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GREENPEACE

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Inquiry on Remediation of Dioxin Contaminated soils at the Cheoy Lee Shipyard Site

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1. Introduction and summary

The former Cheoy Lee Shipyard site is heavily contaminated with dioxins and a range of other toxic chemical pollutants. The current proposed remediation plan for the dioxin contaminated soils, is to utilise Indirect Thermal Desorption to separate and concentrate the dioxins and other organic contaminants, followed by incineration at the Chemical Waste Treatment Centre (CWTC).

After reviewing the technical details of the proposal, Greenpeace has determined that a number of key issues has not been adequately addressed in the current assessment documentation.

In particular, the issues of:

- on-site versus off-site remediation of the contaminated soils;
- the Indirect Thermal Desorption (ITD) process will generate a significant quantity of highly toxic concentrated dioxin/oil residue;

- the decision to utilize incineration at the CWTC as the preferred method of treating the highly toxic dioxin concentrate from the ITD process has not been assessed in sufficient detail, nor has any justification been presented for this decision;
- the review of options for destroying the dioxins from the site has not considered the broader picture of China's international commitments and obligations under the Stockholm Convention on Persistent Organic Pollutants;
- non-incineration destruction technologies are available which have not been considered in the current assessment.

2. Stockholm Convention

Due to international concern over the health and environmental hazards associated with Persistent Organic Pollutants (POPs) such as dioxins and furans, the Stockholm Convention on POPs was formally adopted in Stockholm, Sweden on 22 May 2001.

The Stockholm Convention is the first global, legally binding multilateral environment agreement to aim to eliminate the production and use of persistent toxic substances from use worldwide.

The Convention initially targets a list of 12 POPs, including organochlorine pesticides (eg. chlordane, dieldrin, DDT), industrial chemicals (eg. PCBs) and the so-called by-product POPs (dioxins, furans, PCBs and HCB). The by-product POPs are predominantly formed unintentionally by industrial processes involving organic materials and chlorine, such as municipal, hazardous and medical waste incineration.

The Stockholm Convention has been signed by 117 nations and ratified by 6 nations (as of 15 March 2002). The convention will not formally enter into force, hence international law, until ratified by 50 nations. However, it is important to consider that all signatories to the convention have an obligation not to act in a manner that would undermine the convention, and that the Final Act of the Convention called on all governments to begin implementing the obligations prior to its entry into force.

The Stockholm Convention on POPs sets out a number of key obligations which all Parties to the convention will be legally bound to implement. For the so called by-product POPs (dioxins, furans, PCBs and HCB), the convention requires the continual minimisation of total releases, and, where feasible, ultimate elimination of all anthropogenic sources.

3. Sources of POPs

The Stockholm Convention lists a number of industrial sources of dioxins and other by-product POPs that have the potential for comparatively high formation and release of these chemicals to the environment. These include:

a) Waste incinerators, including co-incinerators of municipal, hazardous or medical waste or of sewage sludge;
b) Cement kilns firing hazardous waste;

c) Production of pulp using elemental chlorine or chemicals generating elemental chlorine for bleaching;
d) The following thermal processes in the metallurgical industry:
   i) Secondary copper production;
   ii) Sinter plants in the iron and steel industry;
   iii) Secondary aluminium production;
   iv) Secondary zinc production.

Furthermore, waste incineration is widely recognised as the major source of dioxins and furans in many nations throughout the world.

4. Disposal of POPs wastes

The Stockholm Convention also sets out specific requires for the treatment of wastes containing POPs chemicals. In particular, Parties to the Convention are to take measures so that POPs wastes are:

> "Disposed of in such a way that the persistent organic pollutant content is destroyed or irreversibly transformed so that they do not exhibit the characteristics of persistent organic pollutants..."

Also, parties must:

> "…promote the development and, where it deems appropriate, require the use of substitute or modified materials, products and processes to prevent the **formation** and release of" dioxins/furans and other by-product POPs.

