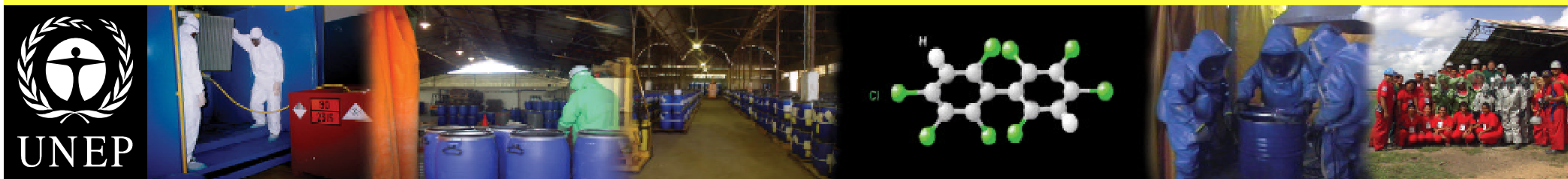


DESTRUCTION AND DECONTAMINATION TECHNOLOGIES FOR PCBs AND OTHER POPs WASTES UNDER THE BASEL CONVENTION

A Training Manual for Hazardous Waste Project Managers

Volume C - Annexes

Secretariat of the Basel Convention



Name of Process: Autoclaving	Status: Autoclaving is a technology that has been around for many years now and is well proven. In general for PCBs, only the oil and transformer components such as ceramics, cardboard and wood are incinerated. After decontamination, the various metals such as copper, steel and aluminium are sent to the metals recycling industry. In fact, the autoclaving cannot be compared with the other technologies dealt with, as it does not treat the PCB itself, but its objective is the clean-up and re-use of the with PCB contaminated materials, which is a completely different purpose as the other technologies. One has to consider that 98% of the contaminated oil is not going into the autoclaving but directly to the incinerator!
Applicable POPs wastes: PCB's and not for other POPs	
Technology description: Autoclaving is a solvent decontamination process that extracts PCBs from contaminated material. The process is most often used in projects in conjunction with high temperature incineration. For capacitors the process involves shredding and placing all the material into the autoclaving chamber and by vacuum extraction with solvent remove the PCB. The condensers solid materials, after sawing and decontamination, are totally treated in the incineration plant through the solid burden way, and only the ceramics can then be landfilled. The extracted oil and PCBs is sent for HTI incineration, Alkali metal reduction or other alternative technologies. Transformers on the other hand are drained, completely disassembled including the core and windings and the casing and all components are placed in the autoclave chamber and decontaminated (SBC, 2002). In the early 1980's it was found that the conventional approach to cleaning PCB transformers, namely the method whereby the units were rinsed (3 to 6 times) and soaked with oil or solvent, could not effectively bring concentrations down to 50mg/kg of PCBs, unless initial PCB concentrations were very low. The usual rinse and soak procedure used previously could be adequate for the decontamination of casings only. It was not adequate for the decontamination of transformer internal components. Concentrations of 0.5% to 4% of PCBs remained associated with the core and windings after 18 hours of soaking and rinsing. These findings influenced the design of equipment and operation methods so that the solvent could reach into internal transformer components. As a result, it has become possible to process materials and meet likely government guidelines. This work has resulted in yet more advanced decontamination procedures which are now the standard for this system. The technology is also used to decontaminate a wide variety of PCB contaminated equipment and materials, including: electro-magnets, breakers, relays, ballasts, cables, radiators, drums, piping, vessels, valves and debris. Various other equipment and materials are evaluated on a case basis.	

