Plan
EPA	Environmental Protection Agency
ESA	Environmental Site Assessment
GHG's	Green House gases
GMCL	General Motors of Canada Ltd.
GPCR	Gas Phase Chemical Reactor
GPH	Gas Phase Hydro-dechlorination
HCB waste	Hexachlorobenzene waste
HCBD	Hexachlorobutadiene
HCE	Hexachloroethane
Heterogeneous waste	Waste in a multiple range of formats such as liquids, sludge's and solid materials
HF Gas	Hydrogen Fluoride Gas
HHCB	Hexahydrochlorobenzene
HM's	Heavy metals (toxic metals and their compounds)
HTI	High Temperature Incineration (thermal destruction)
ICV	In-Container Vitrification
ID	Induced Draught



Term	Definition
ITEQ	International toxic equivalent, the sum of the toxicity of all the PCDD and PCDF congeners present
NAB	National Advisory Board
NOx	Nitrogen Oxides - NOx a major cause of photo-chemical smog
NOx, SOx	Acid gases chiefly responsible for acid rain and hydrogen chloride
NSW	New South Wales
NSW EPA	NSW Environment Protection Agency
O&M	Operation and Maintenance
OCP waste	Organochlorine Pesticide Waste
ODS's	Ozone Depleting Substances
OGTS	Off-Gas Treatment System.
OPP's	Organo Phosphorus Pesticides
PAH's	Polycyclic Aromatic Hydrocarbons; toxic compounds which are precursors to dioxins formation
PCB's	Polychlorinated Biphenyls
PCDD's	Polychlorinated Dibenzo-p-dioxins
PCDF's	Polychlorinated Dibenzofurans
PEE	Polyester Elastomers
PLC	Programmable Logic Controller
PM	Project Manager
Pollutants	Any emissions into the environment, includes particulates (often heavy metals)
POP's	Persistent Organic Pollutants
PPE	Personal Protective Equipment
PVC	Polyvinyl Chloride



Term	Definition
RE	Retention Efficiency
Remediation	The cleanup or mitigation of pollution or of contamination of environmental receptors – soils water by various methods
RMIT	Royal Melbourne Institute of Technology
SIA	Sustainable Infrastructure Australia
SPL	Spent Potlining
TCCP	Toxicity Characteristic Leaching Procedure
TEQ	Toxic Equivalent
TOC	Total Organic Carbon
TSCA	Toxic Substance Control Act
USEPA	United States Environment Protection Agency
VCM	Vinyl Chloride Monomer
VOC	Volatile Organic Compound
WA	Western Australia
WSA	Waste Supply Agreements

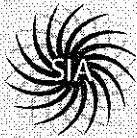


### Units of Measurement

°C	Degrees Centigrade
Amps	Amperes (Unit of electric current)
atm	Atmosphere (Unit of Pressure)
gal	Gallon
GJ	Gigajoules
GJ/h	Gigajoules/hour
kg	Kilograms (1Kg = 1000g)
Kg/hour	Kilogram of weight/hour
kw	Kilowatt
KWh	Kilowatt - hour
mg/m <sup>3</sup>	Milligram per cubic meter
MPa	Mega Pascal
MW	Megawatt
ng	TEQ/m <sup>3</sup>
ng/g	Nanograms per gram (10 <sup>-9</sup> gram per gram)
ng/m <sup>3</sup>	Nanograms per cubic meter
ppb	Parts per billion
ppm	Parts per million
ppt	Parts per trillion
t/day	Tonnes/day
t/h	Tonnes/hour
tpa	Tonnes per annum (year)

### List of Chemicals:

2, 4, 5-T	(2, 4, 5-trichlorophenoxy) acetic acid
2, 4-D	(2, 4-dichlorophenoxy) acetic acid
4, 4'-DDD	4, 4'- Dichlorodiphenyl Dichloroethane
4, 4'-DDE	4, 4'- Dichlorodiphenyl Dichloroethylene
4, 4'-DDT	4, 4'- Dichlorodiphenyl Trichloroethane
Al <sub>2</sub> O <sub>3</sub>	Aluminium Oxide
AlF <sub>3</sub>	Aluminium Fluoride
CaO	Calcium Oxide
CO	Carbon Monoxide
CO <sub>2</sub>	Carbon Dioxide
Fe (III)	Iron (III)
H <sub>2</sub>	Hydrogen
H <sub>2</sub> O	Water
H <sub>2</sub> S	Hydrogen Sulphide
HBr	Hydrogen Bromide
Hcl	Hydrogen Chloride
HF	Hydrogen Fluoride
I <sub>2</sub>	Iodine
NaOH	Sodium Hydroxide
NH <sub>4</sub> Cl	Ammonium Chloride
Pd/C Catalyst	Palladium on Carbon Catalyst
SiO <sub>2</sub>	Silicon Dioxide
SO <sub>2</sub>	Sulphur Dioxide
TiO <sub>2</sub>	Titanium Dioxide
V <sub>2</sub> O <sub>5</sub>	Vanadium Oxide
WO <sub>3</sub>	Tungsten Oxide



## Preamble

Sustainable Infrastructure Australia (SIA) have been engaged to undertake an independent assessment of the capacity within Australia to safely treat the stockpile of hazardous Hexachlorobenzene (HCB) material stockpiled at Orica's Port Botany facility. The stockpile is substantial (exceeding 60,000 drums) and has accumulated since the late 1960's. This has created a major environmental hazard. SIA has been tasked with the priority to assess previous work undertaken and to provide an independent review on the current validity and availability of technologies in Australia to treat this stockpile.

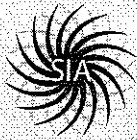
This independent evaluation is provided on all available technologies operating in Australia with respect to their capability to treat the Orica HCB stockpile comprising the following tasks relating to each process/facility:

- Evaluate process capability to treat the waste using existing technology
- Evaluate capacity to treat the significant volume of high concentration HCB waste involved
- Evaluate capacity to undertake any necessary pre-treatment of the waste
- Evaluate capacity to manage environmental hazard and emissions from the treatment of the stockpile
- Evaluate time-frame to treat the stockpile
- Evaluate any issues regarding licenses and permits for a plant to treat the HCB waste
- Evaluate any significant commercial hurdles or risk for treating the Orica HCB stockpile

It must be clearly noted that the assessment of these technologies (which are all proven technologies) is to determine their viability for treatment of the significant stockpile of high concentration HCB waste stored at Botany. This assessment does not apply to any other waste stream and should not reflect positively or negatively on whether the process is technically or commercially feasible in the treatment of other hazardous waste streams or even smaller and/or less concentrated volumes of Hexachlorobenzene (HCB) waste. The scale and concentration of the Orica HCB is unique and there are significant factors to consider in the safe and effective treatment of this stockpile as distinct from the treatment of other hazardous wastes.

The scope of this assessment does not incorporate evaluation of these technologies for treatment of other waste streams and may well provide different outcomes and results in those cases.

This independent assessment has concluded that there are no technologies or facilities available in Australia at the present time or in the foreseeable future which would be capable of the destruction or acceptable treatment of the Orica HCB Botany Stockpile in an environmentally sound manner.



## 1. EXECUTIVE SUMMARY

### 1.1 Introduction

Orica's Hexachlorobenzene (HCB) legacy is a by-product from the company's manufacture of chlorinated solvents, including carbon tetrachloride and tetrachloroethene at the Botany Industrial Park in New South Wales (NSW), Australia between 1963 and 1991.

Due to the variable composition of the HCB waste and its corrosive effect on container packaging, which causes leakage, the waste has been stockpiled in a series of buildings at the Botany facility. The requirement to replace corroded packaging results in an increase of the stockpile through increased contaminated material by approximately 10% per annum. Hence, the storage of the HCB waste is problematic as it is continually increasing and requires additional storage space onsite.

This poses significant risk due to the site's location within an inner city locality and significant health and environmental hazard risk. The Botany facility is located approximately 7 to 8 kilometres from Sydney Central Business District and within close proximity to Sydney Airport (less than 4 kilometres) and surrounded by a major urban population catchment.

This independent assessment has concluded that there are no technologies available in Australia at the present time or the foreseeable future capable of destruction or acceptable treatment of the Orica HCB Botany Stockpile in an environmentally sound manner.

### 1.2 HCB Waste Characteristics

The Orica HCB waste stockpile currently stored at the Botany Industrial Park, collected over a production period of three decades, consists of various compositions including impure HCB waste and materials encapsulated in cement tanks. 90% of the drummed waste is HCB in granular and lump form. Liquids, sludges and viscous materials constitute the other 10%. Other compounds and chemicals that are mixed with this material include perchloroethylene, hexachlorobutadiene, octochlorostyrene, carbon tetrachloride, polymers and tars.

The physical form of the HCB waste widely ranges from its pure and relatively insoluble crystalline form, to liquid with particulate matter in sizes up to 6mm in diameter, polymerized solids and reaction residues. There are also different phases present, from volatile compounds to solids and liquids of high viscosity.

These compounds are listed as Persistent Organic Pollutants (POP's) by the *Stockholm Convention on Persistent Organic Pollutants* as their inherent chemical stability makes them persistent in the environment and resistant to biodegradation. They accumulate in human fatty tissues and have demonstrated signs of being



carcinogenic. High toxicity towards both flora and fauna is one of the main reasons why the Orica HCB waste stockpile has to be treated as safely and as quickly as possible. Another reason is its volatile and flammable in nature which renders it a significant hazard, particularly on the Botany site which is close to relatively high density residential areas and to a major international airport.

### 1.3 Methodology and Requirements for Assessment

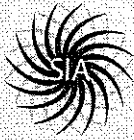
All current available technologies with potential to treat HCB in Australia were reviewed based on six assessment criteria. These criteria have been realistically developed based on technical, license and commercial requirements needed for an industrial scale hazardous waste treatment facility. These are:

1. **Proven Nature of Technology:** This refers to whether the technology is commercially proven to treat, not necessarily HCB but any hazardous wastes. Technical, environmental and commercial risks could prolong the development of any facility. Any unproven technology would face significant risks due to its unproven nature.
2. **Scale and Time to treat the stockpile:** This refers to whether the technologies assessed are capable of treating the volume of the Orica HCB waste stockpile within the time frame as determined as part of this assessment.
3. **Pre-Treatment and Front-End Waste handling:** Considering the heterogeneous and hazardous characteristic of the Orica HCB waste stockpile, pre-treatment and front end waste handlings are vital steps for the safe and successful operation of any potential process. The difficulties with respect to the time required to develop a pre-treatment facility has also been evaluated.
4. **Process Capability to treat HCB:** This refers to whether the technology has been proven to treat HCB waste. If there is no proven capability to treat HCB waste, then this would render the technology unfeasible.
5. **Emissions and Residues from the process:** Any process that is not compliant with respect to emissions and residues is likely to face licensing and commercial risk hurdles. Each technology would be assessed based on its likely emissions and residues from the treatment of HCB waste.
6. **Ability to Permit or License Facility:** Each technology was assessed to evaluate any major issues with permitting or licensing which could preclude the use of this technology as a feasible option.

### 1.4 Key Technologies Assessed

Seven proven, operational technologies have been assessed with the potential process capability or capacity to treat HCB wastes in Australia. These technologies include:

1. **Geomelt:** This is a batch process. The waste is destroyed in a pool of molten slag or glass melt. The melting occurs at high temperature in a treatment zone



between an array of four electrodes. The melt is formed from soil. Waste is continuously fed and simultaneous application of energy causes the melt pool to grow larger until the desired volume is treated.

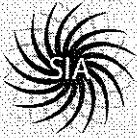
2. Hydrodec: This is a catalytic hydrodechlorination process. The organochlorine substances are chemically converted to hydrocarbons and salts, in an oil medium. The medium usually used is diesel oil which acts as a carrier for the organochlorine compounds.
3. Gas Phase Chemical Reduction (GPCR): This process involves the gas-phase chemical reduction of organic compounds by hydrogen at high temperatures. The chlorinated organic compounds are reduced to methane, hydrogen chloride, benzene and ethylene.
4. Base Catalyzed Decomposition (BCD): This process involves the treatment of wastes in the presence of a reagent mixture consisting of hydrogen – donor oil, alkali metal hydroxide and a catalyst. At temperatures above 300°C, the mixture produces highly reactive atomic hydrogen which reacts with the waste to remove the toxic organochlorine compounds.
5. High Temperature Incineration (HTI): Incineration refers to the controlled destruction of combustible material at very high temperatures, during which the oxygen in air is used to convert or oxidize the wastes to simple gases and solids.
6. Ausmelt: The waste and/or recyclable materials are processed in a molten slag bath using the Ausmelt reactor system. The main destruction reaction occurs in the turbulent liquid slag bath where the waste is in close contact with the slag at high temperatures.
7. PLASCON: The liquid or vaporized waste is directly injected into an argon plasma arc system where it is heated to a very high temperature and is pyrolysed. A controlled amount of oxygen is injected into the system to convert any carbon to CO. The gases are then quenched, cooled and then scrubbed of any acid gases in a packed tower. The off-gases are then flared to burn the CO to CO<sub>2</sub>.

## 1.5 Key Issues Identified in Evaluation

### Lack of scale in Australia's Process and Manufacturing Industries

The review has found there are few commercial scale treatment facilities in Australia capable of treating chemical industry hazardous wastes. This is because the size of Australia's process and manufacturing industries is small in comparison to other countries and hazardous waste volumes are limited and dispersed. If a facility were to be built to manage the scale and nature of the HCB waste stockpile in Australia, due to the lack of hazardous waste requiring such special treatment such a facility would have no significant purpose other than treatment of this single stockpile and would therefore be redundant post destruction of the Orica HCB stockpile. This contrasts significantly to the large industrial complexes in Europe, Asia and North America which generate significant volumes of hazardous wastes and therefore have





supported the technical and commercial development of large scale treatment facilities to manage these wastes.

#### Scale of facilities in Australia

It was clear from the assessment that no facilities are currently licensed to process the Orica HCB stockpile in Australia and that technologies and facilities operating in Australia are not able to take the volume of waste from the Orica HCB stockpile within a feasible time frame.

#### Heterogeneous nature of Orica HCB waste

Another major hurdle has been the problem of dealing with the heterogeneous nature of the Orica HCB waste. The HCB waste is mostly drummed and in varying compositions (outlined in section 1.2 above) with components of other hazardous and contaminated materials. This poses major challenges for front end pre-treatment for most of the likely HCB destruction processes, and the risks associated with this process step alone renders many of these technologies unfeasible.

#### Technology risk

Significant issues relate to the unknown capability of many of the potential technology options in treating industrial scale concentrations of HCB waste. Despite evaluation of destruction/performance of technologies, HTI was the only technology that had a track record or history of treating HCB waste at a commercial scale (not in Australia). This lack of operating history in Australia made the evaluation process difficult, particularly in relation to evaluating predicted emissions and residues from plant, but more importantly would make the permitting process of any new or modified facility extremely challenging particularly for treatment of a large scale toxic stockpile.

In our evaluation of the commercial risks posed by the development of a hazardous waste treatment facility (new build or expansion) to treat the Orica HCB waste stockpile, there were no processes or facilities that were considered feasible. To be feasible any treatment option would require, from a commercial perspective, that all six assessment criteria (section 1.3 above) be feasible. The risks and uncertainty around many aspects of the feasibility criteria in most cases were considered to be significant.

**1.6 Feasibility Status of Technologies to treat Orica HCB Stockpile**

Assessment Criteria	Proven Nature of Technology	Scale and Time to treat the waste	Pre-treatment and front end waste handling	Process Capability to treat HCB	Emissions and residues from the process	Ability to permit or license facility	Feasibility Status
Technology							
Geomelt							
Hydrodec							
GPCR							
Base Catalysed Decomposition							
High Temperature Incineration							
Ausmelt							
PLASCON							



## 1.7 Conclusions

This Assessment Report has reached the following conclusions:

- At the time of writing this report there are no facilities operating in Australia which are considered feasible for the destruction or acceptable treatment of HCB from the Orica waste stockpile at the Botany Industrial Park.
- All technologies assessed were considered not-feasible when considering the scale and time to treat the waste. This was due either to the fact that plant capacity was restricted or the time required to go from initial assessment through to completion of treatment for all of the Orica HCB waste exceeded the 5 year threshold. All technologies other than PLASCON were deemed to represent major or significant risks which would result in significant hurdles or extensive time delays in consideration of permitting or licensing a facility for processing the Orica HCB stockpile.
- Hydrodec, GPCR and BCD were technologies all deemed not feasible on every assessment criterion apart from proven nature of technology. These technologies have too many hurdles to cross before coming close to being feasible for the treatment of Orica's HCB waste stockpile.
- No known technologies in Australia currently have suitable pre-treatment or front end waste handling systems to manage the Orica HCB stockpile. Given the volume, heterogeneous and hazardous nature of the Orica HCB waste it is imperative that any front end system is proven, robust, reliable and safe in its handling of the HCB waste prior to being processed. Achieving these outcomes for most of the technologies would take much development in terms of time and cost.
- Whilst there are commercial facilities available for treatment of hazardous waste in Australia, the volume and the non-homogenous nature of the Orica HCB waste makes the treatment processes unfeasible. Site inspections and discussions with senior management of companies currently operating potential treatment systems, have advised that they are not currently able to treat HCB wastes that contain significant concentrations of HCB in a heterogeneous form.