Furthermore, POPs wastes are,

> "…not permitted to be subject to disposal operations that may lead to recovery, recycling, reclamation, direct reuse or alternative uses for POPs."

A direct interpretation of this language would mean that POPs wastes can no longer be buried in landfills, deep-wells, or salt mines, nor can they be recycled or processed/treated if the process results in outputs, including residues or by-products, exhibiting POPs-like characteristics.

So from the above, it is possible to come up with some basic criteria that reflect the intent of the Stockholm Convention, as applied to the technologies for dealing with POPs wastes.

A technology should:

A1 - Prevent the formation of dioxins, furans and other by-product POPs.
A2 - Prevent the release of dioxins/furans and other by-product POPs.
A3 - Not generate any wastes with POPs characteristics.
A4 - Not utilise any POPs disposal methods which are non-destructive, such as landfilling, recycling, deep-well injection, etc.

In 1998 Greenpeace established a set of criteria to enable the assessment of the range of POPs destruction technologies. It was determined that such technologies should operate in systems that are essentially closed. This means that uncontrolled releases of POPs and other substances of concern can be avoided and all residues from the destruction process (gaseous, solid and/or liquid) can be contained, analysed and, if necessary, further processed prior to release. It also means that the technology can avoid the periodic "upsets" that plague incinerators and other open destruction process.

Furthermore, an appropriate technology should be able to demonstrate total destruction efficiencies (DEs) for POPs and other substances of concern that are effectively 100%. This means that they not only effectively eliminate gaseous, air-emissions of POPs and other toxic pollutants of concern but they also effectively eliminate releases of these pollutants as solid wastes and as liquid wastes. [1] (This approach conforms to the terms of the Stockholm Convention where the obligation is to reduce *"total releases"* to all media with the goal of "*their continuing minimization and where feasible ultimate elimination."*).

For the purpose of this discussion these criteria can be simplified as follows:

- B1 - An effective destruction efficiency of 100% - taking into account all inputs and releases;
- B2 - Complete containment of all process streams to enable testing and reprocessing if necessary to ensure (1);
- B3 - No uncontrolled releases from the process.

A comparison of these criteria with those derived from the interpretation of the requirements under the Stockholm Convention appear to be mutually supportive, and should provide useful guidance in assessing potential POPs disposal methods.

It is considered that one of the key criteria that should be considered in determining the effectiveness of a given technology is that of Destruction Efficiency. However, this is only one of the criteria that should be assessed.

At the first stage of any evaluation, any technologies that obviously do not meet fundamental requirements should be eliminated from further consideration. In particular, those that have been recognised as being dioxin (or other POPs) sources (i.e. have intrinsic dioxin formation), use non-destructive disposal methods, or have an inability to contain all process streams/releases. Technologies should then be ranked according to the relative merits based on treatment effectiveness, capability to contain and re-process process streams, commercial availability, safety, hazards, etc.

[1] Total destruction efficiency (DE) is almost never reported or calculated for incinerators, cement kilns and other combustion technologies because these devices typically fail to achieve high total destruction efficiencies. Rather, most regulatory agencies only require a measure of the so-called "*destruction and removal efficiency*" (DRE). This measure only takes into account contaminants that re present in the stack gases (air emissions), but ignores toxic contaminants of concern released as solid and liquid residues (as waste ash and waste water). Modern incinerators achieve high reported DREs by using filters, scrubbers and other stack gas cleaning devices to capture pollutants of concern, remove them from the device's gaseous emissions, and transfer them to solid waste and/or liquid waste residues. As a result, when only a device's DRE is considered, and when a measure of its total DE is avoided, this encourages the selection and deployment of technologies that transfer contaminants from stack gases into other media (water and ground). The use of DE as a measure, on the other hand, encourages the selection and deployment of technologies that efficiently destroy and eliminate POPs and other organic pollutants.