Autoclaving

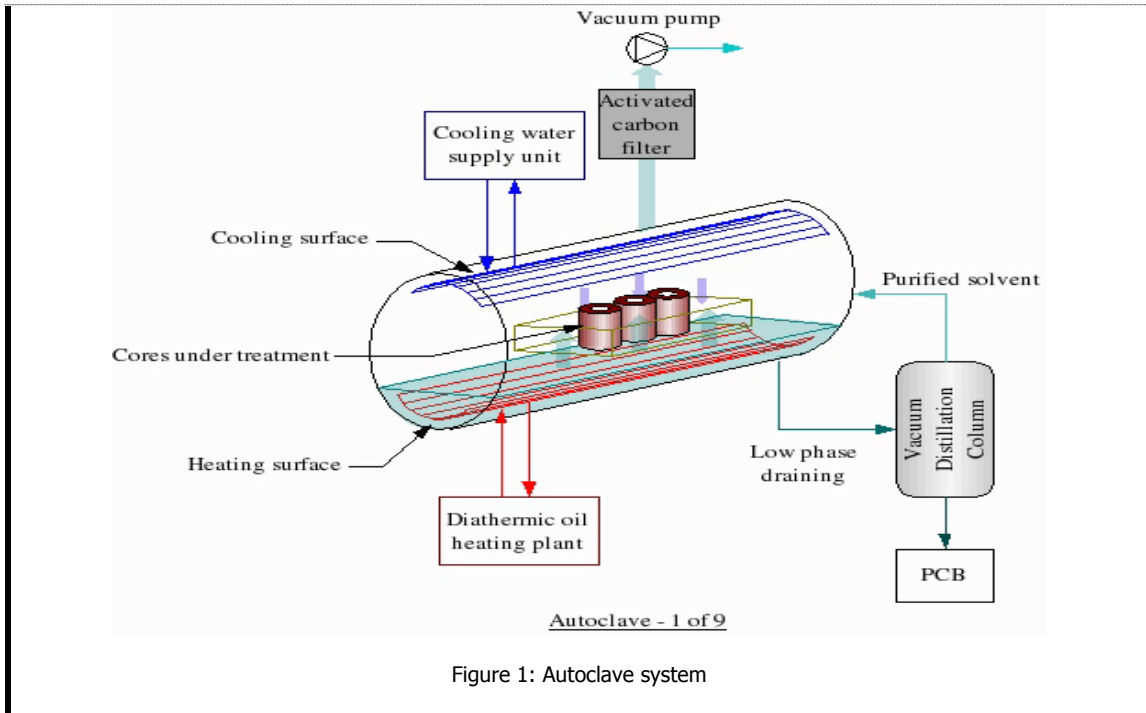


Figure 1: Autoclave system

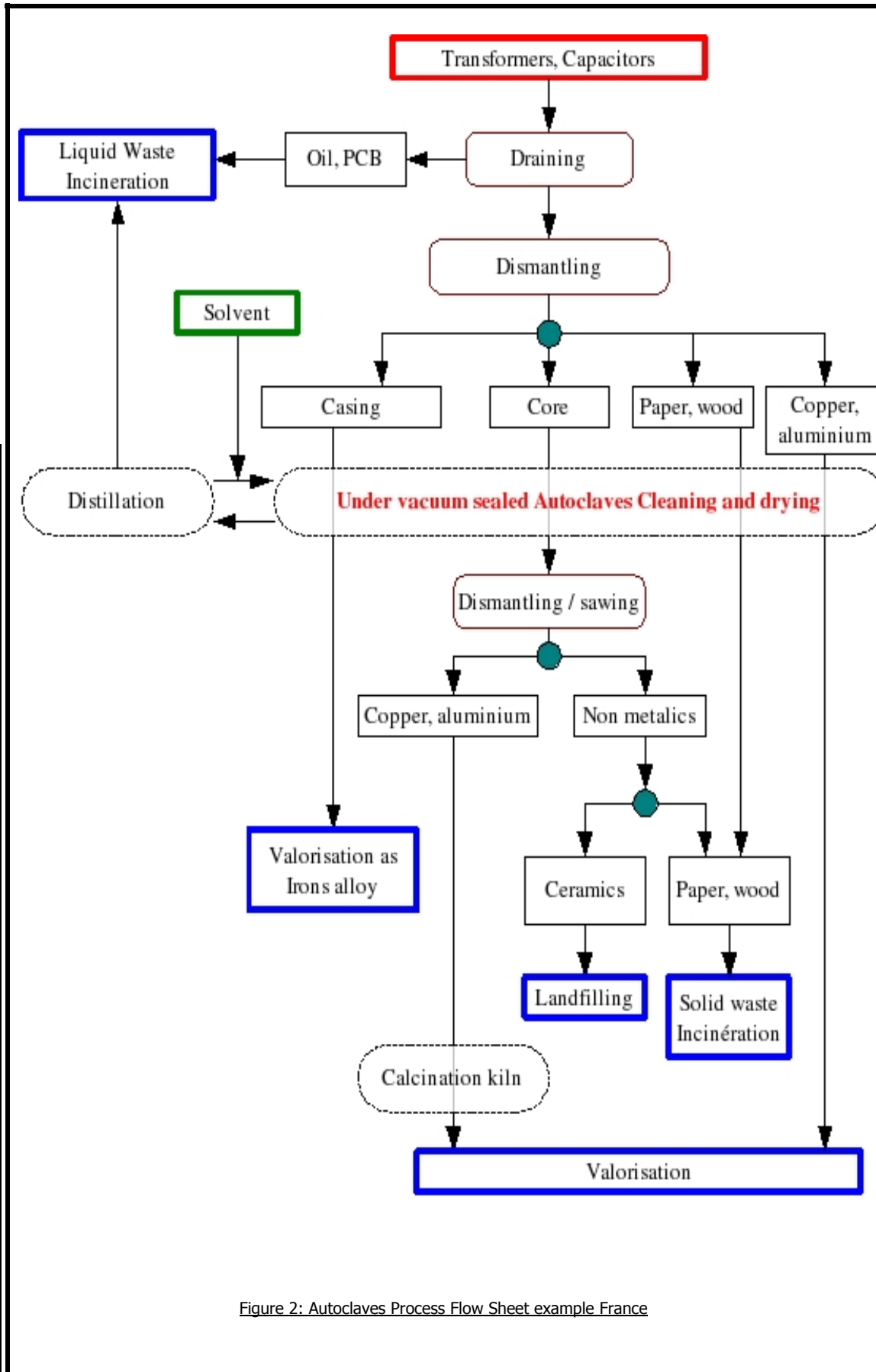


Figure 2: Autoclaves Process Flow Sheet example France

Description of Flow sheet: example France for 9 autoclaves

Type: front door autoclave, material: stainless steel AISI 316 The autoclave door is opened by means of a hydraulic pump. The autoclave area is set on a concrete area whose dimensions were calculated in order to prevent any eventual leakage of oil and solvent. This retention capacity is lined with appropriate epoxy paint for corrosion protection.

Process basis

The property of certain solvents to solubilize PCBs is used to extract these contaminants from casings, cores and windings. This allows transformer and capacitor metal components to be recuperated. The extraction solvent disrobes and solubilizes the PCBs from casing wall surfaces and from internal cores, coils and windings. The efficiency of decontamination is a function of induced cycles of phase changes of the extraction solvent within the material containing the PCBs.

The solvent is regenerated through distillation in a concurrent process step. The distillation process minimizes the volume of the extracted PCBs requiring storage or disposal. The clean distilled solvent is not flammable and is reused.

The decontamination methods used depend on the type of internal components of transformer, being processed and on the size of the equipment.

Description of the different process steps

Transformers to be decontaminated are usually delivered as they were when they have been shut down i.e. filled with PCB. Transformers are weighed full, drained and weighed empty. They are subsequently stored in the storage area.

- Draining

After unloading, transformers are moved to the draining stand which consists of grids and metallic platform. Liquids are drained by means of vacuum pump to storage tanks and then sent to the incineration plant. Draining will recover up to 98% of PCB contents. Transformers can then be moved to a temporary storage prior to disassembly.

- Material separation

After draining, transformers are dismantled in different types of materials:

- Cores are taken out of the transformer casings.
- The ceramics, bolts and piping material are removed and stored in baskets of different sizes to await decontamination.
- The remaining draining oil collected in the retention platform is drained by means of vacuum pump to storage tanks.
- The different components, cores, casing and miscellaneous material stored in baskets are then introduced into the autoclave decontamination unit.

- Decontamination

The washing up process cycles are monitored under control of a PLC which can be recalled by the operators and implemented according to the type and quantity of material to be treated

There are two decontamination cycles:

- Long cycles for core decontamination.
- Short cycles for casings decontamination and miscellaneous material (piping, bolts, ceramics.....)

- Cycle description

Both the long and short cycles include:

- Loading the components for decontamination into the autoclave
- Drawing a vacuum and charging the solvent
- Heating to eliminate water
- Decontamination and drainage of PCB – loaded solvent
- Drying and cooling the charge and final drainage
- Breaking the vacuum and unloading

PCB transfer is handled under vacuum with no pump-down.

Solvent regeneration and recycling

Solvent is regenerated by distillation. As PCB and solvent boiling points are far apart, simple distillation suffices.

Distillation takes place under vacuum. Vapours condense on a closed-circuit water-cooled heat exchanger. Incondensable gases are strained through activated carbon filters prior to being evacuated.

Distillates (PCB + distilled + residual solvent) are drained off and sent to storage for incineration.

PART I: Criteria on the Adaptation of the Technology to the Country

A. Performance:

1. Minimum pre-treatment:

- Draining of contaminated oil from the materials.
- Dismantling for transformers.
- Sawing for capacitors.
- Core, casing, ceramics and piping materials separation.

Each of the three categories of items will be treated separately.