## **2. BACKGROUND**

### **2.1 History of HCB Waste at the Botany Site**

Orica's Hexachlorobenzene (HCB) legacy is a by-product from the company's manufacture of chlorinated solvents, including carbon tetrachloride and tetrachloroethene at the Botany Industrial Park in New South Wales (NSW), Australia between 1963 and 1991.

Between 1991 and 1995, the solvent manufacturing plant was decommissioned and demolished. The HCB waste, along with soil contaminated with hexachlorobutadiene (HCBD), HCB and other contaminants is stored in custom-built storage facilities onsite. Currently, the HCB waste is being stored in nine licensed storage facilities in accordance with the Australian and New Zealand Environment and Conservation Council's (ANZECC) National HCB waste Management Plan (November 1996).

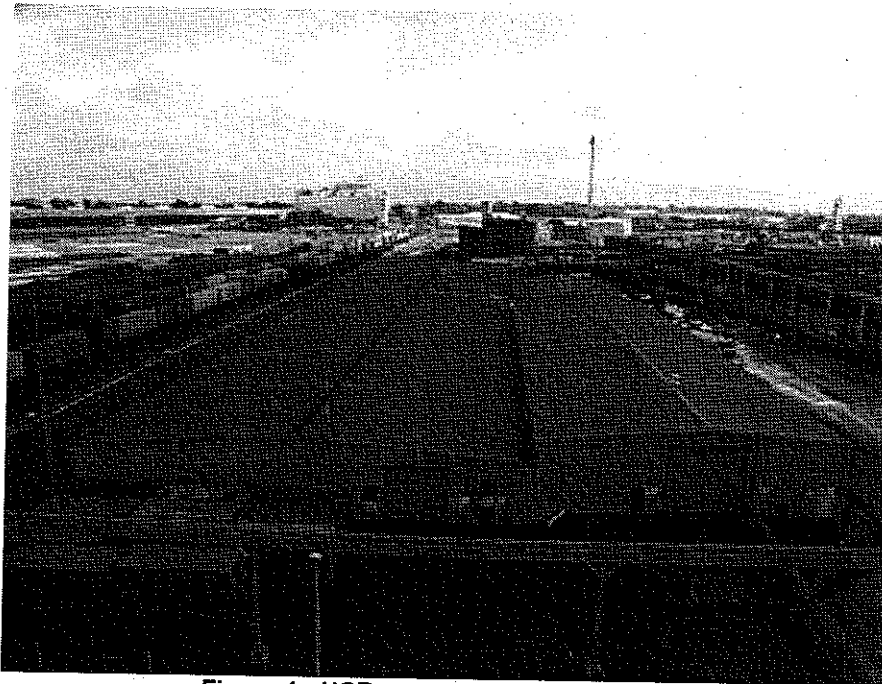
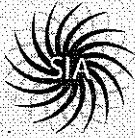
Due to the variable forms of the HCB waste and the corrosive effect it has on container packaging, it is required that the waste be repackaged frequently. This repackaging results in an increase of the HCB waste stockpile by approximately 10% per annum. The waste takes on the form of HCB-contaminated personal protective equipment (PPE), pallets and crushed drums. Hence, the storage of the waste is problematic as it is continually increasing and requiring additional storage space onsite. With over 60,000 drums in storage, each time the waste is fully repacked another 2400 - 2800 tonnes of waste continue to be produced.

The location of the Botany Industrial site is problematic as it is close to Sydney Central Business District (7-8 kilometres) and surrounded by a major population catchment. Residential properties are located within less than one kilometer of the storage sheds. The facility is also within proximity to the flight path for Sydney International Airport where considerable domestic and international flights occur each day.

It is considered an urgent matter that the HCB stockpile is destroyed in an environmentally responsible manner to reduce the significant risk to human health and environmental damage considering the long term storage of the corrosive material and the considerable risk profile of its current storage location.

#### **Report Objectives:**

The objective of this report prepared by Sustainable Infrastructure Australia (SIA) is to assess previous work undertaken and to provide an independent review on the current validity and availability of technologies in Australia to treat the Orica HCB waste stockpile. This evaluation is provided on all available technologies with respect to the processes involved, their suitability to treat the waste, their capacity to be permitted and their commercial status.



**Figure 1 - HCB storage facility at Botany**

*Source – 'Orica Australia Pty. Ltd – Application for Basel export permit pursuant to the Hazardous Waste (Regulation of Exports and Imports) Act 1989 – 4<sup>th</sup> August 2006'*

## **2.2 Characteristics of the HCB Waste**

As outlined in section 2.1, the Orica HCB waste stockpiled at the Botany facility dates back as far as 1963 and is derived from a variety of sources in a variety of formats over the production period of the plant during three decades.

The HCB stockpile is contained within nine licensed storage facilities on the Orica Botany Industrial Park site. This stockpile includes over 60,000 drums of material and waste encapsulated in cement tanks onsite.

Work has been undertaken to evaluate the waste over time, however, due to the highly heterogeneous nature of the waste, it has posed obstacles to treatment from processes requiring a homogenous or known process throughput.

Assessments undertaken on the Orica HCB waste stockpile show that about 90% of the drummed HCB waste is in granular and lump form. The remaining 10% of drummed waste includes liquids, sludge's and viscous materials. As shown below in images (Figures 2 and 3), this waste is mixed into different forms and is not pure. There are other compounds and chemicals mixed with this material which include perchloroethylene, hexachlorobutadiene, octochlorostyrene, and carbon tetrachloride, as well as other polymers and tars.



**Figure 2 - Samples taken from the Orica Botany HCB drums**

Detailed studies have been undertaken by consultants engaged by Orica to investigate separation of these wastes into homogenous streams of liquids, vapor, slurry and solid feed. There are major obstacles with this process and these would all require significant development, including trials with equipment vendors and waste processing companies.

Setting up a facility to pre-treat the material for these further treatment systems would be somewhat developmental and certainly take at least 2 years to achieve the required capacity. Even then there are likely to be some materials rejected on the grounds that they require more extensive pre-treatment. This would pose significant risk from an environmental, economic and time line perspective, considering the size and characteristics of the stockpile. There is also significant consideration that needs to be applied to the mix of other materials within the stockpile making waste handling and treatment options limited.

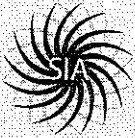


Figure 3 - Orica HCB waste as a rubbery compound - residue from attempted dissolution

The physical form of the HCB waste stockpile varies widely, ranging from its pure and relatively insoluble, crystalline form, to liquid with particulate matter of up to 6 mm in diameter, or partially polymerized solids and reaction residues. There are also different phases present, from volatile compounds to solid and liquids of high viscosity.

These compounds do not occur naturally and are classified as Persistent Organic Pollutants (POP's) by the *Stockholm Convention on Persistent Organic Pollutants* as they are extremely persistent in the environment due to their inherent chemical stability and resistance to biodegradation. They bioaccumulate in fatty tissue and have demonstrated signs of carcinogenic and mutagenic activity and are thus a cause for special environmental concern. Their high toxicity to aquatic ecosystems is one of many reasons that the waste should be dealt with as safely and rapidly as possible. Chronic oral exposure of HCB in humans causes embryo-lethality and teratogenic effects. It adversely affects the skin, thyroid, liver and bone and also causes hair loss, so precaution must be taken in handling HCB and also preventing the entry of HCB into the food chain. HCB has been detected in breast milk and the International Agency for Research on Cancer classifies HCB as a Group 2B carcinogen.



### **3. DETAILS OF THE SCOPE OF STUDY**

Sustainable Infrastructure Australia (SIA) has been commissioned by the Australian Government's Department of the Environment, Water, Heritage and the Arts (DEWHA) to prepare an independent assessment report to review all current available technologies in Australia that would potentially be able to treat the Orica Botany HCB Stockpile. The purpose of this assessment is to establish the feasibility of these technologies to treat the stockpile within a technical, environmental and commercial framework.

This review includes the following:

- Technical evaluation to assess the capacity of treatment processes to manage front end waste input and waste handling in consideration of the nature of the Orica HCB waste stockpile.
- Technical evaluation to assess the capacity of treatment processes to effectively destroy or neutralize HCB.
- Technical and environmental evaluation to assess emissions and residues from each treatment process during the treatment of the Orica HCB waste stockpile.
- Evaluation of the commercial risk and lead times required to establish and have operational a suitable technology to treat the Orica HCB waste stockpile in Australia with current available technologies (including licensing and permitting requirements).

The following areas have been excluded from the scope of this study:

- Review of technologies or treatment facilities outside Australia other than in evaluating current available technologies in Australia.
- Environmental or risk assessment of the current Orica Botany storage facility.
- Environmental or risk assessment for transport/handling of the Orica Botany HCB waste in Australia or for export outside of Australia.

#### **3.1 Study Process**

This project involved extensive assessments of available literature, technical reports and materials provided by DEWHA, Orica, consultants and treatment technology companies. This process was followed by an in depth data analysis, telephone consultation, site visits and face to face meetings with stakeholders. Stakeholders included key technology companies as well as relevant State Regulatory Authorities (including the review of licenses to determine the current level of environmental compliance of the key technologies). Details of the Stakeholder consultation are included in Section 8 of this report.





### 3.2 Legislative Requirements

Australia acceded to the Basel Convention in 1992, and it is implemented by the Hazardous Waste (Regulation of Exports and Imports) Act 1989 (the Act). Through the administration of the Act, DEWHA manages the international trade in environmentally harmful wastes and promotes the environmentally sound management of these wastes in accordance with the Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal.

Under the Convention, Australia is obliged to:

- minimize the generation of hazardous waste
- ensure adequate disposal facilities are available
- control and reduce international movements of hazardous waste
- ensure environmentally sound management of wastes and
- prevent and punish illegal traffic

The Basel Convention establishes a framework for encouraging safe shipment and disposal of such wastes across national boundaries. To import or export hazardous waste, as defined in the Basel Convention, a person must apply to the responsible Minister for a permit. The Minister considers whether the waste will be disposed of safely and will not "pose a significant risk of injury or damage to human beings or to the environment".

The objective of the Stockholm Convention on Persistent Organic Pollutants (POP's) is to protect human health and the environment from the effects of POP's. The Convention sets out a range of control measures to reduce and, where feasible, eliminate POP releases, including emissions of by-product POP's. The Convention also aims to ensure the sound management of stockpiles and wastes that contain POP's.

POP's move freely over wide distances in to the environment via the atmosphere, water and migratory species. POP's may, therefore, enter Australia through the environment as well as through importation of contaminated products.

Only a multilateral approach could adequately address the problem posed by the trans-boundary movement of POP's. Governments agreed in 1997 that the most effective form of multilateral action was by way of a binding international agreement. Negotiations on text for a multilateral convention on POP's began in mid-1998 and concluded in December 2000. Australia, together with 90 other countries, signed the Stockholm Convention on Persistent Organic Pollutants at a diplomatic conference held in Stockholm which entered into force on 17 May 2004.

The Stockholm Convention establishes control measures for twelve POP's, which have been used as pesticides for industrial purposes or are by-products from industrial processes. These chemicals are listed in three annexes to the Convention (as shown in Table 1):

- Annex A – chemicals to be eliminated
- Annex B – chemicals which have restricted use



- Annex C – unintentionally produced chemicals (or by-products)

**Table 1 - POP's listed under the Stockholm Convention**

Chemicals	Pesticides	Industrial	Unintentionally produced	Annex
Aldrin	✓			A
Chlordane	✓			A
Dieldrin	✓			A
Endrin	✓			A
Heptachlor	✓			A
Hexachlorobenzene	✓	✓	✓	A, C
Mirex	✓			A
Toxaphene	✓			A
Polychlorinated Biphenyls		✓	✓	A, C
DDT	✓			B
Dioxins(polychlorinated dibenzo-p-dioxins)			✓	C
Furans(polychlorinated dibenzofurans)			✓	C

Each of these chemicals has been identified for international action due to its persistence, bioaccumulation, long-range dispersion and toxicity. The Convention focuses on three broad areas:

- intentionally produced and used POP's
- unintentionally produced or by-product POP's and
- POP's in stockpiles and wastes

As outlined in Table 1. Hexachlorobenzene is classified as an Annex A and C chemical under the convention.

Australia is also a party to the Rotterdam Convention on the Prior Informed Consent Procedure for Certain Hazardous Chemicals and Pesticides in International Trade which was adopted in 1998 and entered into force in 2004.

The Convention promotes a shared responsibility between exporting and importing countries in protecting human health and the environment from the harmful effects of hazardous chemicals. Under the "Prior Informed Consent" procedure, participating countries learn more about the characteristics of potentially hazardous chemicals that may be shipped to them. The procedure provides a process by which countries can decide which chemicals they want to receive and exclude, based on their ability to manage them safely. Many of the chemicals listed in the Stockholm Convention are subject to export controls under the Rotterdam Convention or the Basel Convention.



## **4. SUMMARY OF CURRENT AVAILABLE TREATMENT TECHNOLOGIES IN AUSTRALIA**

### **4.1 Definition of Technologies Assessed and Feasibility Evaluation**

This independent assessment report includes a review of the following:

- Technical evaluation to assess the capacity of treatment processes to manage front end waste input and waste handling in consideration of the nature of the Orica HCB waste stockpile
- Technical evaluation to assess the capacity of treatment processes to effectively destroy or neutralize HCB
- Technical and environmental evaluation to assess emissions and residues from each treatment process during the treatment of the Orica HCB waste stockpile
- Evaluation of the commercial risk and lead times required to establish and have operational a suitable technology to treat the Orica HCB waste stockpile in Australia with current available technologies (including licensing and permitting requirements)

The technology assessment was made on the basis of six assessment criteria. These six criteria have been developed based on realistic technical and licensing requirements for the complete development of an industrial scale hazardous waste treatment facility and include:

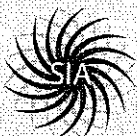
#### **Proven Nature of Technology**

Proven technology refers to technology commercially proven in the treatment of hazardous wastes (not necessarily HCB). If the technology is not fully developed and operational on a commercial scale there are likely to be significant technical, commercial and environmental risk factors that will prolong the development stage of a facility.

#### **Scale and Time to Treat Stockpile**

An important assessment criteria is the time it would take to develop a facility to an operational position and then the time it would take for the facility to treat the Orica Botany stockpile. This involves many factors such as facility size and capacity, time required to obtain permits and licenses and time required to complete commercial negotiations and contracts. Another significant difficulty with treatment of the Orica HCB waste stockpile is the heterogeneous character and volume of the waste. This has resulted in many technologies in the past proving difficult to develop or implement due to their treatment capacity, the scale of the stockpile and problems with pre-treatment of the HCB drummed waste to prepare for processing. It is important from a feasibility view to provide a realistic evaluation of the scale and time requirements for treating the waste.

The feasibility for this time frame has been based on 5 years to develop and license a facility to fully treat Orica's HCB stockpile. The rationale for this 5-year estimate is based on a number of factors and encompasses the constraints of storing waste at the Orica Botany Site and the fact that once the HCB waste is re-drummed it is only possible to transport this waste within a five year window due to dangerous goods



licensing requirements in Australia and internationally. After this time, the drums will need to be re-shredded and re-drummed again if they are to be transported. Other factors include the potential for catastrophic risk to human health and the environment if the stockpile is stored on an ongoing basis, considering its location, the nature of the materials and the issues with maintaining and re-drumming waste on a frequent basis.

#### **Pre-Treatment and Front-End Waste Handling**

Due to the magnitude, heterogeneous and hazardous nature of the Orica HCB waste stockpile, pre-treatment and front end waste handling are critical aspects for the feasibility of any potential process facility. The process feed requirements of technologies need to be considered and the difficulties, cost and time required to develop a pre-treatment process/facility need to be evaluated.

#### **Process Capability to Treat HCB**

A key assessment criterion is the proven nature of the technology to destroy the Orica HCB waste stockpile or otherwise treat to render it innocuous.