5. Traditional POPs disposal technologies

In many of the OECD nations, POPs wastes are routinely burnt in incinerators costing tens if not hundreds of millions of dollars. Many nations also permit the burning of POPs wastes in boilers, metal furnaces, cement kilns and other systems that were not purposely designed for this purpose. Other disposal means for POPs have included deep well injection, land-spreading and burial in subterranean salt cavities.

The scientific evidence of the environmental and public health impacts of incinerators, cement kilns and similar combustion systems has created strong public opposition to the burning of POPs.

Governments have reacted by focussing on regulations that reduce air emissions of dioxins. However, this regulatory focus on air emissions may not have reduced the levels of dioxins (and other POPs) formed and released, but simply transferred the dioxin load from the air to other media (eg. solid wastes from pollution control equipment and ashes, dusts, sludges).

Of great concern is the ultimate fate of these residues. In some countries they have been dumped in landfills, used as road making and building materials or, of greatest concern, used for commercial products such as additives in agricultural fertiliser potentially resulting in soil and crop contamination. Recent studies from the EU showing that the total releases of dioxins and furans in solid wastes are far higher than emissions to air tend to support this concern.

Incineration is also know to be a significant source of other pollutants, including NO_x, SO_x, heavy metals and other halogenated compounds to air and in the solid residues. In fact, only a small percentage of the total number of chemical compounds released into the environment from incinerators have been positively identified.

Disposal in landfills or by immobilization/encapsulation does not destroy the POPs, but may result in wider contamination through weathering, groundwater migration and other processes. Such inappropriate practices may ultimately require expensive groundwater and soil remediation costing far more than properly destroying the POPs in the first place.

6. Overview of available technologies

From the criteria discussed above, it is our conclusion that many traditional waste disposal technologies are inappropriate for the disposal POPs wastes given the adoption of the Stockholm Convention. A preliminary assessment of the available technologies for the disposal of POPs wastes is shown in the table below.

Initial screening matrix for POPs destruction technologies

Technology	Intrinsic PCDD/F formation in process	Capable of containing all process streams	Capable of reprocessing all process streams
Incineration	yes	no	no
GPCR - Ecologic	no	yes	yes
Base Catalysed	no	yes	yes

Dechlorination			
Sodium reduction	no	yes	yes
Solvated electron	no	yes	yes
Super Critical Water Oxidation	?	yes	yes
Electrochemical	no	yes	yes
Vitrification	yes	no	no
Ball milling	no	yes	yes
Molten salt	?	?	?
Molten metal*	?	?	?
Catalytic hydrogenation	no	?	?
Solvent washing	no	N/A	N/A
Landfill/burial	no	no	N/A
Solidification/ stabilization	no	no	N/A
Land spreading	no	no	N/A
Deep-well injection	no	no	N/A

* Company recently filed for bankruptcy so not further evaluated ? – indicates insufficient information available

If we eliminate all processes that fail the basic criteria (dioxin source, containment of all process streams or reprocessing capability), or that sufficient information is not available, we arrive at the following list of possible alternative technologies.

List of technologies that meet initial screening

Technology	**Demonstrated high DE**	**Demonstrated capability to treat dioxins**	**Commercial scale**	**Countries where licensed and/or used for commercial treatment**
Gas Phase Chemical Reduction	yes	yes	full	Australia, Canada, USA, Japan (Argentina?)
Sodium reduction process	no	no	full	France, Germany, UK, Netherlands, South Africa, Australia, USA, Saudi Arabia, Japan, New Zealand
Base Catalysed Dechlorination	yes	yes	full	Australia, USA, Mexico, Spain, New Zealand
Solvated Electron Technology	yes	yes	full	USA
Electrochemical Oxidation	yes	yes	limited	USA
Catalytic hydrogenation	yes	yes	limited	Australia
Super-critical water oxidation	yes	yes	limited	USA

Ball milling	yes	no	demo	Germany

Taking those technologies that meet the basic criteria, have a demonstrated capacity to treat dioxin wastes and have been fully demonstrated commercially, two technologies were considered for further. Those are Gas Phase Chemical Reduction and Base Catalysed Dechlorination.