2. Destruction efficiency (DE):

DE values of greater than 99,999% have been reported for all chlorinated compounds. DRE's greater than 99,999 % of recent treatment are given in the Annex in Table 2.

3. Toxic by-products:

Vacuum pump air exhaust is treated by active carbon filters. Thus, no toxic by-products are noted.

4. Uncontrolled releases:

None.

5. Capacity to treat all POPs:

Compounds treated: only PCB's no other POPs

6. Throughput:

Autoclaves may either be fixed or mobile. If sufficient quantities exist in the country then a mobile autoclave can be considered. Obviously the unit can be moved about according to location of PCB stock. It is also possible to build a fixed autoclave plant in the origin country.

6.1 Quantity [tons/day, L/day]

The treatment capacity of an autoclave can reach 50 t / day on cores.

The overall capacity of the plant is 12 000 t / year (including PCB and metallic material).

6.2 POPs throughput : [POPs waste/total waste in %]

Does not apply here (see under Part II, F)

7. Wastes/Residuals: This issue is dealt with in detail under Part II, F. Output/generation waste

7.1 Secondary waste stream volumes:

7.2 Off gas treatment:

The off gas is treated via an activated carbon filter. The flow of gas is 125 Nm³ / h, conform the EU emission standards.

7.3 Complete elimination:

Detailed information and treatment examples:

9 full scale treatment examples can be found in France.

In the separate Annex the following information is given:

Table 1: Technology overview-Summary Technical Details

Table 2: Some recent examples of decontaminations

Table 3: Utilities required

Table 4: Client References for Autoclaving

PART II: Criteria on the Adaptation of the Country to the Technology

Note: This part has to be filled in every time the "suitability" of the technology has to be examined for a certain country situation!!

A. Resource needs: data on the example of France are given for the 9 autoclaves together

Large amounts of waste are needed to justify location in origin country (in excess of 2000 t). If sufficient quantities exist in the country then a mobile autoclave can be considered. Obviously the unit can be moved about according to location of PCB stock. It is also possible to build a fixed autoclave plant in the origin country.

For developing countries option is interesting as only the oil is sent overseas for destruction thus reducing the amount of material, weight, space and danger in the shipment. The copper, steel and aluminium are recycled in origin country. Decontamination of PCBs and PCB contaminated equipment is to be preferred over complete incineration. It is not sustainable to incinerate transformer coils, windings and tanks.

For autoclaving as a fixed plant in a country consideration must be given to utility supplies such as energy, compressed air, water, trade waste etc.

The data given in the following part are collected for 9 autoclaves together. See further details in Annex in Table 3

1. Power requirements :

Electrical supply: 1000 kVA
Total gas heating power installed :1260 kW

A compressor needs to be installed to deliver compressed air, a 7 bar pressure for the general plant circuit process and for utility (pneumatic tools)

Those values are for 9 autoclaves working together.

3. Fuel volumes:

All on natural gas, see details Annex, Table 2

5. Weather tight buildings

7. Sampling requirements/facilities:

The samples have to be prepared before HPLC analysis.

9. Laboratory requirements:

HPLC and normal standard laboratory equipment.

On site requirements:

HPLC method able to measure very low concentration of PCBs.

Requirements in country:

Depending on the requirements of the concerned authorities. From the side of the autoclave operator strict rules are that all incoming transformers received, have to be analysed before treatment independent of the local or national requirements.

11. Number of personnel required: 16: consisting of 2 shifts of 8 h.

11.1 Number of Technicians required (skilled labour):

Complex plant requires expertise to run in origin country.
10

2. Water requirements:

Water is used in a closed – loop circuit. The volume flow is about 100 m³ / h, but is directly rejected after use.

Thus, no real water consumption can be noted. However, if a well is not available, a cold water unit has to be supplied.

4. Reagents volumes:

Perchloroethylene is used as solvent. The amount needed is around 40 m³; This quantity is recycled and reused. The overall consumption of solvent is 200 t / y.

6. Hazardous waste personnel requirement:

Standard for manual work: helmet, gloves and security shoes.

8. Peer sampling:

The requirements from the French authorities are monthly analysis of air and water in the surrounding of the autoclaves. Periodically e.g. every year, a soil analysis.

10. Communication systems:

Mobile network:

None

Fixed network:

Standard telecommunication facilities.

11.2 Number of Labourers required (unskilled labour):

6

B. Costs:

Autoclaving is very cost effective given the correct circumstances. Installations as used in France report that at least stocks of 2000 tonnes justify establishment. For large onshore origin country stocks of contaminated equipment then mobile or fixed autoclave plant can offer excellent opportunities for cost reduction compared to sending all the material offshore. The costs are comparable with incineration but have none of the attendant cost of packaging and transportation. It has to be taken into account that the recycling of the materials will often produce a positive cost result.

Excellent decontamination standard (to NDT) and recovery of metals often contributes to reducing the overall cost of autoclaving. In some cases the recycling revenue exceeds the autoclaving costs.

One has to consider that 98% of the contaminated oil is not going into the autoclaving but directly to the incinerator!

For the cost estimate an example of Autoclave, not the installations in France but a mobile unit in Argentina has been taken: Total costs ca 1 Mio US \$. Treatment cost between 3 and 5 USD/kg

- | | |
|---|--|
| 1. Installation and commissioning costs [US Dollars]:
5 % | 2. Site preparation costs [US Dollars]:
2 % |
| 3. Energy & Telecom installation costs:
→ needs 300 KVA | 4. Monitoring costs:
1 % |
| 5. Complying costs:
Depending on local situation | 6. Reporting costs:
1 % |
| 7. Running costs with no waste:
Does not matter | 8. running costs with waste:
0,3 to 0,5 USD/kg |
| 9. Decommissioning costs:
2 % | 10. Landfill costs:
only for ceramics depending of local costs |
| 11. Transport costs of residues:
Depending on the local situation | |

C. Impact:

- | | |
|---|--|
| 1. Discharges to air:
125 Nm ³ / h of gas treated according to the EU standards. | 2. Discharges to water:
None |
| 3. Discharges to land:
Ceramics: 400 t / y of non-contaminated neutral material are landfilled. | 4. Soil impact (noise etc):
Conform to the EU norms. |

D. Risks

1. Risks of reagents applied:

Perchloroethylene has toxic issues. Workers wear individual tracing equipments in order to avoid too high exposure to the solvent.

2. Risks of technology:

Although very limited, due to operation under vacuum condition, the following safety and fire considerations have been applied:

1. Fire prevention

As perchlorethylene and askerel are being used, i.e. chlorinated products, and in particular solutions of polychlorobiphenyl in trichlorobenzene, in case of fire these could create conditions for the formation of dioxin, products which are toxic.