#### **Emissions and Residues from the Process**

Emissions and residues from any process that is not proven or compliant will create significant licensing and commercial risk hurdles to any facility being established. Each technology will be evaluated on known emissions and residues from the treatment of HCB.

#### **Ability to Permit or License Facility**

Each technology will be assessed to evaluate any major issues with permitting or licensing which could preclude the use of this technology as a feasible option.



## 4.2 GeoMelt

The GeoMelt process is a batch process by which the waste is destroyed in a pool of molten mineral matter (slag or glass melt). The melting is achieved in a treatment zone between an array of four electrodes. The melt may be formed from soil. It serves as the heat transfer medium whereby electrical energy is converted to heat via joule heating as the current passes through the melt. The process can be operated in-situ (in ground) or in-furnace.

Melt temperatures typically range between 1,500 - 2,000°C. Continued application of energy results in the melt pool growing larger until the desired volume is treated. When electrical power is shut off, the molten mass solidifies into a vitreous monolith. Individual melts up to 7 m deep and 15 m in diameter are formed during commercial operations.

Large volumes of contaminated material requiring more than one batch melt are treated by making a series of adjacent melts resulting in the formation of one massive contiguous monolith, in the in-situ situation. The process is said to be capable of achieving treatment rates of up to 150 tonnes per day.

The GeoMelt process has been in commercial use since the early 1990s and A Managerial and Engineering Company (AMEC) have held a worldwide license for application of the GeoMelt technologies since 2000. They are currently applying the technology in the United States, Japan and elsewhere. AMEC has developed two variations of the GeoMelt process. The first application, called Subsurface Planar Melting, allows the treatment of buried contaminated materials in an in-situ mode, thus minimizing contact and exposure to any potential hazards commonly encountered during conventional handling practices. Subsurface Planar Melting is performed by installing electrodes and a starter path below grade to initiate the melting process. Continued application of power is conducted until all of the contaminants of concern have been effectively treated. A containment hood placed over the area to be treated collects any vapors formed during the vitrification process and routes them to an off-gas treatment system. The starter path is installed as vertically-oriented planes of starter material between two pairs of electrodes.

AMEC has also developed an ex-situ application referred to as "In Container Vitrification" (ICV™) for waste treatment applications. ICV™ is a mobile process that involves the electric batch melting of contaminated soils and other wastes for the destruction, removal, or permanent immobilization of hazardous and radioactive contaminants. The process can be configured in a number of ways to treat a wide range of waste streams including solids, liquids, and debris. ICV™ has been used in Australia, Japan, and the United States, and is currently being furthered by AMEC for United States Department of Energy applications.

The batch technique involves staging and treating wastes in low-cost refractory-lined steel containers. These containers can vary in size and shape from 200 litre drums to large roll-off boxes. After each batch of waste is treated, the melted waste is allowed to cool and solidify in the container. The vitrified treated waste can then be removed from the container for disposal and the container reused. Alternatively, the container can be covered with a lid and the container and vitrified waste can then be disposed



of after each melt. The refractory lining would be substantial due to the need to provide sufficient insulation to protect the steel container from warping, adding considerably to cost and volume of treated waste requiring disposal.

ICV™ works by directing electrical power to the treatment zone via graphite electrodes installed in the melt container. The ICV™ process uses Joule heat generated by passage of electric current through the soil/waste matrix to raise the temperature of the matrix to levels above the melting point of the materials contained therein. Both GeoMelt processes are soil melting processes, in which soil or other glass or slag formers must be present to establish the melt and create a stable, vitrified waste form. Because of its inherent ex situ flexibility, ICV™ can process other waste materials, but soil or another melt-producing mineral must be a major constituent of the materials being processed. Otherwise, soil must be added to the waste materials.

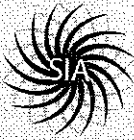
Contaminants that were originally affixed to the surfaces of wastes are transferred into the melt phase during processing and are subsequently immobilized as oxides within the glass matrix or are liberated as gases. The melt is highly corrosive to metal surfaces. The very high temperatures involved are sufficient to destroy all organic matter and produce combustion gases plus acid gases such as hydrogen chloride and sulphur oxides.

When the waste volume has been fully treated, electrical power is turned off and the melt pool is allowed to cool and solidify. The vitrified product normally consists of a mixture of glass and crystalline materials and often has an appearance similar to volcanic obsidian.

During the course of GeoMelt processing, gas convection and concentration-based diffusion are the predominant movement mechanisms, and pyrolysis/dechlorination is the destruction mechanism for organic contaminants. The off-gases require a further stage of destruction in the form of an after burner (off gas incinerator or thermal oxidizer), and the combustion gases must be treated for the removal of acid gases and any refractory organic compounds.

The heat from the processing creates a dry zone adjacent to the processing area, providing an area of reduced pressure drop, enhancing movement of vaporized water and organics and promoting a steam stripping action. Capillary forces cause the moisture and chemicals present in the water adjacent to the dry zone to move into the dry zone where they can be volatilized. The volatilized gases are drawn toward the melt because of the concentration gradient created by the pyrolysis, where they then primarily move up and around the melt in the relatively permeable dry zone or, on occasion, enter into the melt and bubble through the molten soil. Finally, the movement of organic liquids or gases may be retarded by the effects of adsorption onto the soil, which further enhances destruction. However, due to the fact that the rate of adsorption decreases with increasing temperature, it is expected that adsorption plays a very small role in the reactions within the dry zone.

The behavior of hazardous compounds during GeoMelt processing is controlled by several interrelated mechanisms. These mechanisms all interact to cause a general movement of hazardous compounds towards the melt and the surface of the volume



to be treated. These mechanisms serve to maximize the destruction, removal and, in the case of non-volatile heavy metals, the incorporation of the hazardous materials into the molten product. Many of these mechanisms actually occur in the region immediately adjacent to the molten soil interface, which is referred to as the dry zone.

Chlorinated organic compounds in the presence of steam and alumina undergo a dechlorination reaction to produce HCl and CO. This reaction, in combination with the pyrolysis reaction, has proven to be highly effective in organic destruction during GeoMelt processing.

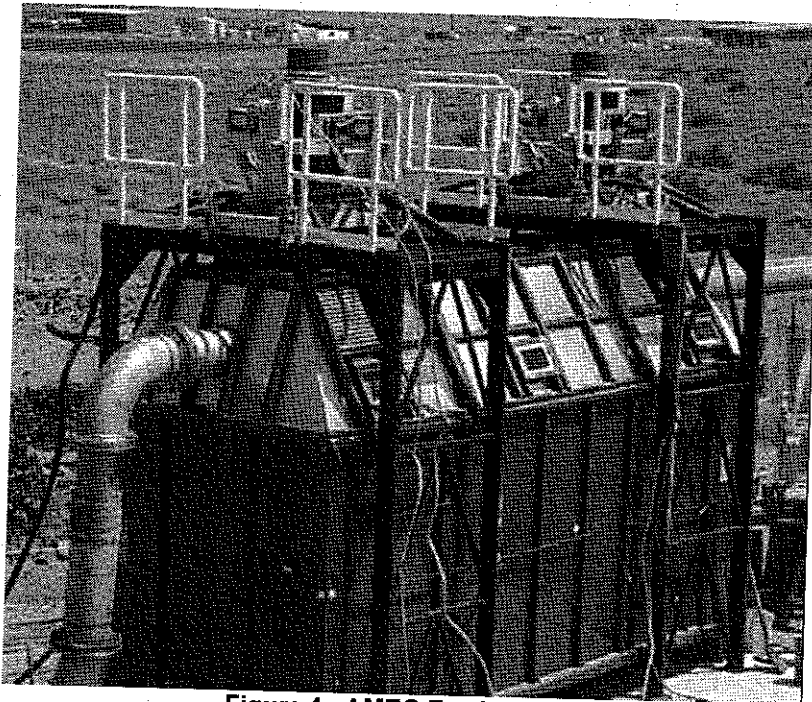


Figure 4 - AMEC Ex situ Plant

#### 4.2.1 Feasibility Status

As a result of the evaluation on all six criteria, it is considered **not-feasible** that the GeoMelt process can be developed in Australia within a reasonable time frame to treat the Orica HCB waste stockpile.

Assessment Criteria	Proven nature of technology	Scale and time to treat the waste	Pre-treatment and front end waste handling	Process Capability to treat HCB	Emissions and residues from the process	Ability to permit or license facility
Technology						
<b>GeoMelt</b>						



#### 4.2.2 Proven Nature of Technology – Feasible ✓

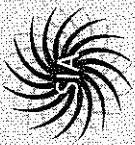
GeoMelt is considered to be a proven technology as it had been operated at Maralinga (in-situ) for the treatment of soil contaminated with radioactive substances. It is currently operating ex-situ in Japan for soils contaminated with organochlorine compounds. This process has been used successfully on a wide range of organic contaminants, including explosive contaminants. Overall destruction and removal efficiencies in excess of 99.9999% have been commercially achieved in the United States, Japan and Australia by the Geomelt process. At present there are no facilities operating in Australia.

In the US, the GeoMelt process has successfully remediated soils contaminated with radioactive materials – including plutonium, uranium, cesium, strontium, americium, technetium, and iodine. Sites contaminated with hazardous heavy metals (e.g. – arsenic, chromium, cadmium, and lead) have also been successfully remediated using the GeoMelt process. The US Environmental Protection Agency has issued a National Toxic Substance Control Act (TSCA) Permit for the GeoMelt process for remediation of sites with PCB-contaminated soils at concentrations up to 17,860-ppm (~1.8-wt%).

The process claims to treat virtually all chlorinated organic compounds including solvents, pesticides, herbicides, 2,4-D, 2,4,5-T, 4,4'-DDD, 4,4'-DDE, 4,4'-DDT, heptachlor, pentachlorophenol, chlordane, dieldrin, dioxins, furans, hexachlorobenzene, polychlorinated biphenyls. In addition, it is effective for remediating materials contaminated with heavy metals including arsenic, lead, cadmium, and chromium.

Although this technology is proven, it has not yet been proven in the commercial scale treatment of HCB, nor has the technology been used in treating industrial waste in quantities or concentrations comparable to the Orica HCB waste stockpile.





**Table 2 - Record of GeoMelt Commercial – Scale Projects**

Project	Contaminated Feedstock	Treatment Quantity and Average Concentration	Destruction Performance	Off-gas Treatment Performance	Leach Test Performance
Wakayama, Japan (Hashimoto) - Industrial waste incinerator	Dioxins, furans, PCBs as contaminated ash, iron scale, sand and protective clothing, Dioxin/Furan up to 190ng/g (TEQ)	36 x 2 tonne melts Up to 190ng/g (TEQ)	DRE 99.9999%	Orders of magnitude Below regulatory requirements	No detectable contamination
Wakayama, Japan (Hashimoto) - Industrial waste incinerator	Dioxins, furans, PCBs as contaminated soil and debris	1200 tonnes. Up to 75ng/g (TEQ)	DRE 99.9999%	Orders of magnitude Below regulatory requirements	Well inside regulatory limits
Maralinga, South Australia - Weapons test site	Plutonium, Uranium, Beryllium, Tonnes of steel, barites bricks, lead, cabling etc.	6,500 tonnes 2-4 kg of Plutonium in total	PU retention in melt > 99.99%	Well inside project regulatory limits	Orders of magnitude below US EAG criteria

Source: Provided by AMEC plc in accordance with strict format specification by Review Panel.

**Table 3 - Record of a Number of Relevant GeoMelt Demonstration and Test Projects**

Project	Contaminated Feedstock	Treatment Quantity and Average Concentration	Destruction Performance	Off-gas Treatment Performance	Leach Test Performance
HCB Waste Demonstration For Orica using a refractory lined for the melting. Adelaide - Australia	HCB waste mixed with soil	Three batches ~2 tonnes. Conc. of HCB from 16.5 to 33 wt%. Test 3 also included mixed debris such as steel, timber, plastic, filter materials, PPE and carbon	Overall HCB destruction typically >99.9999%	Satisfied regulatory criteria, except for dioxin emissions (see discussion in section 4.2.5)	No detectable contamination

Source: Provided by AMEC plc in accordance with strict format specification by Review Panel.



#### 4.2.3 Scale and Time to Treat Stockpile – Not Feasible

x

It is estimated that if a GeoMelt facility was to proceed, the project would extend over a period of nine to eleven years as follows – time to get the facility permitted (2 years), built and commissioned (2 years) and time to destroy the Orica HCB waste stockpile (5 years). This estimate is not taking into consideration any major delays with the permitting process or commercial delays with taking the facility to commercial close (all contracts and financing secured).

It may be feasible to scale up to a considerable degree and, although the process is a batch, or discontinuous one, it seems likely that a cupola capable of handling a charge of 30 tonnes may be feasible. If this were 10% HCB waste then 16,000 tonnes would require 5,333 melts. However, considering both the thermal reactivity (combustibility) and the electrical insulating properties of HCB, it is likely that the blend will need to contain less HCB than this.

It seems that at least two cupolas would be used in sequence so that the feed pretreatment, slag/residues management and off-gas handling plant can be better utilised. Assuming 24 x 7 operation and a twelve hour cycle then there would be 4 melts per day requiring about 4 years operation, plus down-time, to treat the current Orica HCB waste stockpile.

#### 4.2.4 Pre Treatment and Front End Waste Handling – Feasible

✓

GeoMelt was considered by Orica one of the few technologies that could accept the HCB waste with little front end waste preparation for the Orica HCB waste stockpile. It has been previously stated that there is no significant waste pre-treatment required, however, there is obviously a need to incorporate a charge of siliceous material with each HCB waste charge in order to produce a non-leachable disposable residue; it is after all a vitrification process. The mineral additions and the drums of waste would need to be somehow blended to provide the required electrical conductivity path.

The main attraction of the process is its capacity to handle large volumes and large objects; however, with the large proportions of organic matter involved it is likely that pretreatment by shredding and blending would be needed to meet the requirements of sensible cupola charging and electric heating.

The GeoMelt process is effective in treating a broad range of waste debris including rocks, wood, plastic, concrete, and steel and can accommodate large items of such debris with minimal or no size reduction. Organic-based waste materials such as wood, plastic and inorganic compounds are decomposed while metallic wastes such as scrap steel drop to the bottom of the melt pool during processing because the density of steel is greater than that of the molten glass. These metallic wastes are likely to form a 'skull' at the bottom of the solidified mass, maybe partly encased in the vitrified product. The metal, in a non-contaminated form, should then be recoverable.

It is understood that pre-treatment is required for applications involving the in-situ mode of treatment for sites containing high integrity sealed containers, such as



drums. Alternatively, unacceptable materials such as sealed drums can be breached and the contents blended with soils when employing the staged in-situ or stationary batch modes of treatment.

#### 4.2.5 Process Capability to Treat HCB – Feasible ✓

Orica have undertaken trials in South Australia to treat their HCB waste stockpile. Three trials were undertaken on 2 tonne batches with some success. Despite this, there has been no commercial scale treatment of HCB waste through the GeoMelt process as the process is specifically designed for treating hazardous wastes such as contaminated soils, rather than general commercial or industrial wastes.

The results of these applications demonstrate that the technology can effectively destroy chlorinated organic wastes. Results of the Wingfield, SA trials using Orica HCB feedstock indicated effective destruction of HCB, HCBd and HCE to be better than 99.999%, other than in the first trial, which achieved 99.997% destruction of HCB. Further, the vitrified residue was found to be free of chlorinated material. GeoMelt reports that no chlorinated residuals have been detected in any of the company's worldwide operations.

Project	Contaminated feedstock	Treatment quantity and average concentration	Destruction performance	Off-gas treatment performance	Leach-test performance
HCB Waste Demonstration For Orica using above ground refractory lined crucible melting. Adelaide - Australia	HCB waste mixed with soil.	Three batches ~2 tonnes. Conc. of HCB from 16.5 - 33 wt%. Test 3 also included mixed debris such as steel, timber, plastic, filter materials, PPE and carbon.	Overall HCB destruction, typically >99.9999%.	Satisfied regulatory criteria except for dioxin emissions	No detectable contamination

Source - Independent Review – HCB waste destruction

Out of 3 HCB trials conducted in South Australia in 2000, the dioxin/furan emissions from 2 trials were above the 0.1 ng TEQ/m<sup>3</sup> concentration. (Trials 1 and 3, respectively 1.68 and 0.58; the result for Trial 2 was 0.04 ng TEQ /m<sup>3</sup>).