Gas Phase Chemical Reduction (GPCR) – Eco Logic Process

Process: Hydrogen reacts with chlorinated organic compounds, such as PCBs, at high temperatures/ambient pressure yielding primarily methane and hydrogen chloride. Methane generated can be converted to hydrogen (using water shift reaction) to be used in treatment of further wastes. The technology has a high level of process integration/ monitoring/control and system interlocks to prevent process upsets.
Efficacy: Demonstrated high destruction efficiencies for PCBs, dioxins/furans, HCB, DDT and mixed organochlorine pesticides.
Applicability: All POPs – including dioxins, furans, HCB, and PCB transformers, capacitors, and oils. Capable of treating high strength POPs wastes. Capable of treating contaminated soils at rate of 5 tons/hour (with Torbed thermal desorption system), and larger sized fractions of debris in integrated thermal reduction batch processor.
Emissions: All emissions and residues may be captured for assay and reprocessing if needed.
Configurations: Modular; transportable and fixed.
Concerns: Use of hydrogen gas, although company has good environmental/regulatory track record that demonstrates a suitably mature technology. Fate of arsenic/mercury in system is not fully defined. If the methane generated in the process is flared, there is a concern if treated gases not sufficiently well tested before release.
Applicability under Stockholm Convention for POPs destruction: Appears suitable.
Licensing: Commercially licensed in Australia for POPs wastes. Recently licensed in Japan for PCBs and dioxin wastes. Has been licensed and used for full scale remediation project in Canada and pilot scale remediation in USA. Is currently under final assessment for US Army Chemical Weapons demilitarisation program (ACWA).
Vendor(s): ELI Ecologic International, 143 Dennis St., Rockwood, Ontario, Canada N0B 2K0. Phone: (519) 856-9591, Fax: (519) 856-9235
Website: www.eco-logic-intl.com

Base Catalysed Dechlorination - BCD

Process: A non-conventional heterogeneous catalytic hydrogenation process which reacts organochlorines with an alkali metal hydroxide, a hydrogen donor and a proprietary catalyst to produce salts, water and carbonaceous residue. Note, there are a number of variants of the BCD process, which have been developed over the last 15 years. The earlier variants only partially decomposed

the chemicals of concern, whereas the development of more active catalysts has resulted in almost complete decomposition of chloro-organic materials.
Efficacy: High destruction efficiencies have been demonstrated for DDT, PCBs and dioxins/furans.
Applicability: DDT, PCBs, dioxins/furans. Limited to approximately 15-30% strength PCBs. Is currently being used for dioxin (and other POPs) at Homebush Bay, Sydney. Capable of treating contaminated soils with thermal desorption pre-treatment.
Emissions: Solid residues may be captured for assay and reprocessing if needed.
Concerns: Solid residues not fully defined in all variants of the process, although newer variants (eg. ADOX) appear to have overcome this problem. There exists the potential for emissions through pressure relief valve unless plant allowed to operate at pressures greater than 5 bar. A fire occurred in unit operating in Melbourne, Australia in 1995 due to operator error.
Configurations: Modular; transportable and fixed
Applicability under Stockholm Convention for POPs destruction: potentially suitable if operated to maximum treatment effectiveness.
Licensing: Commercially licensed in USA, Australia, Mexico, Japan and Spain.
Vendor(s): BCD Group Inc., Cincinnati, OH 45208, USA, kornel_a@bcdinternational.com
Website: www.bcdinternational.com

Both of these commercial technologies, if utilised at maximum effectiveness and with sufficient monitoring and control regimes in place, appear capable of treating concentrated dioxin/POPs waste in a manner that is most consistent with the intent of the Stockholm Convention. Traditional incineration fails the test as it is an essentially open system, is incapable of capturing all waste streams for testing/reprocessing and is a known to form and release dioxins and other POPs.