However, the materials used in the system are mainly constituted (95% min.) by inflammable liquids: steel, aluminium, copper, and the operating temperatures are always much lower than the ignition temperature of the few combustible materials such as paper, wood, rubber, mineral oil and plastic materials (5% max.)

As far as regards the risk of fire of combustible materials inside the autoclave, the system is equipped with very strict temperature controls for the working solvent (perchloroethylene) so that it is impossible under any circumstances for the solvent molecules to reach temperatures approaching the cracking point, which is in the order of magnitude of 140°C.

2. Fire fighting equipment

Although the PCB products chlorobenzene and perchlorethylene are inflammable, these products the unit is nevertheless equipped with powder extinguishers located at easily accessible points particularly those closest to storage area of solvent, PCB + oil, paper, woods and plastics.

3. Operational risks:

Mechanical risks due to manipulation of heavy metallic components.

E. Constructability:

1. Ease of installation/construction of plant:

Complex plant requiring expertise to run in origin country.

3. Ease of operation:

Complex plant requiring expertise to run in origin country.

2. Ease of shipping/transit:

The mobile autoclave in Mexico, for example, requires 3 x 20 ft containers, and one 40 ft container for transport. Autoclaves of the size of those installed in France are not mobile, of course, and have to be assembled and built completely in situ.

4. Ease of processing :

F. Output/generation waste: Date are based on 12 000 t/y transformers and capacitors.

Care has to be taken on the determination of below-listed generated and deposited waste, as this system is not as many of the other technologies, a destruction system of the contaminants and as such are these factors not comparable with this other technologies!

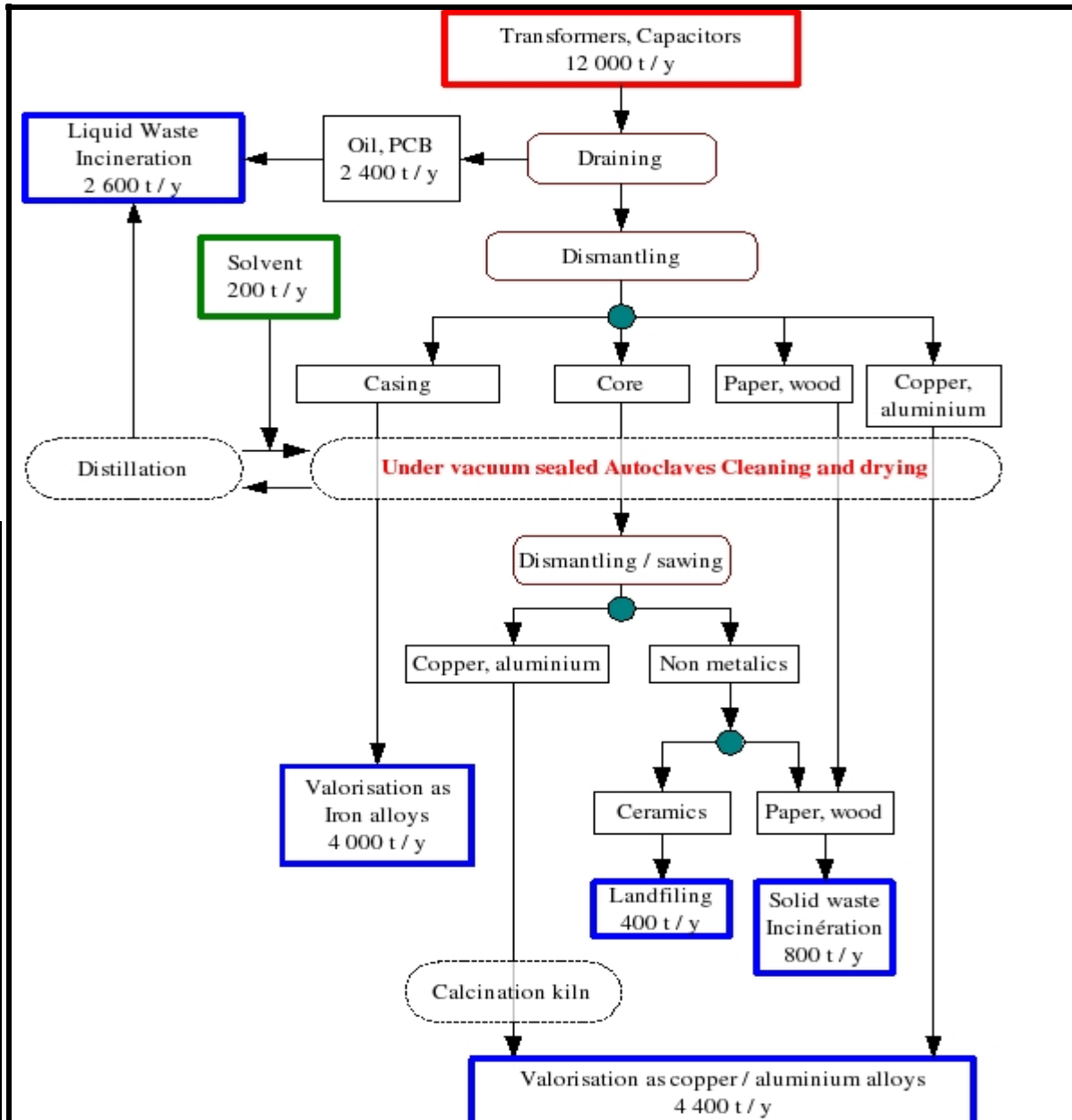


Figure 3: Autoclaves process, Mass Balance

1. Generated waste (% of input waste)

2. Deposited waste at landfill (% of input waste)

$400\text{t}/12000\text{t} = 3.3\%$

3. Waste quality properties (pH, TCLP)

**Note: This Technology Specification and Data Sheet (TSDS) does not certify any particular technology, but tries to summarise the state of the art of the concerned technology on the basis of data delivered by the companies or other sources, which have been made available to the author and refers the reader to original documents for further evaluation. Without the efforts below listed technology suppliers it would not have been possible to set up this TSDS. Date: 15.04.2005*

Technology suppliers that have contributed to this TSDS: :

TREDI - Groupe S  ch  , France

References:

SBC, 2002, Secretariat of the Basel Convention, Destruction and Decontamination Technologies for PCBs and Other POPs Wastes under the Basel Convention, A Training Manual for Hazardous Waste Project Managers, Volume A, ISBN: 92-1-158611-9, ISSN : 1020-8364