There were a few significant differences in the components of the gas treatment system which led to the non-achievement of 0.1 ng TEQ/m<sup>3</sup> limit in the trials:

- High Temperature ceramic filters, a vital component in dioxin/furan reformation control, to provide fine particle removal before cooling through the de Novo synthesis reaction regime of 420 to 200°C were not used. Instead, a glass fiber roughing filter was utilized.
- The activated-carbon adsorber was of limited size in the trials (25 L) despite Orica suggesting a more comprehensive design with a residence time of at least 2 seconds. It is also suggested that the gas temperature was not nearly optimized for this adsorption.



- During the trials, the thermal oxidizer was maintained at a temperature of only 900°C while Orica had proposed a temperature of at least 1200°C. At 900°C, complete destruction of organochlorine compounds is not guaranteed but could occur at 1200°C, provided the design of the thermal oxidizer is appropriate to achieve the temperature and residence time with adequate turbulence. Results of the trials suggest that reformation in the post combustion zone was occurring during the trial, and that this was the cause of failure to meet the limit rather than carry over of dioxins present in the feed materials unchanged or generated in the melt process itself.

#### 4.2.6 Emissions and Residues from the Process – Not Feasible

x

To quote several sources, the GeoMelt processes are relatively safe and represent a low risk to the environment as demonstrated by successful commercial operations in the US and in Japan. However, that work appears to be all based on low level contaminated soils. One of the chief reasons the process was denied a license to operate on the Botany site seems to be related to the large batch volume of highly toxic waste residing in a high temperature container, and the potential for a catastrophic accident.

There is a major unknown with GeoMelt in that the HCB waste stream has a higher volatiles content and will produce much greater volumes of fuel and of combustion product gases than has been the case with previous applications. The off-gas will vary considerably in volume and content as the batch treatment progresses. There will therefore be a need for considerable attention to off-gas treatment including a thermal oxidiser to guarantee the required destruction, and a scrubbing system for removal of particulates and toxic volatile compounds such as dioxins and their precursors, acid gases and Polycyclic Aromatic Hydrocarbon (PAH) compounds.

#### 4.2.7 Ability to Permit or License Facility – Not Feasible

x

It seems highly unlikely that a permit or license would be granted for the Geomelt facility to treat industrial scale volumes of HCB in Australia. The key hurdle for permitting and licensing is the lack of proven treatment of concentrated HCB waste on a commercial or industrial scale. Trials to date have shown unacceptable levels of emissions that do not comply with licensing requirements.

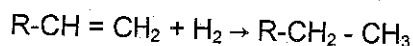


### 4.3 Hydrodec

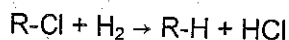
The Hydrodec process is a catalytic hydrogenation process. A gas or liquid stream, containing unsaturated (hydrogen deficient) hydrocarbon compounds, is passed over a catalyst bed in the presence of excess hydrogen to yield the corresponding saturated hydrocarbon. Temperatures are usually above 200°C with pressures in excess of 10 bar. The HCl which is released as a part of the hydrodechlorination of organochlorine compounds reacts with ammonia to form ammonium chloride which can be retained in the gas phase and, therefore pass easily through the reactor.

Hydrogenation of the form used by Hydrodec has a long history of wide usage in the oil (e.g. low sulphur diesel), petrochemical and food industries.

The basic chemical reaction is:



Temperatures above 200°C are normal and pressures up to 10atm can be used. The hydrogenation process can also be used to replace electronegative groups on hydrocarbons. When the hydrogenation of chlorinated compounds is involved the liberated chlorine reacts with the hydrogen to form HCl.



This reaction occurs at the catalyst surface and, in the case of dechlorination or dehalogenation, causes deactivation of the catalyst. Previous attempts to solve this problem have generally been uneconomic but the in-phase ammonia neutralization is successful and thermodynamically favours complete dechlorination (multi phase reaction system). There are no combustion reactions required anywhere in the process and there are no additional complications with respect to reactions and reactants giving the process many advantages over other chemical dehalogenation systems, such as;

1. Greater control,
2. Lower energy requirements,
3. Less opportunity for side reactions, and,
4. No difficult to handle by-products.

For the process to continue efficiently, the temperature and pressure must be selected to prevent ammonium chloride precipitation either on the catalyst or on the walls of the vessel. Hydrogen and ammonia are mixed with the feed solution prior to heating it to near the reaction temperature, which is usually about 300°C. The system pressure is in the vicinity of 2.5 MPa (25 bar).

After quench cooling, the oil mixture emerges from the reactor in association with water; an aqueous solution of ammonium chloride is produced from which the ammonia can be recovered for reuse, as is the carrier oil.



### 4.3.1 Feasibility Status

As a result of the evaluation on all six criteria, it is considered **not-feasible** that the Hydrodec process can be developed in Australia within a reasonable time frame to treat the Orica HCB waste stockpile.

Assessment Criteria	Proven nature of technology	Scale and time to treat the waste	Pre-treatment and front end waste handling	Process Capability to treat HCB	Emissions and residues from the process	Ability to permit or license facility
Technology						
<b>Hydrodec</b>						

### 4.3.2 Proven Nature of Technology - Feasible ✓

Hydrodec has one commercial operation in Young NSW which successfully treats Polychlorinated Biphenyl (PCB) contaminated transformer oils. It has not been demonstrated for use on solid waste or polymers. Trial treatment of very small samples of HCB material has been completed at bench/pilot scale.

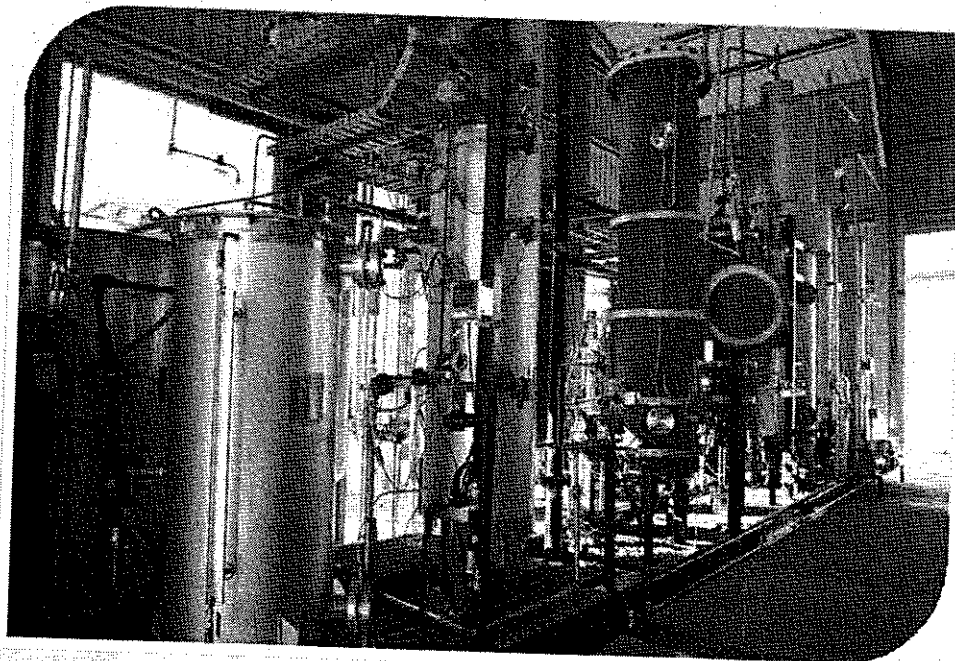
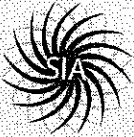


Figure 5 - Hydrodec Plant in Young. Courtesy of Hydrodec



#### 4.3.3 Scale and Time to Treat Stockpile – Not Feasible

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The process has been developed to commercial scale for transformer oils, from the original CSIRO bench scale work, in 2 years. The next scale-up is already underway for applications to the USA transformer oil recycle market. A further scale-up and other adaptations to the Hydrodec process are needed to apply Hydrodec to the Orica HCB waste. This could take at least another 3 to 5 years.

The present Hydrodec process could not handle the Orica HCB waste stream without considerable pre-treatment and dilution into some large volume oil stream. This makes the volume of the stream to be treated, over any reasonable period, very large indeed.

Any present, or indeed presently proposed commercial operation (150,000 litres/day of PCB contaminated oil, plant in construction at Laurel Mississippi USA), is several orders of magnitude smaller than it would need to be for this duty. Hence the conclusion that for disposal of the Orica HCB waste the size and state of development would render the Hydrodec process not feasible.

The difficulties being –

- The concentration of the chlorine content of HCB waste, way beyond anything involved with present day transformer oils
- The need for a pre-treatment process capable of producing a purified liquid feed suitable for the process
- The fact that the main thrust and importance of their existing operations is recovery and recycle of a high value product, compared with the HCB case of charging a gate fee because there is no valuable product, only another waste requiring disposal.

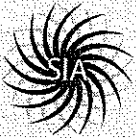
There may also be significant difficulty and delay in permitting and licensing a waste management facility compared with an oil processing plant, and there are hazards or risks involved both on a commercial and environmental level.

#### 4.3.4 Pre Treatment and Front End Waste Handling – Not Feasible

x

The pre-treatment process required to get the HCB into a suitable oil stream has not so far been developed and is regarded as still needing a lengthy development period. Orica has attempted several approaches and not yet succeeded. Indications are that a low concentration slurry may need to be the first step, in order to separate HCB from 'tramp' material and to partially decontaminate these residues.

The HCB would then have to be extracted from the slurry into a suitable oil stream to prepare a satisfactory feed for the hydrogenation process. Such a process is fraught with difficulties and environmental risks, and therefore the pretreatment process was deemed to be not feasible for the large volume of HCB waste accumulated by Orica. This is not a reflection on the capabilities of the Hydrodec process itself.



### Slurry Preparation Concept:

For the Hydrodec process a liquid hydrocarbon (oil) feed is needed. Several routes for preparation of a suitable feed have been explored. The Orica preferred route involved preparation of a water slurry from which the organochlorine compounds could be extracted into a solvent oil.

A liquid feed could be prepared by condensing a vapour stream which could be generated by a thermal desorption or evaporation process. This was not favoured since the HCB mixed waste components have a wide range of boiling points which would result in a more complex and expensive processing system.

Laboratory scale tests conducted in 1994 – 95 showed that a stable slurry of HCB in water at concentrations of 70% w/w can be prepared. It was found that this needed to be prepared on a batch basis to suit the differences in the feed material, thus guaranteeing that a pumpable liquid could be produced and transferred to the destruction facility.

Preparation of the water-based slurry (HCB in water) entails the processing of unopened drums and their contents through a drum shredder and a hazardous waste Hydropulper.

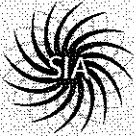
The drums are located, two at a time, on a drum elevator and launched into a shredding system through a double door airlock chamber. The shredding system combines two slow-speed rotary shear-type shredders, which puncture and shred the drums and their contents. The primary shredder is fitted with an in-feed ram to ensure that proper feed conditions are achieved and also to prevent the material from bridging within the cutting chamber. The secondary shredder is structured to deliver a more uniform size (typically 50mmx100mm particle).

Spark and heat generation can be controlled by the speed and design of the shredders. The system also includes an inert gas purging system, oxygen monitoring, fire suppression and rupture panels as safety precautions for ignition or explosion.

The shredded material is then fed into the Hydropulper (1.5m diameter, 2.25m<sup>3</sup>) which is located below the shredder. The Hydropulper is a vertical pulping machine that admits materials in any form and reduces the particle size in liquid slurry. The function is accomplished by a vaned rotor turning inside a tub which is fitted with perforated plates. Accepted slurry is then passed on to a conical screw mixer. The Hydropulper is charged with waste and enough liquid to obtain desired consistency. The waste is left in the Hydropulper until the desired degree of particle reduction has been obtained.

A chamber is used to constantly remove the heavy residues from the Hydropulper during operation, including the shredded drum tramp material. This chamber consists of a jacketed spool section between two knife gate valves. During the process, the upper knife gate valve is opened to permit the movement of any accumulated heavy residues via gravity into the junk chamber. The jacketing inner sleeve permits any free liquids to drain off and return to the Hydropulper while the large wastes are





trapped in the chamber. While the upper knife gate valve is closed to allow all free liquids to drain off, the lower knife gate valve is then opened to allow the residues to drop via gravity into a scrap bin.

Due to the insolubility of HCB in water, the shredded drum metal leaves the Hydropulper in a clean state. To further decontaminate the metal, only a simple washing step is needed, although there may be issues with corroded containers that have been re-drummed, as destruction is required once the rusted metal is impregnated, due to this contamination.

The batch is conveyed to a conical screw mixer (capacity – 5m<sup>3</sup>) once slurring is complete. To ensure the continuity of operations, the feed preparation process is first decoupled from the destruction facility. The waste is discharged from the mixer to the hydraulically-driven piston pump and then finally to the particular destruction facility.

A liquid feed suitable for the Hydrodec process can also be formed by dissolving the waste into carrier oil. The low solubility of HCB in oil, however, confines the feed concentration to ~2% thus making this a poor choice. In fact, slurries of HCB in oil can also be prepared in the Hydropulper but, since HCB is soluble in oil, decontamination of shredded drums and other trash becomes more difficult.

Water was clearly the carrier fluid of choice for slurry strategies. However, many technologies could not bear high water loads in the feed. The use of drum shredders and the Hydropulper appeared attractive for some of the waste material. However, the loose polyethylene drum liners, rubber content of Personal Protective Equipment (PPE) and contaminated concrete proved difficult materials for this concept. Significant segregation of the waste stockpile would be required for the slurry option to work.

As previously stated, for the treatment of HCB waste by the Hydrodec process, the waste would need to be completely dissolved in a suitable carrier oil. The Hydrodec process is presently designed to operate on transformer oils with low organo-chlorine contaminant levels and Orica's understanding is that with further development it would still be limited in treatment to a HCB concentration of ~5%. The extraction of organochlorine compounds into a carrier (solvent) oil from the water slurry is a process that would require further development.

Key development requirements are:

- Research for selection of a stable solvent, suitable for recovery and recycling; and
- Design of facilities for safe dissolution of the waste, including filtration of the solution and handling of any residual solvent washed solids
- Design of a solvent extraction process for transfer of HCB's and other organo-chlorine compounds from the solvent stream into the Hydrodec oil circuit

Added risks with the segregation of the waste stockpile alone could preclude this as a feasible option. For example, it would add considerably to the work performed by personnel at the Orica re-drumming operation and would produce a significant



volume of highly contaminated by-product waste stream requiring another destruction or disposal process.

#### 4.3.5 Process Capability to Treat HCB – Not Feasible

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This process in its present form is unsuited to the treatment of Orica's HCB waste stockpile, but it has been trialled successfully on HCB's. It could no doubt be developed to handle higher concentrations and the much larger quantities required for the Orica waste stream. Existing and planned Hydrodec facilities are much too small to handle this waste stream. This would require an additional stage of development which Hydrodec are unlikely at this time to incorporate into their business strategy.

Another complication is that benzene is formed during the chlorine removal process and the management of benzene will involve developing a separation process for solvent recovery and the recovery of benzene in a marketable form, or its safe destruction.

Catalyst protection has been well addressed throughout all previous work but the HCB stream may offer new challenges because of the unusual contaminants present in the drums, pallets, concrete, PPE and bags, and in the polymerised solids, within the Orica HCB waste stream. This is a major unknown at present but the dual processes of water slurring and oil extraction go a long way towards providing opportunities for the exclusion of inorganic and organic catalyst poisons.

Assuming some other business interest was to handle the pre-treatment, resolving all the issues with the HCB tar polymers, other polymerized solids, timber pallets, concrete, steel drums and polythene bags and the high water content which would otherwise complicate processing by Hydrodec, there is still the unacceptable risk of water, solids and impurities polymerizing in the process and ruining the catalyst. Tight specifications would have to be developed and stringent guarantees would have to be met.

#### 4.3.6 Emissions and Residues from the Process – Not Feasible

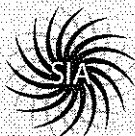
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The Hydrodec chlorine removal process applied to HCB would produce large quantities of benzene as a by-product and this is also a likely toxic contaminant in the wastewater produced. Management of the benzene product will require development of a separation process for the solvent (oil) recovery step.

As applied to the processing of waste oils the Hydrodec process requires several steps of containment and management for reduced sulphur compounds (eg. hydrogen sulphide) a potential odour issue.

These processes, as applied to waste oil treatment are described as follows –

- In present and planned Hydrodec facilities for transformer oil reprocessing, the unloading and bulk storage of oxidised transformer oil can release some reduced sulphur compounds, hydrogen sulphide and mercaptans. During the refining process, light hydrocarbons and hydrogen sulphide (H<sub>2</sub>S) are



produced. This stream is passed through caustic scrubbing to remove the H<sub>2</sub>S and the light hydrocarbons are bled out of the system with some of the process hydrogen through a final caustic scrubber before being incinerated in a catalytic thermal oxidiser. Sulphur compounds would otherwise be 'poisonous' to the thermal oxidiser catalyst.