7. Contaminated Soil Treatment

Soils and other media (eg. sediments, debris) contaminated with dioxins and other organic chemicals of concern can be treated with a number of techniques to separate and concentrate the contaminants from the soil matrix. Such techniques enable the organic contaminants to be concentrated into a form that will enable more efficient destruction of the dioxins and other chemicals of concern.

The question of whether to treat contaminated soils on-site versus off-site require thorough and detailed assessment and public debate. Arbitrary time deadlines should not dictate this decision, but it should be based on the best outcome from environmental, health and public safety concerns. Greenpeace believes that in the majority of cases, on-site treatment is far preferable than off-site transport.

8. Thermal desorption

Indirect Thermal Desorption (ITD) a well characterised method of separating organic contaminants from soil and sediments. If operated to a sufficiently high standard and with an appropriate monitoring regime, ITD has been demonstrated in some situations to be capable of removing dioxins and other organic chemicals to an efficiency of greater than 99%. Although the main criteria for the effectiveness of an ITD unit will be whether it is capable of removing the dioxins from the soil to sufficiently low levels that they no longer present a hazard.

There are however, many vendors offering different ITD systems. In particular the process of containing the concentrate and the associated air treatment system need to be carefully examined. The use of flares or oxidisers as the final stage of the air treatment system should be carefully examined to determine if there exists the potential for formation of dioxins and furans and alternative treatment regimes considered.

As such, ITD may represent a useful first stage in the treatment of soils contaminated with dioxins and other POPs chemicals. However, the concentrated mixture that results from the process will contain highly concentrated levels of dioxins and other organic chemicals and must be further treated by an appropriate destruction technology.

9. Case Study of ITD/BCD treatment of dioxin wastes at Homebush Bay

During the remediation of the main Sydney 2000 Olympic Venue site, approximately 400 tonnes of soil and scheduled chemical wastes, containing dioxins and other chlorinated compounds, together with remnants of steel drums, other debris was uncovered. Details of the dioxin contaminated waste composition is shown in the table below.

Summary data set for the scheduled waste characterisation.

Sample No.	Material	Concentration %	I - TEQ ng/g	Sum of PCDD and PCDF Congeners ng/g
D.075/047/15 Sample 14	T Pe	82 10	311	7440
6-8DS4	T	13	45.4	2020
7-8DS4	T Pe	88 10	13.3	806
11-8DS3	T Pe	67 8	5.46	515
12-8DS2	D	80	0.118	116
16-8DS2	PCP TCP TeCP	20 - 5	1540	498000
20-8NS2	D TCP TeCP PCP	trace 59 16 1	962	231000

Key:
T tetrachlorobenzene; Pe pentachlorobenzene
D dichlorobenzene; PCP pentachlorophenol
TCP trichlorophenol; TeCP tetrachlorophenol
I-TEQ International toxic equivalent; ng/g equivalent to ppb.
PCDD Polychlorinated dibenzo-p-dioxin; PCDF Polychlorinated dibenzofurans

Following an intense lobbying campaign by Greenpeace, the Olympic Co-ordination Authority (OCA) announced its intention to treat the waste on-site using non-incineration technology. In 1998 the OCA contracted ADI Limited (ADI) to treat the wastes on-site at Homebush Bay using a two-stage approach to destroy the waste:

Stage 1 – Indirect Thermal Desorption to separate and concentrate the chemicals
Stage 2 – ADOX/BCD process to destroy the resultant concentrate.