AUTOCLAVING – ANNEX TO POPS TECHNOLOGY SPECIFICATION AND DATA SHEET

1. Table 1: Technology Overview – Summary Technical Details

Technology Provider	Technology	Scale	Components treated	Location	Number of units	Applicability Ranking	Additional Remarks
TREDI - Séché	Autoclaving	F	PCB - TCB in various contaminated materials, mostly from electrical supply equipments	France	9	DA	Plant of St Vulbas Basis of the technical descriptions of the autoclaving process About 12 000 t / year
TREDI - Séché	Autoclaving	F	PCB - TCB in various contaminated materials, mostly from electrical supply equipments	France	2	DA	Plant of GEP (Générale d'Extraction du Pyralène) Although a bit different in concept, and smaller in size, the decontamination process is similar (heating and cooling under strong depression) About 1500 t / year
TREDI - Séché	Autoclaving	F	PCB - TCB in various contaminated materials, mostly from electrical supply equipments	Taiwan	1	DA	Similar to the apparatus of St Vulbas About 1500 t / year
TREDI - Séché	Autoclaving	F	PCB - TCB in various contaminated materials, mostly from electrical supply equipments	Mexico	3	DA	Similar to the apparatus of GEP About 2000 t / year
TREDI - Séché	Autoclaving	F	PCB - TCB in various contaminated materials, mostly from electrical supply equipments	Argentina	1	DA	Mobile unit – has worked in various countries before. About 500 t / year

ON EACH OF THOSE APPLICATIONS, EVERYDAY OPERATION AND ANALYSIS SHOWS DRE OF MORE THAN 99,998 %.

THE EXITING FLOWS OF MATTER (METALIC MATERIALS AND EXHAUST GAS) ARE IN CONFORMITY WITH THE EU STANDARDS.

AUTOCLAVING – ANNEX TO POPS TECHNOLOGY SPECIFICATION AND DATA SHEET

TABLE 2 : SOME RECENT EXAMPLES OF DECONTAMINATIONS

DATE OF TREATMENT	MANUFACTURER	YEAR OF MANUFACTURING	TOTAL MASS (KG)	DIELECTRIC MASS	DIELECTRIC NATURE	POST – DECONTAMINATION ANALYSIS	DRE
20 DEC. 04	MERLIN GERIN N°745 614	1974	1775	570	PYRALEN	STEEL PARTS : 1 PPM PRIMARY COPPER : 2 PPM SECONDARY COPPER : 4 PPM	99,9997 %
20 DEC 04	TRANSFORMER N° 102 147 D2	1974	860	246	ASKAREL	STEEL PARTS : 1 PPM PRIMARY COPPER : 1 PPM SECONDARY COPPER : 2 PPM	99,9997 %
6 DEC 04	TRANSFO N° 344 9302	1977	1220	340	PYRALEN	STEEL PARTS : 1 PPM PRIMARY COPPER : 5 PPM SECONDARY COPPER : 14 PPM	99,9992 %
13 DEC 04	TRANSFIX N° 28700	1963	626	175	PYRALEN	STEEL PARTS : 1 PPM PRIMARY COPPER : 8 PPM SECONDARY COPPER : 3 PPM	99,9996 %

DATA MEASURED AT THE COMPANIES OWN LABORATORY

AUTOCLAVING – ANNEX TO POPS TECHNOLOGY SPECIFICATION AND DATA SHEET

TABLE 3 : UTILITIES REQUIRED

Utility	Units	Quantity required per tonne of waste input	Quantity required per month (GEP - type autoclave)	Quantity required per month (St Vulbas type autoclave)
Electricity	MWh	584	24.3	65.7
Natural Gaz	MWh	649	27	73
Solvent (with recycling equipment)	kg	kg	550	1500
Cooling water	Closed loop - No real consumption			
Processing Rate	kg / min		0.95	2.8
	t / month		42	125
	t / yr		500	1500

AUTOCLAVING – ANNEX TO POPS TECHNOLOGY SPECIFICATION AND DATA SHEET

TABLE 4 : CLIENT REFERENCES FOR AUTOCLAVING

Organisation	Activity
ALSTOM	Supply of great scale electrical materials
EDF	French state compagny for electricity supplying - use of great, medium and small scale electrical materials
SNCF	French state compagny for railroad exploitation - use of a great variety of electrical materials
USINOR	Metallurgy - use of various size of transformers or condenser
PECHINEY	Industry of aluminium - use of big scale transformers and electrical materials
AVENTIS	Pharmacy - use of medium and small scale transformers
ORGAMOL	Pharmacy - use of medium and small scale transformers
CLARIANT	Chemical products manufacturer - use of medium and small scale transformers
ATOFINA	Fine chemistry - various sizes and natures of electrical materials

Name of Process:

Alkali Metal reduction (Sodium reduction)

Applicable POPs wastes:

Alkali metal reduction has been demonstrated with PCB-contaminated oils containing concentrations up to 10,000 ppm and for Askarel transformers (>10,000 mg/kg of PCBs).

In Japan, successful destruction has been performed on Pesticides such as chlordane and hexachlorobenzene (Ministry of Environment of Japan, 2004). Also first lab scale tests have been performed for BHC (HCH).

Status:

This process has been used commercially for approximately 20 years. It has been used extensively in particular in North America and in Germany where most of the oil above 50 ppm has now been treated. Plants are also in France, Spain, Iran and Japan.

In the last years, one of the Canadian technology suppliers has commercialised a variation the so-called Sodium Powder Dispersion Process for the destruction of PCBs in contaminated solids, specifically fluorescent light ballast wastes and capacitors. A commercial plant began operation in Canada in 2003. In Japan, in such a system 214kg of PCBs in capacitors was treated in Okayama prefecture in 2002 and other plants are now under construction.

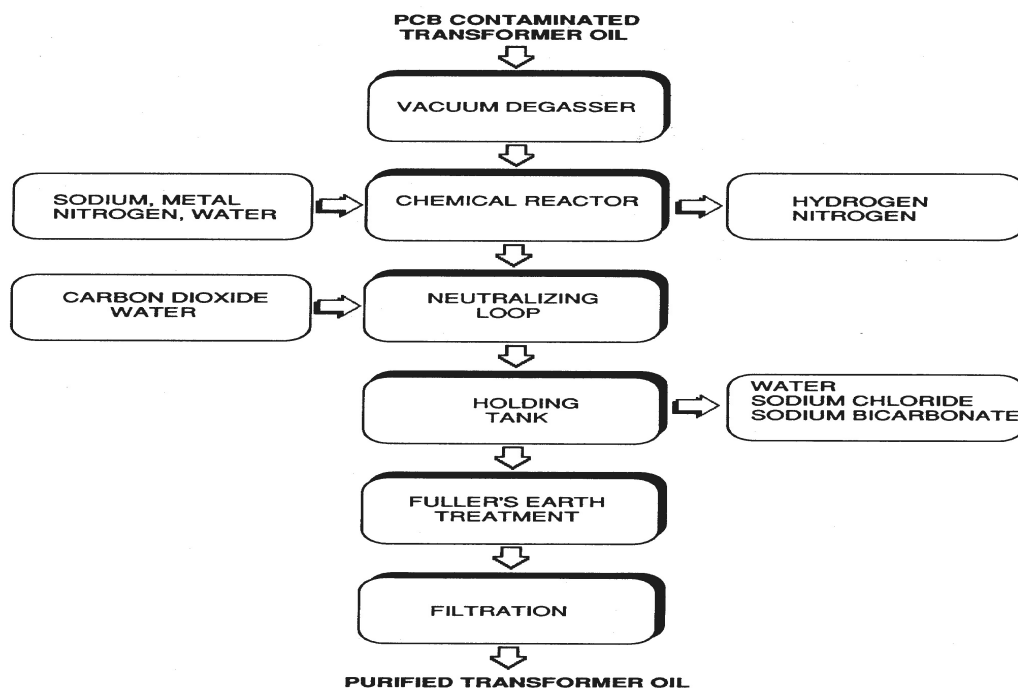
The process has been developed since 1997 based on the Canadian process, for the dechlorination of PCBs and Dioxins in the contaminated wastes to adopt Japanese regulatory standards, and was approved by the treating technology evaluation committee of the government in 1999.