- The scrubber waste caustic containing sulphide has a pH of 13 and Hydrodec treats this waste stream onsite by pH correction prior to discharge to sewer. In a larger facility this will require sulphide removal prior to discharge.
- The refining process uses water to wash the oil and recycles the wash water once through the system to cool down the off gas stream. This waste water is then treated onsite by a batch process involving dissolved air flotation for oil removal. There is a small quantity of hydrogen sulphide in this waste water and the Dissolved Air Flotation (DAF) step liberates the hydrogen sulphide from the waste water, an odour source requiring control.

In present operations after processing oxidised transformer oil through the Hydrodec process the oil is saturated with water and gas. After settling out the free water the oil is dried by vacuum degassing. This degassing stage removes any gases which are left in the oil.

In the case of transformer oil processing there is of course an oil product and this has to pass stringent physical and chemical tests in order to be sold back into the market.

Trials have also been carried out on other 'wastes' producing very high destruction efficiencies for DDT, HCB and dioxins.

The following table indicates the capability of the Hydrodec process in achieving this end with respect to its chemical contaminant level (PCB).

Source: Table provided by Hydrodec

Pollutant	Concentration in Feed Oil (mg/kg)	Concentration in Product Oil (mg/kg)
PCB	1,024	Not detectable
DDT	2,000	Not detectable
HCB	1,340	Not detectable
Dioxin	46 (NATO method ug/kg)	Not detectable (NATO method ug/kg)

In the case of Orica HCB waste stockpile treatment, there would be a hydrocarbon product that would also be required to meet certain chemical specifications. No doubt this stream would be disposed of as waste oil for fuel use on industrial furnaces and would need to pass the appropriate tests. It seems certain that the produced oil would pass all such requirements with respect to organo-chlorine content.



#### 4.3.7 Ability to Permit or License Facility – Not Feasible

x

Hydrodec Australia is the holder of Environment Protection License No. 11385 issued under the Protection of the Environment Operations Act 1997. The license authorises the carrying out of Scheduled Activity. The license only allows for the treatment of waste mineral oils containing a scheduled concentration of Polychlorinated Biphenyls (PCB) using the small Hydrodec Hydrogenation Plant at the premises.

If HCB wastes were to be treated, Hydrodec would need to undertake a full Environmental Impact Statement (EIS) process for a newly developed industrial scale facility. This process would take some time (1-3 years) and face significant hurdles due to the lack of history in treating the HCB waste, or even significant quantities of industrial hazardous wastes.



#### 4.4 Gas-Phase Chemical Reduction (GPCR)

This hazardous organic waste treatment technology was developed by Doug Hallett and patented and implemented together with Eco Logic of Rockwood, Ontario, Canada. Internationally accepted and tested, GPCR has been used to treat thousands of tons of polychlorinated biphenyls (PCBs), dioxins and furans, Hexachlorobenzene (HCB), organochlorine pesticides (OCP's) and other Persistent Organic Pollutants (POPs). The process involves the gas-phase chemical reduction of organic compounds by hydrogen at temperatures of approximately 875°C. Chlorinated organic compounds are ultimately reduced to methane, hydrogen chloride, and minor amounts of low molecular weight hydrocarbons (benzene and ethylene). The hydrochloric acid is neutralized by addition of caustic soda during initial cooling of the process gas.

Four waste preparation and feed systems have been proposed to allow the treatment of a variety of waste materials including organic liquid waste streams, contaminated watery wastes, solid wastes such as soil or sediment, and gases, including product gas produced in the process. Product gas may contain products of incomplete destruction and these may be recycled through the system to ensure the final product gas meets licensed emission limits.

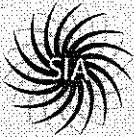
The mixture of gases and vaporized liquids are passed over electric heating elements situated around the central ceramic-coated steel tube of the reactor. Treated gases pass through a scrubber where water, heat, acid and carbon dioxide are removed. A caustic scrubbing agent is added to neutralize acids.

The process uses hydrogen gas under pressure and precautions are taken in the design and operation of the system to ensure that explosive air-hydrogen mixtures do not form. For most of the wastes treated, the product gas generated provides much of the process fuel needs. Chlorinated organics may be converted into fuel, and the chlorine is converted into a salt solution which will require disposal to sewer (some arsenic may also be expected in the scrubber water). Desorbed solid waste can be disposed of to landfill if other waste constituents such as heavy metals are at acceptable levels.

##### 4.4.1 Feasibility Status

As a result of the evaluation of all six criteria, it is considered **not-feasible** that the Gas Phase Chemical Reduction (GPCR) process can be developed in Australia within a reasonable time frame to treat the Orica HCB waste stockpile.

Assessment Criteria	Proven nature of technology	Scale and time to treat the waste	Pre-treatment and front end waste handling	Process Capability to treat HCB	Emissions and residues from the process	Ability to permit or license facility
Technology						
<b>GPCR</b>						



#### 4.4.2 Proven Nature of Technology – Feasible ✓

The GPCR process is a proven technology. In mid-1995, a GPCR plant (Eco Logic) was commissioned in Kwinana, Western Australia. The majority of waste treatment activities using GPCR occurred at this plant, which began commissioning operations in 1995 and achieved commercial throughputs by 1998. The plant was closed in December 2000 due to declining waste availability in Australia. In total, the plant treated in excess of 2,000 tonnes of waste including PCBs, pesticides and other POP's, with up to 1,500 tonnes having been treated in the last two years of operation.

Another large-scale operation was conducted at General Motors of Canada Limited (GMCL) in St. Catharines, Ontario. This demonstration project, which began in February 1996 and concluded in September 1997, saw the destruction of approximately 1,000 tonnes of PCB-contaminated electrical equipment (transformers, capacitors, ballasts), concrete, oil, soil and miscellaneous other solids and liquids.

There are currently three GPCR plants in existence worldwide. A demonstration-scale plant is currently housed at Eco Logic's head office in Rockwood, Ontario, Canada, where it is being used for treatability testing and engineering development. This unit had been previously housed at a US Army facility where it underwent extensive testing for chemical munitions treatment. A second demonstration-scale plant is located in Japan, where it has been used for regulatory testing for PCB and dioxin waste treatment. Eco Logic's Japanese partners have recently completed construction of a semi-mobile GPCR plant, which will be used for commercial treatment of PCB wastes throughout Japan.

This technology has been accepted as environmentally sound under the Basel Convention's General Technical Guidelines for destroying Persistent Organic Pollutants.

#### 4.4.3 Scale and Time to Treat Stockpile – Not Feasible ✕

Eco Logic facilities to date have processed waste streams with low to medium hydrocarbon and organo-chlorine contamination levels, such as contaminated soils, and this is the continuing projected market for the technology. The Orica HCB waste stockpile has highly concentrated high chlorine content and is a high organics (hydrocarbon) content material.

Plant capacity or size can perhaps best be visualized in terms of the process hydrogen requirement. Hydrogen is consumed not only in the formation of hydrogen chloride but in the addition of up to 4 atoms of hydrogen to every atom of carbon to produce methane. For a plant processing 10 tonnes per day of the Orica HCB waste stockpile, this amounts to approximately 1.1 tonnes per day of hydrogen. An electrolytic hydrogen plant with this capacity consumes about 2.75MW of electricity, or 66,000 kWh of power per day.

This is a large plant. Present Eco Logic operating facilities have hydrogen consumption 300 times smaller so we are looking at a significant scale-up to achieve a practicable treatment rate of 10 tonnes per day, requiring approximately 5 years to



process the Orica HCB waste stockpile. This size of plant may be feasible, probably in multiple units, but there is certainly no such plant in existence.

#### **4.4.4 Pre Treatment and Front End Waste Handling – Not Feasible** x

The Eco Logic process was established with a hydrogen vaporization front end. Trials with Orica's HCB waste stockpile were disappointing and not all of the Chlorinated Hydrocarbons (CHC's) were volatilized. The residual material in the drums had transformed during the soaking process into a hard, not volatile char-like substance that would require a further treatment step. There were many other practical issues related to the use of hydrogen.

A cost effective hydrogen source would need to be identified to make front end treatment feasible and the hydrogen plant constructed nearby. The pretreatment process would need to produce a uniform vapor gas stream of CHC's in hydrogen gas (from a waste that is a mix of polymerized materials, tars, and water-based sludge's), all of which would make pre-treatment of the Orica HCB waste stockpile a very complex process without any certainty that no difficult-to-manage residues would remain.

Safety aspects and the environmental risks associated with heating a large container of explosive and toxic materials at high concentrations in the solid, liquid and gaseous states results in a complex and difficult development design that is likely to encounter significant issues with the permitting process.

The presence of water and other oxygen containing compounds would demand another stage of treatment to prepare the gaseous stream for the subsequent dechlorination step, assuming, as seems likely, that it would not be practicable or acceptable to pre-dry the waste.

The dechlorination process has so far been applied only to wastes with low concentrations of organo-chlorine contaminants and the vaporizing processes used to date would not be applicable to the Orica HCB waste stockpile. Puncturing drums and distributing waste so that vaporization can proceed at a satisfactory pace and without pyrolysis and charring by overheating are aspects yet to be addressed.

From experience, this whole development process would take considerable resources and time, at least 3 years of development work and many uncertain years for the permitting process.

#### **4.4.5 Process Capability to Treat HCB – Not Feasible** x

The technology is not suitable in its present state for treating HCB waste, primarily due to the wide range of melting and boiling points of the compounds present in the waste.

With further development, however, the technology could no doubt be suited to the destruction of the HCB waste. Some preliminary testing on the Orica HCB waste stockpile produced an off-gas with dioxin content 10 times the generally acceptable level. Further processing of the off-gases would have to be considered.



A batch of some 27 drums of Orica's HCB waste stockpile was treated in a trial operation at the former Kwinana plant. The test work showed that significant levels of black tarry material were produced which would cause difficulties within the gas scrubbing system and which showed incomplete destruction of the waste.

Operational process issues which may be encountered in the application of GPCR technology to the treatment of Orica's HCB waste stockpile include:

- Problems in fully vaporizing the waste material prior to dechlorination (98% on test) thus leaving residues requiring further destruction by some other means.
- Severe corrosion potential arising from high temperatures and the presence of HCl gas, as for Geomelt process, but possibly exacerbated by the reducing conditions
- Other potential difficulties with materials of construction such as possible hydrogen – related embrittlement of metals
- Considerable development work required to scale up to the size of plant required for the Orica HCB waste stockpile.

#### 4.4.6 Emissions and Residues from the Process – Not Feasible

x

The major concerns with Gas Phase Chemical Reduction (GPCR) were the demonstrated high dioxin level in stack emissions (0.85-1.59ng/m<sup>3</sup>) compared to the 0.1 ng level required, the resulting solid residues which did not meet landfill criteria (HCB > 2mg/Kg), and the production of "black tarry material" in the scrubbing system.

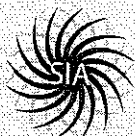
Orica engaged trials for treatment of the HCB waste stockpile at the Kwinana facility and Kvaerner Engineering, who observed the trials, recommended major modifications to the plant – including additional scrubbers, column packing changes, and burner /combustion condition changes.

In addition, there were several residual streams which may be difficult to reprocess and would need further assessment and possible treatment before disposal. There are also the unresolved problems of dealing with the black tarry material formed in the dechlorination process.

The plant at Kwinana did not meet the 0.1 ng (TEQ)/m<sup>3</sup> limit for dioxins/furans during the HCB tests. Eco Logic questioned the accuracy of these results. Eco Logic suggested that more effective scrubbing, changes to gas reticulation rates and changes to auxiliary burner design would enable the process to meet emission criteria.

The main advantage of the Eco Logic process, in theory, is that it avoids the de novo synthesis of dioxins/furans. In practice, dioxin/furans were found in Eco Logic residuals and in the gaseous discharge.



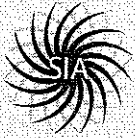


#### 4.4.7 Ability to Permit or License Facility – Not Feasible

x

Feedback from the Western Australian Department of Environmental Protection (Kwinana Branch) has been positive with respect to the technology. They were heavily involved in the permitting process for the original plant. They would be supportive of any other application to permit another Eco Logic plant.

However, it appears unlikely that a new plant would bear very much similarity to the original plant, and that there would be considerable work required with a full Environmental Impact Statement (EIS) to secure a permit and to license such a facility. This process would face significant challenges with no history of either treating large industrial scale volumes of waste or the HCB waste stream successfully.



#### 4.5 Base Catalyzed Dechlorination (BCD)

The BCD process involves treatment of wastes in the presence of a reagent mixture consisting of hydrogen-donor oil, alkali metal hydroxide and a proprietary catalyst. When the mixture is heated to a temperature above 300°C, the reagent produces highly reactive atomic hydrogen. The hydrogen reacts with the waste to remove the toxic constituents and the organochlorine compounds.

The Base-Catalyzed Dechlorination (or Base-Catalyzed Decomposition) (BCD) process was developed to treat halogenated organic compounds, particularly PCBs. The process can involve direct dehalogenation of waste materials, although it is essentially a liquids treatment process. More practically the process can be linked with a pre-treatment step such as thermal desorption which yields a relatively small quantity of a condensed volatile phase for separate treatment.

The BCD process involves the addition of an alkali or alkaline earth metal carbonate, bicarbonate or hydroxide. The proportions added range from 1 to about 20% by weight, the amount required being dependent on the concentration of the halogenated contaminant contained in the medium.

A hydrogen donor compound, such as a paraffin oil solvent, is employed to provide hydrogen for reaction with the halogenated contaminants, if these components are not already present in the contaminated waste. In order to activate these compounds to produce hydrogen ions, a source of carbon must be added, either in solution or in suspension.

The mixture is heated at a temperature and for a time sufficient to totally dehydrate the medium. After dehydration, the medium is further heated at a temperature between 200 and 400°C for a time sufficient to effect reductive decomposition of the halogenated and non-halogenated organic contaminant compounds, typically 0.5 to 2 hours. At this temperature, the catalyst derived from the carbon source facilitates hydrogen transfer from donor compound to the organochlorine compound.

Generally, oxygen will not adversely affect the BCD process and therefore air does not need to be excluded. However, when applied to the decontamination of hydrocarbon fluids, either aliphatic or aromatic, air needs to be excluded in order to prevent ignition of the hydrocarbon at the elevated temperature of the BCD reaction. This is achieved by passing nitrogen gas through the reaction vessel. The treatment is usually carried out as a batch process with all steps completed within a single reactor. Organochlorine Compounds (OCP's) which are contaminated with volatile heavy metals such as arsenic could potentially be treated with the BCD process.

BCD Technologies, a subsidiary of DoloMatrix, operate the BCD process at their facility in Queensland. BCD Technologies also operate the plasma arc process, PLASCON.



#### 4.5.1 Feasibility Status

As a result of the evaluation on all six criteria, it is considered **not-feasible** that the BCD process can be developed in Australia within a reasonable time frame to treat the Orica HCB waste stockpile.

Assessment Criteria	Proven nature of technology	Scale and time to treat the waste	Pre-treatment and front end waste handling	Process Capability to treat HCB	Emissions and residues from the process	Ability to permit or license facility
Technology						
BCD						

#### 4.5.2 Proven Nature of Technology – Feasible ✓

DoloMatrix has a waste treatment facility in Brisbane, Queensland for treating halogenated wastes using the BCD process.

This technology has been accepted as environmentally sound under the Basel Convention's General Technical Guidelines for destroying Persistent Organic Pollutants (POP's).

BCD should be capable of treating wastes with a high POP concentration, with demonstrated applicability to wastes with a PCB content of above 30%.

#### 4.5.3 Scale and Time to Treat Stockpile – Not Feasible ✗

The scale of the BCD facility is too small to allow the waste destruction program to be completed in a satisfactory timeframe.

BCD can process as much as 2,600 gallons of PCB contaminated oil per batch of about 10 tonnes, with a capability of treating two to four batches per day. This is based on a chlorine equivalent concentration several orders of magnitude less than that of the Orica HCB waste stockpile.

Considering the size of the Orica HCB waste stockpile and the anticipated additional time required to process this type of waste stream, it would require something like 10 of these plants operating at the current capacity about 5 years to treat the Orica Botany HCB waste stockpile.

#### 4.5.4 Pre Treatment and Front End Waste Handling – Not Feasible ✗

The BCD process is used to mainly treat PCB contaminated transformer oils. Producing the liquid feed required for this process would require considerable pretreatment of the Orica HCB waste, a problem already raised for several other processes mentioned.