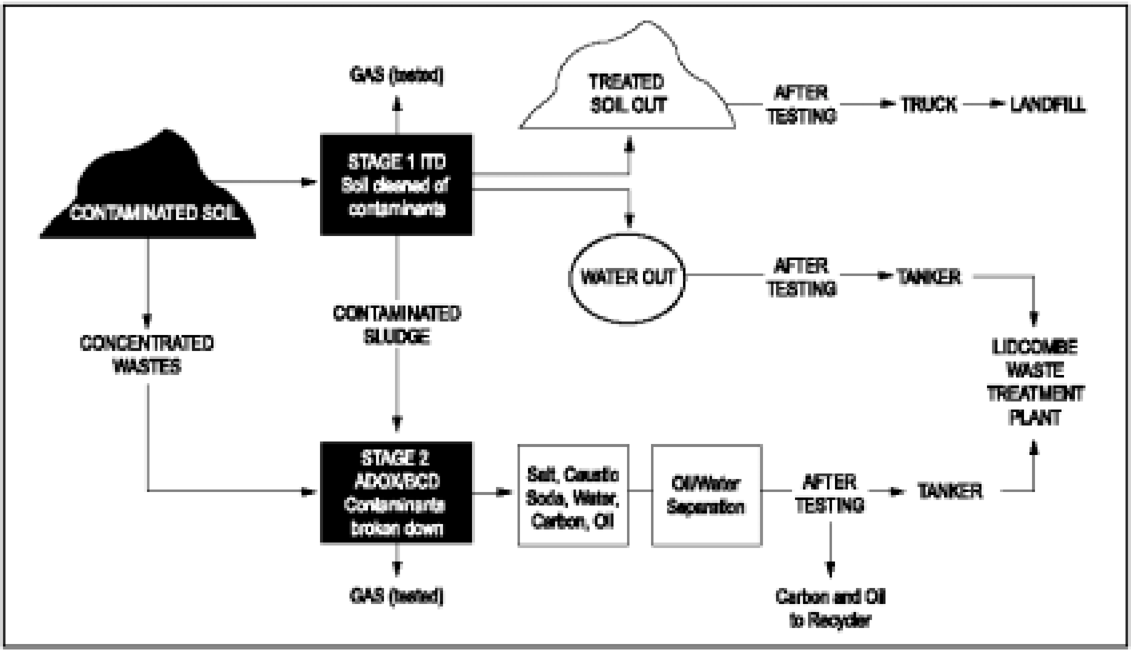
The New South Wales EPA was the agency responsible for permitting the remediation project.

The New South Wales EPA criteria for disposal of the Scheduled Chemical Waste (SCW) under the relevant Chemical Control Orders is as follows;

- If the aggregate concentration of SCW is equal to or less than 1ppm then the treated material is no longer classified as SCW and can be disposed of on-site.

- If the aggregate concentration of SCW is less than 50ppm then the material is still classified as SCW but can be disposed of at an appropriately EPA licensed landfill facility.
- If the aggregate concentration of SCW is greater than 50 ppm then the material cannot be sent to landfill but must be stored in an EPA licensed facility.
- The dioxin content of the treated material is not to be greater than 10 ppb.

The license requirements were based on existing legislative standards for the remediation of scheduled wastes and dioxins. Unfortunately, the regulations on dioxins were set in the 1980's and the remediation standard for dioxins was set at the level of 10 ppb TEQ. Greenpeace and many community members were concerned that this was unacceptably high, but ADI insisted that the actual treatment level which would be obtained by the two stage treatment system would treat the wastes to levels far below the 10 ppb level.



Treatment method

The NSW EPA also required the remediation project to disclose a considerable amount of information to the public, including summaries of the relevant HazOP assessments of the technology and all testing and monitoring data in a timely manner. In particular:

- disclosure of all relevant info
- HazOp studies/
- all monitoring for dust, contaminants, stack emissions and validation data
- required to release testing data and provide monthly reporting
- all info placed on the OCA website and at local depository
- also required a 24 hour complaint register (24 hour phone line service)

The Stage 1 treatment of the wastes was carried out between August and November 1999 and the ITD removed from site. This converted 400 tonnes of waste to approx 385 tonnes of residual soil. This residual soil was tested and results indicated licence compliance (less than 1ppm aggregate concentration of SCW) to allow onsite disposal. EPA required testing for four analytes of concern. Also, the results for the dioxin levels reached during ITD treatment ranged from 0.0001 to 0.3270 (I- TEQ) µg/ kg (ppb), far exceeding the 10 ppb level set in regulations.