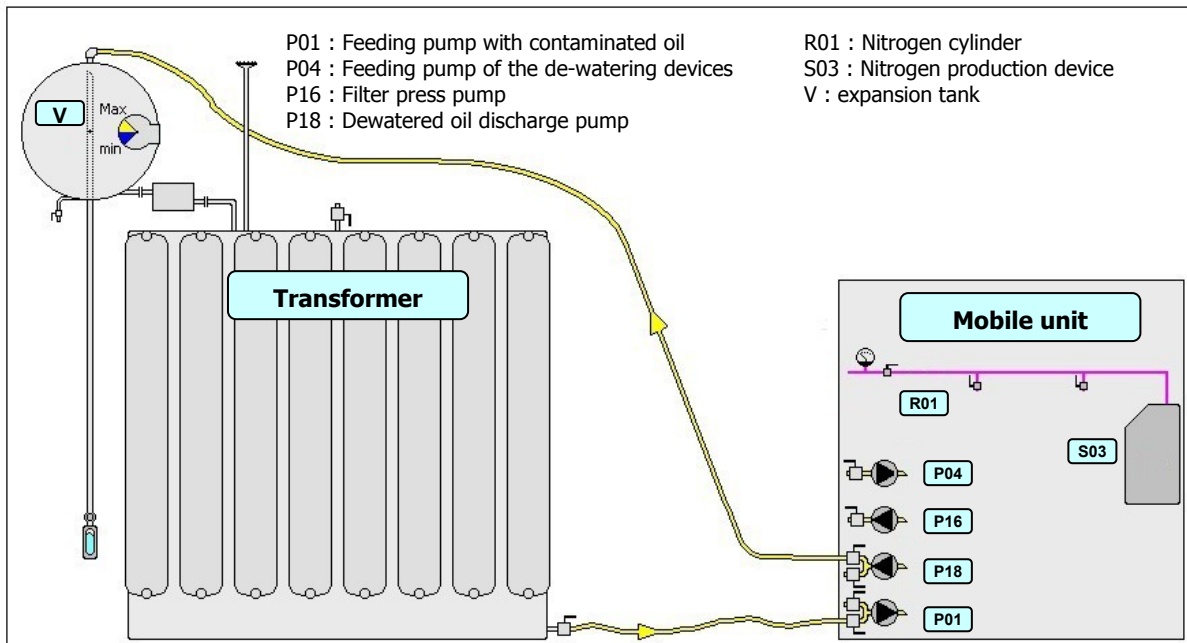
A French supplier applies since 1995 the so-called Sodium Hydride process, which involves Na H instead of sodium in its metallic form. The reductive element is here the H- ion, which is also very reactive, but there is no chance of flames or explosions and the supplier claims a much more safe system.

Technology description:

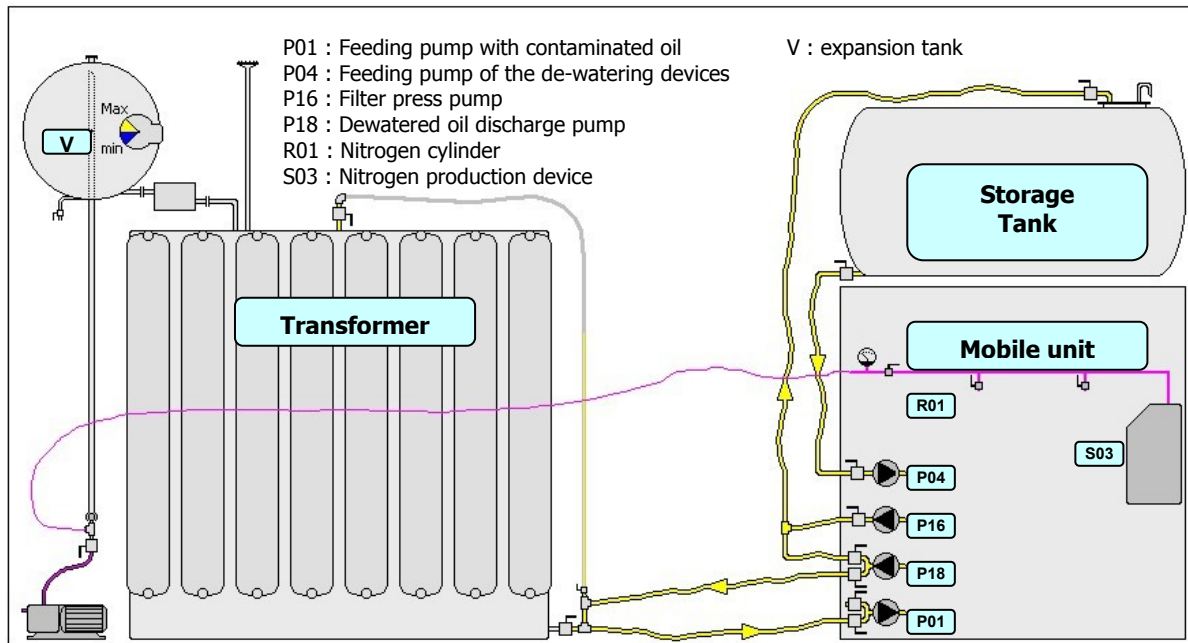
Alkali metal reduction involves the treatment of wastes with dispersed metallic alkali. Metallic alkali reacts with chlorine in halogenated non-aqueous waste to produce salt and non-halogenated waste. Typically, the process operates at atmospheric pressure (sometimes up to 4 atmospheres) and temperatures between 100°C and 180°C (Ariizumi et al., 1997) (actually normally between 90 °C and 165 °C, the quality of transformer oil deteriorates above 165 °C, so higher temperatures are undesirable as most chemical decontamination is followed by dielectric regeneration to allow re-use of the oil as a transformer fluid). Treatment can take place either in-situ (i.e. PCB contaminated transformers) or ex-situ in a reaction vessel (the term in-situ is probably misleading, treatment almost always takes place in a processing unit that is exterior to the transformers; the two main treatment variations are bulk treatment whereby oil flows from a feed tank to the processing unit and then to a treated oil tank, and on-line treatment, whereby oil flows from a transformer to the processing unit and back to the transformer; in this second mode, some of the PCB associated with the internals of the transformers are removed and destroyed). There are several variations of this process. Although potassium has been utilized, metallic sodium is the most commonly used reducing agent (other reagents, mostly organo-metallic ones, are also used). The remaining information is based on experiences with the metallic sodium variation.