The HCB waste stream contains a significant amount of polymerized materials, tars, sludge's and other residues with widely ranging volatiles and temperature sensitivities, which would make thermal desorption treatment difficult. The process would need considerable process and engineering development to make it suitable for the treatment of this waste stream.

The Orica HCB wastes are highly variable as they have already been consolidated. Inorganic contaminants (such as mercury, tin and copper) may be present in varying quantities in the waste mixture and need consideration. This may require separation and treatment of the HCB residue.

#### **4.5.5 Process Capability to Treat HCB – Not Feasible**

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HCB waste presents particular difficulties for treatment by the BCD process, and preliminary tests carried out with the BCD technology have been unsuccessful in treating the waste. Particular issues include:

- Test work with HCB waste has shown that the nature of the material, containing polymerized materials, tars, sludge's and other process residues, makes treatment by thermal desorption extremely difficult if not impracticable.
- The nature of the HCB waste makes it very difficult to feed the waste safely into the BCD process. Particular issues include: it is highly acidic, it is not a liquid as it contains predominantly solids and sludge's, and it contains moisture.
- Some of the HCB waste is highly concentrated in terms of its chlorine content, and a at least tenfold dilution would be required to have the waste in a form that would be acceptable to the BCD treatment process as presently developed.

This would involve dilution of the TD condensate with other waste oil prior to such treatment, greatly increasing the size of the required BCD treatment plant.

Trials on dissolving HCB waste in a suitable solvent or oil have been unsuccessful to date. Such a process, solvent extraction direct from the waste, would be far simpler and more direct if it could be developed, however a first step might need to be the water slurry process with which Orica has experimented and had some degree of success. This avoids the need for multiple stages of extraction and solvent rinsing, to render the solid residues sufficiently clean for disposal or recycle. Solvent extraction from the slurry would then require selection of a suitable water immiscible solvent, possibly even more difficult and uncertain than what has already been attempted by way of solvent testing to date.

#### **4.5.6 Emissions and Residues from the Process – Not Feasible**

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The disposal of residual materials is further complicated by their partial contamination, requiring further treatment before they are suitable for safe disposal.

In the past, it has been reported that the BCD process was unable to treat high-concentration wastes because of the accumulation of sodium salt. However, the



Company has indicated that the build-up of salt within the reactor simply limits the amount of waste that can be fed to the reactor and that this problem does not appear unsolvable.

Air emissions are expected to be relatively minor. The potential to form PCDD's and PCDF's during the BCD process is relatively low. However, it has been noted that PCDD's can be formed from chlorophenols under alkaline conditions at temperatures as low as 150°C. A catalytic thermal oxidizer or afterburner would have to be considered but it is more likely that for the small volumes involved, a scrubber and return of contaminants to the process would be the better solution. In addition, BCD plants are equipped with activated carbon traps to minimize releases of volatile organics in gaseous emissions.

Other residues produced during the BCD reaction include sludge containing primarily water, salt, unused hydrogen-donor oil and carbon residue. The vendor claims that the carbon residue is inert and non-toxic. A slurry residue may also be formed, but this is dependent on the oil utilized as a hydrogen donor in the process. If this is the case, the sludge may be disposed of as a fuel in a cement kiln. If more refined oils are used, these may be removed from the sludge by gravity or centrifugal separation. The oils can then be reused and the remaining sludge can be further treated or sent to a landfill for disposal.

Since the BCD process involves stripping chlorine from the waste, the treatment process may result in an increased concentration of lower-chlorinated compounds. This can be of potential concern in the treatment of PCDD's and PCDF's, where the lower-chlorinated compounds are more toxic than the higher-chlorinated compounds. It is therefore important that the process be appropriately monitored to ensure that the reaction continues to completion.

It is also possible that large quantities of scrubber water may be generated, forming a significant waste stream with contaminants requiring further treatment.

Many of these problems can be resolved by developing treatment processes to deal with them. However, all such aspects lower the potential for the BCD process to meet the necessary requirements when it comes to the necessary approvals and a realistic time frame to treat the Orica HCB waste stockpile.

#### **4.5.7 Ability to Permit or License Facility – Not Feasible**

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BCD is operating under a Queensland EPA license as an Environmentally Relevant Activity and is licensed as a waste treatment and storage facility. BCD monitors their emissions quarterly – Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD) and heavy metals.

Discussions with the Queensland EPA noted that, though theoretically BCD technology can treat HCB's, the Queensland EPA would need to be convinced that trials should be allowed on the current site. Should trials be proposed, the facility would need to comply with the National Protocols for the Treatment of Hazardous Wastes.



BCD would also need to undertake a full EIS process. This process is estimated to take up to two years. As no proven capability to treat industrial scale volumes of HCB exists, it seems unlikely that a permit or license to operate would be granted.



#### 4.6 High Temperature Incineration (HTI)

High Temperature Incineration is generally acknowledged as the best available technology for the destruction of most hazardous and toxic waste in heterogenous form.

The Basel Convention's General Technical Guidelines list HTI as one of the acceptable technology types for the destruction and irreversible transformation of persistent organic pollutants including HCB waste.

There are a number of small HTI facilities operating in Australia designed to handle specific wastes such as hospital and quarantine wastes and waste from resource based industries. No HTI facility in Australia is in anyway capable of currently treating large scale industrial stockpiles such as the Orica HCB waste stockpile.

Within the hazardous waste industry, incineration is the controlled high temperature destruction of combustible material. During incineration the oxygen in air is used to convert or oxidize wastes to simple gases and solids.

Effective incineration requires:

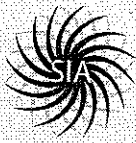
1. sufficient temperature
2. sufficient residence time at that temperature
3. adequate turbulence
4. excess oxygen

*Temperature:* The higher the temperature, the more effective the incineration and the lower the possibility of any unburnt waste being released or hazardous by-product being formed. Temperatures of 900 - 1100°C will destruct hydrocarbon waste. Temperatures of 1100 to 1300°C are needed for chlorinated solvents and other wastes which are difficult to incinerate. Temperatures over 1200°C are needed for bond break up. At temperatures below 900°C hazardous by products can be formed these include dioxins and dibenzofurans. At temperatures below 800°C incomplete combustion is likely to occur and soot formation will result.

*Residence time:* It is necessary to hold the waste at high temperatures for sufficient time to ensure destruction. The longer the material is held at high temperature, the more likely it is to be destroyed. It is generally acknowledged that an adequate residence time for gaseous substances is a minimum of 2 seconds at 1100°C and 1 second at 1200°C, the limits in force in several states for biomedical waste destruction. For solids the residence time could be minutes or even hours.

*Turbulence:* This is a requirement in order to ensure that the waste and the combustion air are well mixed, that the combustion reactions proceed adequately and that all combustibles have sufficient oxygen for complete combustion and sufficient time at temperature, avoiding short-circuiting.

*Excess oxygen:* This must be present to ensure that the oxidative processes predominate and the pyrolytic processes are minimized. Generally, oxygen should be



present at 50-100% higher concentration than to the stoichiometric requirement for decomposition of the waste.

Gases leave the afterburner at 1100 to 1200°C - there is considerable potential for heat recovery. Recovered heat can be used to reheat a wet plume, so making it invisible. Recovered heat can be used for power generation, partly reclaiming fuel costs. Re-formation of dioxins is the big problem associated with heat recovery, corrosion another.

Combustion gases contain some unburnt solids and gases, and other particulates such as fly ash. They also contain acid gases and other polluting gaseous compounds which all require removal down to very low levels to meet emission standards. To achieve this, the gases must be cooled. The cooled cleaned gases do not possess the kinetic energy required to pass up the stack for atmospheric discharge, consequently an induced draught fan and/or reheat facilities are usually employed.

Comprehensive plant condition monitoring covers temperature measurement at every critical point throughout the system. Measurement of oxygen levels and measurement of main discharge consent parameters are usually recorded on a real time basis.

This is essential for:

- Operating plant at peak efficiency, and maximizing return on investment.
- Providing proof of compliance with conditions of authorization.
- Providing customers with evidence of satisfactory waste disposal.

#### 4.6.1 Feasibility Status

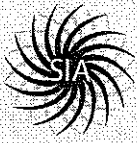
As a result of the evaluation on all six criteria, it is considered **not-feasible** that the HTI process can be developed in Australia within a reasonable time frame to treat the Orica HCB waste stockpile.

Assessment Criteria	Proven nature of technology	Scale and time to treat the waste	Pre-treatment and front end waste handling	Process Capability to treat HCB	Emissions and residues from the process	Ability to permit or license facility
Technology	HTI					

#### 4.6.2 Proven Nature of Technology – Feasible ✓

There are hundreds of HTI facilities operating to dispose of hazardous waste to acceptable levels throughout Asia, Europe and North America. HTI is the most frequently used technology for the disposal of hazardous wastes.





In Australia, there are a number of small HTI facilities in operation including Tox Free, located in Western Australia, which provides high temperature incineration at Port Headland.

Prior to the environment and health industry policy changes of the nineties, there were hundreds of hospital-based medical waste incinerators in Australia. These were rapidly replaced by centralized incinerators with a variety of emission control improvements. As environmental concerns and legislation have raised the bar with respect to emissions, many have closed rather than expend the money needed to upgrade. Alternative technologies have taken on some of this waste stream but there are several bio-medical waste (BMW) incinerators still in operation. These HTI's all have a measure of emission control but none are capable of meeting the environmental standards required of new plant.

Such incinerators exist in Perth, Sydney and Brisbane. Their capacities range from 350kg/h to 1.5 tonnes/h. All except the smallest unit, at the Perth facility, are fully occupied in handling biomedical waste. None are suitable for handling the Orica HCB waste stockpile whereas there are HTI's in Europe that do have this capacity. The problem is not only in throughput capacity but in the size of objects the incinerators can handle and the degree of emission control facility installed.

The European plants employ rotary kiln type furnaces which can generally take objects up to the size of a 200 litre steel drum, whereas the Australian BMW incinerators are all solid stepped or moving hearth type and are very limited in the size of object they can handle. The Australian furnaces operate at the required temperatures and could certainly burn the HCB waste, but not in large parcels and not in sufficient quantities, and it is unlikely they would be available as they are largely occupied in burning BMW.

The Tox Free HTI is a rotary kiln type and has successfully treated PCB's, Organochlorine pesticides, drilling waste and hydrocarbon-contaminated wastes.

#### 4.6.3 Scale and Time to Treat Stockpile – Not Feasible

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As indicated all current HTI facilities in Australia are small, 350kg/h to 1.5 tonnes/h, mainly for biomedical and quarantine wastes. One unit has a rated capacity of 2 tonnes per hour and that is of soil (damp and contaminated with hydrocarbons). Considering the heat capacity of this furnace it could handle about 60 to 90kg/h of HCB material, say 1.5 to 2 tonnes per day. To provide retention and contact/reaction time the HCB waste would need to be blended with other, low energy, low chlorine, waste, such as contaminated soil. The solid product would be a decontaminated soil suitable for use at a secure landfill as cover material, for example. On this basis this furnace might be able to destroy the 16,000 tonnes HCB waste stream in 30 years. At this stage this facility does not have the sort of secure waste storage and handling system, nor the emission controls, nor the license, required for destruction of the HCB waste.

To dispose of the Orica HCB waste stockpile in 3 years requires a kiln type incinerator that can handle about 18 tonnes/day of HCB waste. Any such facility would need a highly automated and secure storage, handling and pre-blending plant.



It would also require a very extensive emission control system to handle emissions from incineration of this highly chlorinated waste, much more than for a soil remediation unit or even for a hospital waste incinerator. Facilities of this type are used in several European countries for such wastes. At its smallest the plant would need to have about 10 times the capacity of the existing Tox Free incinerator. Putting this in perspective, such a facility would have capacity to incinerate all of Australia's biomedical and quarantine waste. This is not to suggest that a single central incinerator could be contemplated for a country the size of Australia, the logistics alone, including refrigerated and high security transport, would preclude such considerations.

In making these estimates consideration has been given to the energy content of the HCB waste and to its chlorine content. The former dictates the size of the furnace (kiln), the latter influences the extent of the emission control system. Furnace size dictates the volumetric throughput and hence the dilution factor or the waste blending ratio required for incineration of the high energy HCB waste.

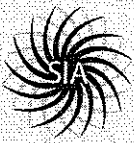
The time frame to develop, permit, construct and commission a facility, with best practice front end waste handling and a full emission control train at the back end, sufficient to comply with Australian standards, to treat the HCB waste from the Orica Botany site, would take at least six years and most likely more, depending on the scale of the facility and the location, and on the permitting authority. This excludes the time required to treat the waste depending on the proposed scale of such a facility.

#### 4.6.4 Pre Treatment and Front End Waste Handling – Not Feasible x

Even in much larger kilns overseas waste streams of this nature must be broken down or pre-blended to reduce heat release surges and acid gas generation rates to manageable proportions. This considerably reduces the capacity to handle high heating value and high chlorine content wastes and the usual practise is to make up the volumetric capacity of the kiln (mass and volumetric throughput) by blending or co-feeding with low heating value, less reactive and lower chlorine content wastes. The quantity required depends on energy and chlorine content but is likely to be in the order of 160,000 TPA.

It is certain there are insufficient quantities of such wastes requiring thermal destruction in Australia. Stockpiles and continuing arisings of industrial wastes, some chemical industry but mainly mining, and soils from contaminated sites, are generally being effectively managed by on-site treatments and re-processing options. Hospital and quarantine wastes and perhaps some highly contaminated soils might qualify, they are certainly sufficiently lower in energy and chlorine content. The approximate quantities and present destinations of these wastes as generated throughout the entire country are –

- 30,000 TPA biomedical waste (about 35% of which is incinerated and the remainder chemically or thermally disinfected and disposed to landfill)
- 10,000 TPA sea-port quarantine waste (some of which is incinerated and the rest landfilled)
- 35,000 TPA international airport quarantine waste (mostly going to secure landfill)



Assuming that any single facility would be located near a major city so as to be able to command say 25% of this waste, it would only amount to about 20,000 TPA, plus whatever contaminated soils might be available. This is obviously insufficient and blending with less or non-contaminated wastes, or other 'raw materials' would have to be considered.

The facility for storage, handling and blending such waste streams would have limited life, there being little or no further waste streams requiring such, once the Orica waste has been processed. The facility would then be redundant. Siting and licensing such a facility would be a long and uncertain process.

#### **4.6.5 Process Capability to Treat HCB – Feasible** ✓

HTI has the capability to treat HCB wastes. Currently there are no known HTI facilities in Australia capable of treating HCB in their current license operating condition. Tox Free are not treating any schedule X substances, their license conditions allow them to treat 5% halons via the destruction process and they mainly use this process for the treatment of dry cleaning wastes. They noted during the consultations phase that, given the appropriate commercial impetus, they would look at relocating the HTI to Karratha and apply for permits to treat schedule X substances.

However, besides the consideration of waste blending and therefore the need to handle a much larger feed volume, there would also be a requirement for addition of extensive waste preparation and flue gas treatment facilities.

#### **4.6.6 Emissions and Residues from the Process – Feasible** ✓

All Incinerators produce emissions, these falls into two basic categories.

- Gas phase emissions
- Particulate emissions

Gas phase emissions from hazardous waste incinerators comprise carbon dioxide, water, excess air, oxides of nitrogen, oxides of sulphur and phosphorous and halogen acids gases.

The major problem from an atmospheric emissions viewpoint is the acidic gases: Sulphur dioxide and hydrochloric acid. These are the products of incineration of sulphur-containing and chlorinated compounds respectively. Both gases are water soluble and can thus be removed from the effluent gas stream using wet scrubbers - a number of strategies exist to accomplish this. On dissolving, these gases produce an acidic solution which needs to be neutralized normally prior to sewer discharge or further treatment. This neutralisation step is usually made easier by using alkaline solutions in the scrubber water. This has the further advantage of increasing the scrubbing efficiency of such a system.

Particulate emissions are very different in nature, they comprise solid particles of either unburnt feed materials, organic, or ash, inorganic mineral matter formed in the incinerator and can be removed by a number of wet or dry processes.



The vast majority of incinerable wastes are organic in nature, i.e. they contain carbon. Other elements present in organic wastes are hydrogen, oxygen, nitrogen, sulphur, phosphorus and chlorine. During incineration the formation of  $\text{CO}_2$ ,  $\text{H}_2\text{O}$ ,  $\text{SO}_x$ ,  $\text{PO}_x$ , HF, HCl, HBr,  $\text{I}_2$  occurs. Also present are metal oxides and traces of unburnt waste. The solid products of incineration can comprise metals, oxides and non-combustibles. The key to effective incineration is control.