The Stage 1 process produced approximately 15 tonnes of concentrated organochlorine wastes for treatment in the Stage 2 process.

The stage 2 process was established on the OCA site in 2000. The original intent was for the remediation to be completed in time for the Sydney Olympic Games in September 2000. However, despite claims by ADI that this was feasible, many (including Greenpeace) were exceedingly sceptical that this was a realistic assessment.

The deadline was not met and the treatment of the concentrated wastes is still on-going. Although the ADOX/BCD process has so far successfully treated 120 batches of the most highly concentrated waste (900,000 ppm) and there remain about 25 batches of less contaminated Stage 1 sludge material for treatment. (82% complete).
There also remains approximately 15,000 litres of condensate to treat, which was not originally envisaged and this required a new licensing arrange with the EPA.

There are a number of significant reasons for the delays in the completion of this project. The original ADOX/BCD equipment required modification to meet local standards of operation, which caused some delays. There were also a number of unanticipated technical issues which required further modifications of the plant and equipment causing further delays.

ADI was sold and purchased by the company Enterra, even though the contractual arrangements for the treatment remained with ADI. Further, the management of the project remains with the OCA, which ceased to exist after the 2000 Olympic Games and is now a new Authority called the Sydney Olympic Park Authority, although the project is being financed by residual monies from the OCA. Not surprisingly there are also on-going legal disputes between ADI & Enterra, and ADI & the OCA.

The lessons learned from this case and other similar experiences are valuable for future remediation projects of dioxin contaminated wastes. While from a technical point of view the remediation project will most likely be declared a success, the management and unresolved legal difficulties that have been experienced complicate the assessment of the overall project.

10. Conclusions

- The decision to utilise ITD for the first stage of the remediation of Cheoy Lee shipyard soils containing dioxins may be an appropriate first stage treatment method;
- the ITD process will generate a significant quantity of highly toxic concentrated dioxin/oil residue which will require appropriate further treatment;
- the decision to utilize incineration at the CWTC as the preferred method of treating the highly toxic dioxin concentrate from the ITD process has not been assessed in sufficient detail, nor has any justification been presented for this decision;

- the review of options for destroying the dioxins from the site has not considered the broader picture of China's international commitments and obligations under the Stockholm Convention on Persistent Organic Pollutants;
- non-incineration destruction technologies are available which have not been considered in the current assessment;
- the decision to base the treatment facility off-site versus on-site should be based on the best option from an environmental, health and safety perspective, and not be based on arbitrary time deadlines;
- the Homebush Bay remediation project provides a number of salutary lessons about any large scale remediation project.

11. Additional recommendations

- The documentation contains no detailed assessment of the proposed destruction of the concentrated dioxin/oil mixture resulting from the ITD treatment of the soil at the Chemical Waste Treatment Centre (CWTC). For completeness, full details of the CWTC treatment should be incorporated in the assessment, including details of the process, costs, destruction efficiency and detailed analysis of all gaseous, liquid and solid wastes, residues and releases.
- It should be explained why the option of incineration as the primary treatment option was abandoned, yet incineration of the concentrated dioxin wastes at the CWTC is considered acceptable.
- All available non-combustion treatment methods should be assessed.
- Full monitoring data from the operation of the ITD unit and any subsequent treatment method chosen for the concentrated wastes should be publicly accessible on a timely basis (eg. monthly reporting).
- The decision on whether to treat the contaminated soil on-site or an alternative location must place as a priority the health and safety issues of the transportation of the contaminated soils and concentrated wastes. Greenpeace considers that on-site treatment to be preferable to off-site transport.
- One concern with current proposed implementation of ITD for the Cheoy Lee Shipyard remediation project is the use of a thermal oxidiser to treat off-gases from the system. In the case of a process upset or failure in the system, this could result in a substantial loading of dioxins and other chemicals of concern to the oxidiser with the resultant potential for the formation and release of dioxins and other by-product POPs.