Process diagram





Example of Canadian Mobile Unit with direct operation mode with transformer



Example of Canadian Mobile Unit with indirect operation mode with transformer using intermediary oil tank

PART I: Criteria on the Adaptation of Technology to the Country

A. Performance:

1. Minimum pre-treatment:

Ex-situ treatment of PCBs can be performed, however, following solvent extraction of PCBs. Treatment of whole capacitors and transformers could be carried out following size reduction through shearing.

Pre-treatment should include de-watering to avoid explosive reactions with metallic sodium. Drying of oil is normally accomplished to achieve a moisture content of approximately 100 ppm. This is normally done using the vacuum degasser that is also used for the regeneration of the dielectric properties of the oil. Reactors are equipped with pressure and temperature sensors that automatically shut down the feed pump if the monitored values come to exceed the normal operating range. It can be noted that some other dechlorination reagents such as K-Peg are much less sensitive to water and do not require the same extent of safety precautions.

2. Destruction efficiency (DE):

DE nor DRE has been reported (DE varies typically between 99% and 99,9% in most applications, it is also possible to go to a much higher DE as some vendors do when processing askarel or other PCB-chlorobenzenes commercial fluids). The sodium reduction process has been demonstrated to meet regulatory criteria in the EU, United States, Canada, South Africa, Australia and Japan for PCB transformer oil treatment, i.e. less than 2 ppm in solid and liquid residues (to less than 0.5 ppm in Japan; the North American target most often used for chemical dechlorination of oil is 2 ppm, but the process has the ability to reach 0.5 ppm in most cases) (note that this type of treatment is used almost only for transformer oil; it is ineffective in liquid residues that contain an aqueous component and the effectiveness is low for solid residues)(UNEP, 2004a).

Destruction efficiency (DE) values of greater than 99.999 percent have been reported for chlordane and hexachlorobenzene (Ministry of Environment of Japan, 2004).

For destruction Removal efficiency (DRE) values of 99.9999 percent have been reported for chlordane and hexachlorobenzene (Ministry of Environment of Japan, 2004).

One Canadian fixed plant indicates DE for PCB residual < 2 ppm for solids and < 0.05 ppm for liquids and another one indicates total destruction of the residuals (UNEP, 2004)

A commercial Canadian plant with the sodium dispersion process for the destruction of PCBs in contaminated solids, specifically fluorescent light ballast wastes and capacitors, began operation in Canada in 2003. Capacitors containing 20% PCBs by weight are shredded and decontaminated to a level of lower than 5 PPM, for an equivalent destruction efficiency of 99.997%.

3. Toxic by-products:

The by-products of the reaction are most often a salt solution that contains some oil and biphenyl polymer. These wastes have been characterised with respect to dioxins and furans and have been found to be innocuous in this respect. The residue can have a high pH because of the presence of NaOH or of KOH. Air at the vent of the units is routinely analysed for PCB, chlorobenzene and other organic compounds in Canada. The PCB concentration at the vent must be less than 1 ug/m³ in Canada.

4. Uncontrolled releases:

Units are constructed with a steel pan under the process equipment to collect any leak from the piping and vessels. Hoses between the units and the tanks and transformers are typically wrapped with sorbent material at the connections and are underlain by a plastic liner.

5. Capacity to treat all POPs:

Pesticides that are not halocarbons will likely not respond appropriately to this type of treatment. Sodium reduction has been demonstrated with PCB-contaminated oils containing concentrations up to 10,000 ppm (UNEP, 2004a). Some vendors have also claimed that this process is capable of treating whole capacitors and transformers (UNEP, 2000). Whole transformers have been decontaminated routinely with this process over the past 20 years when the initial PCB concentration in the transformer was low enough; when transformers are processed on-line, PCB associated to the internals is partially removed, and if a further reduction is required, a second visit is planned with the processing unit after approximately 90 days, which is the time required for PCB remaining in the porous constituent of the core and coil assembly to leach back in the dielectric oil of a live transformer; depending on initial concentrations, a third visit is planned,(more is rare) (capacitors normally contain about 30% of PCB and it is not cost-effective to treat them with sodium as it is not cost-effective to deal with the porous constituents of transformers when PCB concentrations are above 10,000 ppm).

Compounds treated by Alkali Metal reduction: PCB's , dioxins and furans, hexachlorobenzene, dieldrin (only small quantities have been treated for compounds other than PCBs)

6. Throughput:

6.1 Quantity [tons/day, L/day]

Mobile facilities are capable of treating 15,000 litres per day of transformer oil.

For mobile units average flow rate 1000 L/hr, depending on the concentrations of PCB.

Full-Scale Plants: Data since about 1983 for several units, mostly in the US and Canada. PCB in transformer oil treated to less than 2 ppm. About 400 million litres treated since 1983.

Two fixed plants in Canada, one having a capacity of 7,000 t/y and the other one 2.400 million L/y and 1.65 million kg solids/y.

Mobile units of one Canadian treatment companies are installed in a 12 meter (40') container. The modules are positioned close to the inventory of contaminated oil and close to the tankage used for storage of the treated oil.

In the smaller models, contaminated oil is processed in batch. Oil with low level of PCBs is decontaminated in batches of 3000 L. The dual reactor unit allows for treatment of low level PCBs at an average rate of 1000 L/hour.

In the bigger model, the contaminated oil is processed directly in a continuous flow system. Processing of the oil is performed by chemical decontamination followed by the regeneration of the dielectric properties of the transformer oil.

Through the process, PCBs are destroyed irreversibly in reactors by adding an alkali based reagent to the pre-treated oil. The reagent is stable at room temperature, easy to handle but is incompatible with water or oxidizing materials.

The mobile unit can be constructed to meet the client's needs in PCB oil decontamination and regeneration. It is assured that contact with water and oxidizing materials is avoided. Transformer oil is the fluid treated with these units. Water is not soluble in this type of oil and the oil is inspected and tested beforehand to verify that there is no colloidal water present in the oil. In such an occurrence, the oil is dehydrated prior to chemical dehalogenation.