In Australia no HTI operation has emission control equipment that compares with best practice European standards for the treatment of gas or particulate emissions. The Tox Free facility in WA has an EPA license for the site which specifies minimum temperatures for certain types of waste. Supplementary fuel is automatically added to the kiln on triggering of the alarm to maintain kiln temperature. Continuous oxygen, carbon monoxide and carbon dioxide monitoring also occurs in real time. This information is recorded in a Programmable Logic Controller (PLC).

A Venturi scrubber efficiently removes particles and also performs the rapid quenching of the flue gas required to restrict/prevent dioxin formation and prepares the gas stream for downstream alkali scrubbing. The venturi provides intimate gas/water contact in order to wash out the fine solid particles carried over from the furnace and is followed by a cyclone separator to remove the bulk of the water from the gas stream.

The quench water is dosed with caustic soda prior to injection to maintain pH above 8 to enhance removal of acid gases and reduce corrosion. The quenched temperature is below the boiling point of water so the feed to the cyclone is a gas / liquid / solids mixture. Water and solids are separated from the gas and the resultant slurry is discharged from the bottom of the cyclone via a counter-weighted door.

The water saturated waste gas flows out of the top of the cyclone at a temperature of approximately 60-70°C and through an induced draft (ID) fan to the exhaust stack and then to atmosphere. The ID fan provides the driving force for moving the combustion gases through the kiln and waste gas handling system. Flow through the fan is controlled by adjusting a damper on the venturi to maintain the fan motor current at 45 Amps.

These emission controls are basic and will require considerable improvement to meet the required standards. Venturi scrubbers are highly efficient (98 to 99%) for particulates removal but are of very low efficiency (70%) with respect to acid gas removal. They will need to be backed up with two stages of packed tower scrubbers for high efficiency acid gas removal (99%) to achieve not only the low acid gas limits of 5 to 10mg/Nm<sup>3</sup> but also to improve dioxins removal ahead of the activated carbon filters needed to achieve the 0.1ng/Nm<sup>3</sup> iTEQ requirement.

There is one other requirement that appears not to be included with the existing Tox Free incinerator: a second stage combustion chamber. This is a must, running the kiln at the required afterburner temperature of 1100 to 1200°C produces fly-ash and slagging problems, generates more NO<sub>x</sub> and makes steady temperature maintenance impossible. In the case of a rotary kiln, it will mean more support fuel



consumption because it is not so easy to maintain sub-stoichiometric combustion in the first stage and therefore some of the heat value of the waste is squandered.

The bottom ash product is suitable for general landfill disposal but it may also be used in low grade concrete products. Fly ash contained in the venturi scrubber sludge and exhausted activated carbon contains dioxins and should be recycled to the incinerator for toxics destruction, with some agglomeration pre-treatment. Liquid chemical effluent from the tower scrubbers is usually acceptable to sewer, but in the case where sewer access is not available, this stream will require on-site wastewater treatment and the resulting sludge will need to be recycled to the incinerator.

Instrumentation and control of the entire system together with on-line measurement of operating parameters  $CO_2$ ,  $CO$ ,  $O_2$ , and emission contaminants such as opacity (particulates),  $NO_x$ ,  $SO_x$ ,  $HCl$ ,  $VOC$  and  $TOC$ , will be necessary.

#### **4.6.7 Ability to Permit or License Facility – Not Feasible**

x

If HCB wastes were to be treated, any new or expanded HTI facility would need to undertake a full Environmental Impact Statement (EIS) process for a newly developed industrial scale facility. This process would take considerable time and face significant hurdles.

There have been numerous attempts over the past three decades to establish a major HTI facility in Australia, however all of these attempts have failed due to permitting difficulties or failure to secure commercial waste contracts. The likelihood of a new facility being permitted within a reasonable time frame to treat the Orica HCB waste stockpile is considered not feasible.



#### 4.7 Ausmelt

Ausmelt Technology has been developed for applications in the non-ferrous, ferrous and waste treatment industries. The Technology evolved from work commenced in the CSIRO during the 1970s, and was first commercialised in 1978 at Associated Tin Smelters in Sydney, Australia, in an application processing slag produced from smelting tin concentrates in reverberatory furnaces.

The technology is based on the top entry submerged lance system, delivering combustion gases, fuel and process air below the surface of a liquid slag bath. The air may be oxygen-enriched to improve process efficiency. The turbulence achieved by injecting gases down the Ausmelt lance promotes rapid chemical reactions and excellent heat transfer. These traditional process-engineering goals have attendant benefits in reduced fuel requirement, operating costs, furnace size, and capital cost, and increased plant throughput and diversity of feed materials which can be processed economically.

The process is designed to:

- treat a wide range of wastes (waste minimization);
- destroy toxic organic and inorganic compounds, including organo – halides;
- recover valuable components as marketable products;
- produce a solid product that is clean, safe and useable as a raw input for building materials.

Organic compounds are completely broken down and catalytic oxidation occurs through iron oxide dissolved as ferric oxide in the slag. The ferric oxide is regenerated by oxygen injected down the top submerged lance system. The other slag components ( $\text{SiO}_2$ ,  $\text{CaO}$ ,  $\text{Al}_2\text{O}_3$ ) act as the solvent phase and are in a suitable composition range to ensure a fully liquid and fluid slag at reactor temperature.

The second oxidation reaction is the post combustion of CO above the bath with air and/or oxygen injected down the shroud pipe of the lance. This occurs in the energetic fountain cascade of liquid slag above the bath, which provides suitable oxidising conditions (time, temperature and turbulence again) for the reaction to go to completion, and for the energy released to be recovered to the bath.

##### 4.7.1 Feasibility Status

As a result of the evaluation on all six criteria, it is considered **not-feasible** that the Ausmelt process can be developed in Australia within a reasonable time frame to treat the Orica HCB waste stockpile.

Assessment Criteria	Proven nature of technology	Scale and time to treat the waste	Pre-treatment and front end waste handling	Process Capability to treat HCB	Emissions and residues from the process	Ability to permit or license facility
Technology	<b>AUSMELT</b>					



#### 4.7.2 Proven Nature of Technology – Feasible ✓

Ausmelt Technology has been commercialised in copper, lead, tin, zinc plant iron residues and precious metals and for recovery of metal values from metallurgical process residues. The 50,000 tonne per annum Whyalla plant had been used to develop an iron making process and has more recently been used to process zinc residues, and has been considered for processing various other metallurgical by-products (wastes).

This facility has recently closed as a result of problems in the metallurgical feedstock business. It has been stated that this is due to the recent drop in metals prices and the marginal nature of the metals recovery process.

This range of applications and uses for the technology result from its ability to be operated and controlled under a wide range of conditions, from strongly oxidizing, through neutral, to strongly reducing. Operating temperatures range from 900°C (lead) to 1400°C (iron).

When the Ausmelt facility was commercially available it was operating on, or proposed for, several waste streams with similarities to the Orica HCB waste, such as high halogen content solid wastes, chlorinated solvents, shredded tires (with the steel), contaminated solid wastes, including concrete, ceramic and soil, waste oils and bitumen like tank and column bottoms from the oil industry.

As an example, there is a plant at Portland, Victoria, designed to manage the problem of Spent Potlining (SPL) which has long been a disposal problem for the aluminium industry (the plant is not operational at this stage). SPL comes from replacement of the lining of cells used to produce aluminium metal by electrolyzing alumina dissolved in a cryolite electrolyte. The pot lining comprises carbon cathode material and refractory insulation and deteriorates over time as a result of reaction with and dissolution by the electrolyte. The primary toxic contaminants are cyanide and fluoride.

SPL is a prescribed hazardous waste and its disposal is now proscribed in most countries. The Ausmelt Technology has been applied successfully to the recycling of the fluoride in the aluminium smelter process, whereby the SPL is converted under high temperature, oxidising conditions to generate a hydrogen fluoride containing gas stream and an inert slag. Cyanide is decomposed while fluorine is recovered from the SPL as HF gas and is concentrated and used to manufacture  $\text{AlF}_3$  for recycle to the aluminium smelter.

The Ausmelt process is robust and flexible and can treat other materials such as waste anode carbon and floor sweepings, metal concentrates, metal process residues, scrap and waste fuels, oil, gas and solids. The operating furnace has a large energy and mass content and its operation is therefore very stable. The essential destruction processes take place within the molten slag bath and are not subject to uncontrolled emission spikes like HTI furnaces.

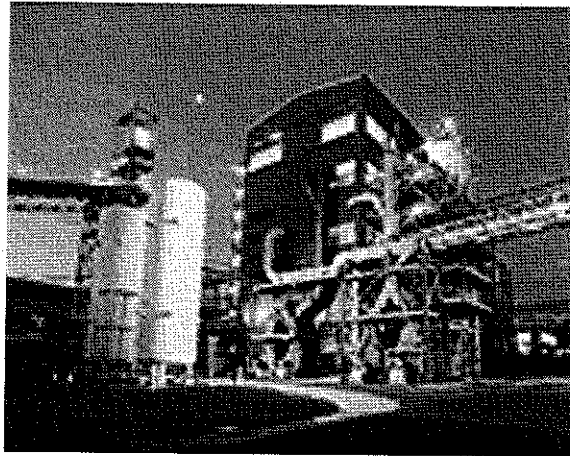


Figure 6 - Ausmelt Plant in Portland, Victoria

#### 4.7.3 Scale and Time to Treat Stockpile – Not Feasible

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There is little doubt the molten bath technology can be provided at a scale suited to the destruction of the Orica HCB waste.

The now closed Whyalla plant would have been the most suitable Australian plant to treat the Orica HCB waste stockpile. This is because it is the only plant owned by Ausmelt Global EnviroMetal Technologies and as such Ausmelt would have been in a position to have a commercial discussion with Orica.

Ausmelt have indicated the development of the application, employing existing pilot facilities to establish operating parameters associated with the destruction of a highly volatile semi-solid organic waste stream can be established. From here, the development of the pre-treatment and front end handling would be as follows:

- 3 months for a pre-feasibility study and concept design, then;
- 6 months for detailed design and drawings, then;
- 9 months to construct and undertake commissioning trials (assuming the placement of orders for long lead time items during the detail design phase)

In parallel with this pre-treatment design, additional off-gas treatment could be designed and the permitting process could be advancing.

A period of 18 months has been assumed for permitting of the plant. This is in addition to the permitting effort taken in the pre-treatment design and construction phase, that is, 18 months. It is anticipated that completion of the destruction of 16,000 tonnes of the waste could be accomplished in a further 3 years and this allows only for a 10% utilization of the reactor fuel and reductant requirement as HCB waste.

In summary, the steps involved would be:

- a) Orica and Ausmelt start discussions. Assuming a path forward can be agreed (4 months)





- b) Design and development of possible Pre-treatment and front end handling system (18 months)
- c) Permitting and approvals: assuming no serious community pressures and delays (18 months in addition to stage (b) time)
- d) Orica and Ausmelt discuss, agree and sign all commercial agreements (4 months) assuming some discussions during stage (c)
- e) Inter-jurisdictional approval to ship waste from NSW to SA (timing unknown)
- f) Design, procure and construct any additional emission control equipment (happens in parallel with stage (b))
- g) Commissioning (12 months)
- h) Treat all HCB waste (3 years)

Therefore, if the Whyalla plant was in operation the best case estimate for time required to treat the Orica HCB waste would be approximately 7.5 years not including stage (e). In consideration of the fact that the Whyalla plant has recently been closed there would likely be a range of commercial and operational issues that would need to be addressed before proceeding. It would seem unlikely that the facility would be re-opened to process the Orica HCB waste on its own. This would not meet the timing threshold under the feasibility assessment, of 5 years.

#### **4.7.4 Pre Treatment and Front End Waste Handling – Not Feasible** ×

Ausmelt have stated they would undertake whole drum shredding immediately preceding furnace feeding into the process. However considering the nature of the Orica HCB stockpile and the heterogeneity of the waste stream, detailed analysis, development and trials would need to be undertaken before any process can be considered successful.

During analysis of the waste stream Orica have found heavy agglomeration of the HCB material. This did not pose a significant problem with Geomelt as the waste was blended with soil in the pre-treatment process, however this could cause considerable issues with any shredding processes being considered.

It is clear that a significant development stage needs to occur before front end waste handling can be considered feasible for the Ausmelt process.

#### **4.7.5 Process Capability to Treat HCB – Feasible** ✓

In terms of wastes with high halogen content, the Portland (Victoria) smelter, with capacity for reprocessing 12 000 tpa of the SPL prescribed waste from the aluminium smelter, will have similar off-gas treatment and materials of construction issues. In that process the toxic components are destroyed and fluoride in the feed is captured as aluminium fluoride for recycling to the aluminium electrolytic smelting process.

The Whyalla plant has the standard Ausmelt quench cooling step aimed at preventing dioxin re-formation, followed by bag filters for particulates removal and alkali wet scrubbing for acid gas removal. This has achieved emission levels better than the stringent European emission standards.



If required, a further step in the off-gas train could include reheat and activated carbon filtration, the final capture system required at most other destructors handling wastes with high organo-chlorine content.

To date the Ausmelt process has not been applied to HCB waste and there have been no trials.

#### **4.7.6 Emissions and Residues from the Process – Feasible** ✓

Emission controls for the Ausmelt process are similar to those for HTI. The off-gas stream is water quenched, thus avoiding re-forming of dioxins which is promoted by slow cooling through the de Novo synthesis region of 250 to 450°C in the presence of high surface catalyzing solid particle. The next step is a fabric filter where particulate matter is removed and this is followed by wet alkali gas scrubbing for removal of acid gases, converting them to neutral salts such as calcium and sodium chloride. This treatment train, if required, could be followed by a reheating step and activated carbon filtration for a final dioxin and organics removal.

Another possibility would be to check the gas cooling at a slightly elevated temperature (approximately 180°C) at which temperature it could be reacted with solid lime and powdered activated carbon ahead of a bag filter. The filter would thus be removing fly ash and the spent additives with adsorbed and neutralized acid gases and dioxins all at the same time. Most of these solid residues would then be further destroyed or 'remediated' by recycle to the furnace.

This is all available technology and much is already used in the Ausmelt process as applied to various metallurgical processes.

The only solid residue from the standard process is the solidified melt 'product'

#### **4.7.7 Ability to Permit or License Facility – Not Feasible** ✕

Ausmelt holds licenses issued by the relevant state environmental protection authorities for all operating facilities. These licenses specify limits and regulate the management of discharges to the air and storm water run-off associated with the operation of their facilities as well as those relating to the storage of hazardous materials.

The EPA license to allow operation of the AusIron Demonstration Plant at Whyalla was renewed in order to allow processing of zinc residues and the plant has been exhaustively tested for emissions. There have been no known breaches of the license conditions.

The main risk to permitting is the unproven nature of treating large scale volumes of HCB and uncertainties regarding the process. The facility would be considered a high permitting risk and therefore not feasible.



#### 4.8 PLASCON

The PLASCON process was developed in Australia by the CSIRO and a private firm in the late 1980's. In this process, an arc of ionized argon gas at 15,000°C is projected into a reaction zone at 5,000°C. The waste is injected into the stream and pyrolysis occurs within about 20 milliseconds, splitting the compounds into atoms and ions. The stream of gas exits the flight tube now at about 2,000°C and is rapidly quenched to near ambient temperatures to prevent recombination into complex molecules. The gas stream is scrubbed to remove particulates and acid gases and the remainder, mainly combustible CO, is flared.

As a demonstration of its capacity to destroy organochlorine compounds and produce acceptable emissions, trials on a mixture of 34% chlorophenols, 47% phenoxies and 19% toluene resulted in very low level of toxic stack gas emissions. The chlorophenols were about 1mg/m<sup>3</sup> and dioxins/furans 0.006 - 0.009ng/m<sup>3</sup>, less than one tenth the limits enacted in Germany in 1990 for incinerator emissions of 0.1ng/m<sup>3</sup>.

Plasma arc systems can be linked with thermal desorption to treat the organic components of OCP wastes contaminated with arsenic, however the remaining inorganic component requires further separate treatment. The PLASCON process can be used to destroy any liquid or gaseous molecular waste, but cannot directly treat solids. However, many applications involving solid waste such as the remediation of contaminated soils are effectively addressed by the utilization of compatible "front-end" technologies. As an example, thermal desorption is being used to evaporate and condense liquid concentrate from solid wastes such as electric power industry equipment, condensers, circuit breakers, etc. Solvent extraction can also be applied in specific cases to treat contaminated solid waste.

The process is ideally suited to the destruction of concentrated forms of halogenated organic waste. Nufarm Chemicals in Melbourne have been operating two such units for destruction of organo-chlorine by-products and process residues for about fifteen years.

There are several PLASCON facilities operating to destroy similar chemical wastes.

The PLASCON plant in Queensland is for destruction of medium to high level PCB waste oil and some other organo-chlorine wastes, and to detoxify the electrical equipment mentioned above.

PLASCON are well advanced with the installation of another unit at the Chemsal Laverton North site in Melbourne, not far from the two units at Nufarm Chemicals. There is a unit in Mexico, relocated recently from the UK, with a possible second unit to be provided shortly, and there are four more units operating in Japan.

The process requires a liquid feed and so for a heterogeneous solid waste there is required up-stream processing including thermal desorption and oil vapor condensation as provided on existing facilities for oil contaminated items such as electrical transformers, switchgear and condensers.



The PLASCON unit is a full size single train single tube in-flight plasma destructor, with a capacity of 1 tonne a day depending chiefly on fuel value or heat release capacity of the reactants.

For the Orica HCB waste quantities involved, a facility comprising 10 to 12 of these units would be required, plus several large desorbers. There are multi-unit PLASCON facilities in existence, including the Nufarm twin-unit plant and a four-unit plant in Japan.

The acid gas scrubber and flare which remove chiefly the hydrochloric acid gas and the carbon monoxide generated in the destruction process would also be needed for each unit or for multiple units.

There is a question about the desorption step as applied to the Orica HCB waste stockpile which contains a variety of other by-products, some of which have been found to decompose rather than vaporize, generating another solid waste in the form of a char or tar-like residue still contaminated to a lesser degree with HCB or other hazardous contaminant.

Two trials have been conducted on Orica HCB waste stockpile, but only on small samples of 12 kg or so, and without very complete reporting according to Orica. PLASCON indicated that they would have liked to have had larger samples so as to address some of the issues associated with the desorption step and possible residues. However, Orica were not satisfied that a suitable front end could be developed in view of the difficulties already experienced in producing a liquid feed from their waste stream for other processes.

It would be expected that a reprocessing step could be devised for any such residues. The quantities would be very much smaller than the original waste volume and any contaminants of concern would be readily treatable.

The technology is certainly well suited to destruction of high heating value, highly chlorinated, concentrated waste and should certainly function well for HCB waste, provided a clear solid free fluid stream can be prepared.

#### 4.8.1 Feasibility Status

As a result of the evaluation on all six criteria, it is considered **not-feasible** that the PLASCON process can be developed in Australia within a reasonable time frame to treat the Orica HCB waste stockpile.

Assessment Criteria	Proven nature of technology	Scale and time to treat the waste	Pre-treatment and front end waste handling	Process Capability to treat HCB	Emissions and residues from the process	Ability to permit or license facility
Technology						
<b>PLASCON</b>						



#### 4.8.2 Proven Nature of Technology – Feasible ✓

Both DoloMatrix in Queensland and Nufarm in Melbourne have operating PLASCON facilities. Nufarm's facility has a capacity of 1 tonne/day and is used to treat the liquid waste streams from organo-chlorine pesticide manufacturing. It is not available for the destruction of hazardous waste from external sources. DoloMatrix's facility also has a capacity of up to 1tonne/day. The DoloMatrix Queensland plant treats mainly PCB contaminated oil for the electric power industry.

Four plants in Japan and one in Mexico treat a variety of organo-chlorine waste streams. A further plant is under construction for Chemsal in Melbourne. This plant will be very close to the Nufarm site in Laverton North. In the first instance, it will handle PCB contaminated waste oil and solvents and other organic wastes accumulated over several years in and around Melbourne.

A criticism leveled at the technology has been that the units are far too small to be considered for the Orica HCB waste stockpile. PLASCON consider the present design and size of their unit to be optimal, and multiple unit installations are necessary for larger quantities. This could be regarded as an issue as the more units required, the more maintenance likely. Experience suggests however that, in the case of plasma, larger units actually require more downtime due to the load on the electrodes; they also require much more exotic materials for the temperatures involved and due to the difficulties or inefficiencies of cooling.

#### 4.8.3 Scale and Time to Treat Stockpile – Not Feasible ✕

A 150 kW PLASCON unit can process 0.3 to 1.0 tonnes per day. As the waste is required in a liquid form it will require significant time to develop a pre-treatment process for the Orica HCB waste stockpile.

A project life of about 10 years or greater is likely. That is, from development, permitting, construction and treatment through to closure.

#### 4.8.4 Pre Treatment and Front End Waste Handling – Not Feasible ✕

The PLASCON process requires the waste stream to be treated in a liquid phase. HCB wastes may be treated; however pre-treatment to produce liquid or a very finely divided solids slurry would be required. Such a process is not currently known and would have to be developed.

The solid residues inorganic components such as metal scrap and non-volatile organic materials such as fabrics would then require further treatment and disposal but should be free of chlorinated organic contaminants.

The only concern with respect to the Orica HCB waste stockpile is how to get it into a clean liquid stream, whether by Thermal Desorption (TD) (vaporizing and condensing into an oil) or by solvent extraction.



Pre-treatment is not required for most liquid waste streams. Solids such as contaminated soils, capacitors and transformers are regularly pre-treated using thermal desorption or solvent extraction

#### 4.8.5 Process Capability to Treat HCB – Not Feasible

x

PLASCON is a continuous, automated, electric-arc plasma process that can be used to destroy any gaseous or liquid compound. PLASCON is an "in-flight" plasma process, where waste is injected directly into the plasma torch. There are several configurations of plasma based waste destruction processes, however; the in-flight PLASCON process offers a number of critical advantages as follows:

- All of the waste is subjected to the highest possible temperatures, i.e. thorough mixing of the waste with the plasma is readily achieved
- More efficient use of the plasma energy is achieved because there is no large thermal mass (chamber) to heat
- The entire plasma torch, reaction chamber and scrubber system can be kept to the footprint of a 20 foot shipping container (due to the very short residence times needed to destroy the waste at temperatures in excess of 10,000°C)
- With very low volumes of waste in the system at any one time, and the fast acting control system, the process is inherently very safe
- The process doesn't produce a "melt" into which solid, and often toxic, waste could otherwise be mixed
- No toxic off-gas is produced, eliminating the need for down stream processing
- Because the process doesn't rely on combustion, the "fuel value" of the feed is of no relevance
- The process becomes increasingly cost effective as the concentration of the hazardous/toxic component in the feed increases

The throughput rate is dependent on a number of factors:

- Chemical composition of the waste
- Contamination, e.g. particulate and inorganic levels
- Physical properties of the waste, i.e. liquid, gas, viscosity, etc
- Residual discharge limits

This technology is not immediately suitable for treating the Orica HCB waste stockpile because:

- desorption of a waste containing polymerized materials, tars, sludge's and other process residues to obtain a liquid feed waste stream is likely to be extremely difficult;
- the vaporization process would have difficulty in treating the waste due to the very different melting and boiling points of the compounds within the waste; and some components have low decomposition temperatures



#### 4.8.6 Emissions and Residues from the Process – Feasible ✓

Process emissions include gases consisting of argon, carbon monoxide, methane and water vapor. Residues arising from the wet scrubbing of the off-gases, which comprise an aqueous solution of inorganic sodium salts, such as sodium chloride, sodium bicarbonate and sodium fluoride. Bench-scale tests with PCBs showed PCDD levels in scrubber water and stack gases in the part per trillion (ppt) range. At a PLASCON facility in Australia, used to treat a variety of wastes, the level of PCBs in the effluent discharged complies with a 2 ppb limit. POP concentrations in solid residues are unknown.

The rapid water quench from very high temperature in scrubber using recirculating alkali-water for acid gas absorption and neutralization has given satisfactory results. This could be readily augmented with a second stage scrubber if desired for backup, plus the usual activated carbon filter. However, none of this is likely to be necessary.

Management of desorber residues for the Orica HCB waste stockpile is regarded as a concern; however, the technologies, engineering and chemistry involved are relatively simple. If there are organo-chlorine contaminants then these solid wastes will need alternative processing. All plasma process residues are capable of reprocessing by plasma (recycle).

Desorber residues would require another form of destruction, or treatment and disposal. In this case, as with many destruction processes, there would be a residue for disposal or further treatment. This may simply be a matter of bundling and feeding to a cement kiln as mineral and metal additions, a regular practice in some Australian kilns.

#### 4.8.7 Ability to Permit or License Facility – Feasible ✓

BCD Technologies hold an EPA license and have a site EMP in place for this technology. There are several operating plants in Australia and none have been the subject of stakeholder or legal action.

PLASCON themselves have indicated that over a period of time they could have a larger facility in operation, depending chiefly on the length of the planning approval process. This should not be unrealistic in view of the fact that there are several units already in operation in two states.



## 5. COMMERCIAL RISK AND FEASIBILITY

As a separate aspect of the independent assessment undertaken by SIA all technologies were reviewed from a commercial perspective. This has involved a thorough understanding and review of all key requirements of plant modification or new build to establish an industrial scale waste treatment facility.

Issues considered in the assessment included:

- Waste type, volume and security of waste supply
- Technology guarantees
- Construction costs and contracts
- Operation and maintenance cost and contracts
- Development time and cost (inclusive of permitting, approvals and financing risk).

A number of significant commercial risk issues were common across all technologies assessed.

### Waste Supply Risk

As stated previously Australia has a limited process and manufacturing base and any facility developed to an appropriate scale to treat the Orica HCB stockpile within a realistic time frame would have significant commercial risk associated with future waste supply. There are very limited quantities of hazardous waste generated in Australia requiring special treatment of the nature proposed for the HCB stockpile. There are also limited known stockpiles of chemical waste in Australia (currently estimated to be less than 100 tonnes of mostly residual mixed waste from chemical drum collection programs).

To develop a facility of the required scale would incorporate significant commercial risk as its viability would be primarily dependant on one waste stockpile. This would have a significant impact of the feasibility of any project in addition create a high level of risk with contract development and project financing.

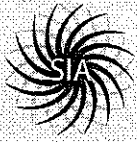
It is probable that any new or expanded plant for the treatment of HCB Waste would only be utilised for the HCB destruction. The plant would then have limited further requirement.

### Technology Risk

All technologies reviewed in this assessment other than HTI have no proven track record of treating large scale volumes of industrial hazardous waste, specifically HCB. This poses significant levels of risk in consideration for the potential for catastrophic failure should there be any accidents or plant failure relating to the unproven nature of pre-treatment, processing or emission control equipment.

This technology risk would have a commercial impact on technology guarantees, permitting, key development, construction and operation contracts as well project financing.





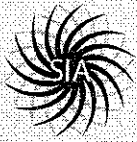
There will always be commercial risk associated with the development of commercial scale hazardous waste treatment facilities and there are considerable additional risks not represented in this assessment report. In respect of the two commercial risks summarised in this section of the assessment SIA believe that the commercial risks of any current existing technology in Australia to develop capacity to treat the Orica HCB waste stockpile within a reasonable time frame is commercially not feasible.



## 6. CONCLUSIONS

This Assessment Report has reached the following conclusions:

- At the time of writing this report there are no facilities operating in Australia which are considered feasible for the destruction or acceptable treatment of HCB from the Orica waste stockpile at the Botany Industrial Park.
- All technologies assessed were considered not-feasible when considering the scale and time to treat the waste. This was due either to the fact that plant capacity was restricted or the time required to go from initial assessment through to completion of treatment for all of the Orica HCB waste exceeded the 5 year threshold. All technologies other than PLASCON were deemed to represent major or significant risks which would result in significant hurdles or extensive time delays in consideration of permitting or licensing a facility for processing the Orica HCB stockpile.
- Hydrodec, GPCR and BCD were technologies all deemed not feasible on every assessment criterion apart from proven nature of technology. These technologies have too many hurdles to cross before coming close to being feasible for the treatment of Orica's HCB waste stockpile.
- No known technologies in Australia currently have suitable pre-treatment or front end waste handling systems to manage the Orica HCB stockpile. Given the volume, heterogeneous and hazardous nature of the Orica HCB waste it is imperative that any front end system is proven, robust, reliable and safe in its handling of the HCB waste prior to being processed. Achieving these outcomes for most of the technologies would take much development in terms of time and cost.
- Whilst there are commercial facilities available for treatment of hazardous waste in Australia, the volume and the non-homogenous nature of the Orica HCB waste makes the treatment processes unfeasible. Site inspections and discussions with senior management of companies currently operating potential treatment systems, have advised that they are not currently able to treat HCB wastes that contain significant concentrations of HCB in a heterogeneous form.

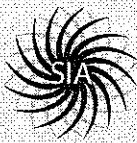


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## **Appendix 1.**

### **ALTERNATIVE TREATMENT TECHNOLOGIES IN AUSTRALIA**

#### **6.1 Feasibility Requirements**

The following summary provides information on various non-feasible technologies that are considered capable for the treatment of Persistent Organic Pollutant (POP) stockpiles. It is important to note that certain technologies require a combustion process following the main treatment process to secure the treatment of POP or to allow for heat recovery.

The summary classifies the technologies into:

##### **A. Promising Technologies**

These technologies require minimum research to prove their capability to destroy high strength POP stockpiles or these are successfully and currently operating pilot plants. Processes which have demonstrated in the laboratory the ability to treat moderate to high strength POP with a high efficacy and no formation of toxic daughter products are included. These include:

1. Mediated electrochemical oxidation (CerOx)
2. Mediated electrochemical oxidation (AEA Silver II Process)
3. Catalytic hydrogenation

##### **B. Technologies that Require Significant Research**

Certain technologies require significant research to determine whether they can destroy POP's. These include technologies that have proven they can treat low levels of POP's but not for high strength wastes. It also refers to technologies for which there is limited data. No technologies found were suitable for this category though basic research has been undertaken on some technologies. These include:

1. Micro emulsion Electrolysis
2. Ultrasonic Irradiation
3. Photo catalytic Degradation using  $\text{TiO}_2$  and
4. Electron Beam Injection

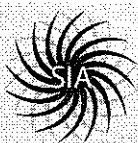
##### **C. Technologies that are Unlikely to Destroy the POP Stockpiles**

Certain technologies have natural defects which makes it unlikely for them to treat high strength POP waste. Also, due to the unavailability of certain data, we may not be able to see whether these technologies are feasible or not. These include:

1.  $\text{MnO}_x/\text{TiO}_2\text{-Al}_2\text{O}_3$  Catalyst Degradation
2.  $\text{TiO}_2$ -based  $\text{V}_2\text{O}_5/\text{WO}_3$  Catalysis
3. Fe(III) Photo catalyst Degradation

**Appendix 2. SUMMARY OF TECHNOLOGY EVALUATION FOR TREATMENT OF ORICA HCB STOCKPILE**

Assessment Criteria Technology	Proven Nature of Technology	Scale and Time to treat the waste	Pre- treatment and front end waste handling	Process Capability to treat HCB	Emissions and residues from the process	Ability to permit or license facility	Feasibility Status
GeoMelt							
Hydrodec							
GPCR							
Base Catalysed Decomposition							
High Temperature Incineration							
Ausmelt							
PLASCON							



### **Appendix 3.**

## **DETAILS OF STAKEHOLDERS CONSULTATION**

<b>No</b>	<b>COMPANY</b>	<b>TECHNOLOGY</b>
1.	BCD Technologies Pty. Ltd. (Narangba, QLD) and Enterra Pty. Ltd. (Kingsgrove, NSW)	Base Catalyzed Dechlorination or Base Catalyzed Decomposition.
2.	Tox Free – Waste Management Solutions	Thermal Desorption/destruction , High Temperature Incineration
3.	DoloMatrix Group of Companies	
	▪ SRL Plasma	PLASCON waste destruction plants (using Plasma technology)
	▪ Chemsal	Hazardous waste collection, disposal, resource, recovery, recycling, chemical treatment, chemical fixation and depackaging
	▪ BCD Technologies Pty. Ltd	It utilizes Base Catalysed Dechlorination with high temperature Plasma Arc (PLASCON) technologies.
4.	Hydrodec Australia Pty. Ltd.	Hydrodec
5.	Zealmore Pty. Ltd.	Plasma-electric Waste Converter (PWC)
7.	Bridle Consulting	HEAT (used to be Ecologic)
7.	Ausmelt	Ausmelt Process
8.	Department of Environmental Protection (DEP) – WA	General knowledge of Kwinana operations and Ecologic
9.	Queensland EPA	General knowledge of BCD and PLASCON
10.	Orica	▪ Review of the Botany Industrial Storage Facility ▪ Collection of data and information ▪ Discussions regarding previous studies