6.2 POPs throughput : [POPs waste/total waste in %]

Mobile unit oil treatment capacity :		
Average treatment flow rate"	PCB concentration range	Maximum throughput"
1,000 L/hour	50 to 10,000 ppm	24,000 L/day
"For PCB concentration in oil that are less than 500 ppm. The processing rate decreases with increasing concentrations of PCB.		

Generally PCB 1254 and 1260 is the type of PCB found in transformer oil.

7. Wastes/Residuals:

7.1 Secondary waste stream volumes:

Residues produced during the process include sodium chloride, sodium hydroxide, polyphenyls and water. In some variations, a solidified polymer is also formed (UNEP, 2000).

After the reaction, the by-products can be separated out from the oil through a combination of filtration and centrifugation.

The decontaminated oil can be reused (after processing to regenerate the dielectric properties of the oil, involving normally dehydration, degassing, Fuller's earth treatment and microfiltration; this must be part of the processing for on-line treatment otherwise the transformer will fail, probably in a catastrophic fashion).

The sodium chloride solution cannot be re-used, but centrifuged organo-metallic reagent is normally re-used in the chemical dechlorination process.

A small amount of sludge is generated which contains both sodium chloride and the solidified polymer with some oil and water; it is normally solidified and directed to an approved landfill).

7.2 Off gas treatment:

Air emissions include nitrogen and hydrogen gas. Emissions of organic compounds are expected to be relatively minor. A granular activated carbon filter is used to intercept organic contaminants that may be present in gas vented; this is sampled and analysed periodically to ensure compliance with applicable environmental standards

However, it has been noted that PCDDs can be formed from chlorophenols under alkaline conditions at temperature as low as 150°C (Weber, 2004). This very recent issue could not be clarified at present: Chlorophenols are not present in transformer and the gases are vented through an activated carbon filter to intercept any organic contaminant.

7.3 Complete elimination:

Sodium reduction used for "in-situ treatment" of PCB contaminated transformer oils will not destroy all the PCBs contained in the porous internals of the transformer. It has to be noted that there are certain limits on such treatment. In case that decontaminated oil is circulated in a transformer and is returned to the treatment unit, a certain amount of cleansing of the internals of the PCB transformer takes place, especially if the transformer remains in operation; some of the PCB in the porous constituents gets desorbed in the hot clean oil that returns to the treatment unit; (no reagent is directed to the

transformer).

After 20 years of commercial operation, there is a lot of information on this, equations have been developed to anticipate % decontamination in transformers after on-line treatment, and a lot of experience has been acquired on this over this period, it is advised to discuss % decontamination and PCB leachback with experienced technology vendors.

Detailed information and treatment examples:

In the separate Annex the following information is given:

Table 1: Technology Overview – Summary Technical Details

Table 2: Overview project experience per technology supplier

Table 3: Overview detailed project information per project - Project name (from Table 2)

Table 4: Utilities Required for PCB Capacitors Treatment

PART II: Criteria on the Adaptation of the Country to the Technology

Examples on basis of real case: mobile decontamination units in 3 Models used in Canada.

The smallest model enables PCB oil decontamination in a batch process.

The medium model additionally generates transformer oil

The largest one operates on a direct mode instead of a batch process and has an on-line continuous process.

Other fixed types are mentioned specifically if such information is available.

Note: This part has to be filled in every time the "suitability" of the technology has to be examined for a certain country situation!!

A. Resource needs:

1. Power requirement :

Power requirements for mobile units are electrical (60 amp at 575 V) and no 2 fuel oil for heating of the oil (about 750,000 BTU/hr depending on the unit). Units can also be built to be entirely electrically powered.

For one of the fixed plants power requirements are 100 A. Electrical heating of the oil is preferred if oil heat will require # fuel oil of about 750 000 BTU/h

3. Gas volumes:

5. Weather tight buildings:

the mobile units are built to prevent contact between water and reagent and are built to work outside

7. Sampling requirements/facilities:

All analysis are done in an off-site laboratory. No sampling equipment works in - situ. At the beginning of the operation, a sample of the first litres of treated oil is sent to the laboratory in order to validate the running parameters.

One other Canadian company uses PUF (Poly-Urethane Foam) for air monitoring, solvent extraction and GC for solids (UNEP, 2004)

9. Laboratory requirements:

On site requirements:

A laboratory module is provided for the smallest model. The company offers an optional gas chromatograph for PCB analysis in oil.

Requirements in country:

Dependent on the specific country's regulatory requirements.

11. Number of personnel required: 2 technicians in total are sufficient or alternatively it could be run with only 1 technician and 1 labourer, if the technician is skilled enough to supervise alone the operation.

11.1 Number of Technicians required (skilled labour): 2 people are sufficient to run a unit. 1 typically is responsible mainly for the process, the second one being responsible for sampling, analysis in the on-board lab and quality control. People are on day shift and on night shift. When significant work is required to connect to many tanks and/or transformers and to rinse tanks, a third person is on the day shift. Typically, a chemist or engineer works from the office to communicate with clients and provide overseeing for the company.

2. Water requirements:

None for the mobile units.

For the fixed unit about 80 L/1000L of PCB contaminated oil is needed.

4. Reagents volumes:

Maximum reagent volumes carried with a unit are approx. 200 kg (for a 40% sodium dispersion in oil) or approx. 2000 litres for K-Peg.

6. Hazardous waste personnel requirement:

One Canadian fixed plant operator indicates that all workers receive training on the hazards and how to deal with them (UNEP, 2004)

8. Peer sampling:

10. Communication systems:

Mobile network:

Fixed network:

11.2 Number of Labourers required (unskilled labour):

B. Costs:

Transformer oils: Costs are the same in Canada, the US, England and other locations, but the method of calculation may change from one organisation to another; costs reflects the assumed initial PCB concentration and other factors such as the economy of scale; prices are about the same in Canada and in the US; the US\$0.15/L is a cost for oil with low PCB concentration and the US\$3.3/gallon, US\$0.70/kg is a price for oil with higher PCB concentrations or with more impurities. Here the costs of pre-treatment and disposal of the residuals are included.

Waste oils: US\$0.50/kg (UNEP, 2000). Actually treating waste oil is more expensive than treating transformer oil, by a factor of 2 or more depending on the viscosity of the oil and on the impurities present in the oil; waste oil often contains solvents, water, solids, paint, etc., which requires extensive pre-treatment and makes a 2 ppm decontamination target often impractical; often the target for waste oil is less than 50 ppm of PCB rather than 2 ppm of PCB and the treated waste oil is then used as a fuel supplement in an authorised cement kiln. For waste oils, the costs of pre-treatment and disposal of the residuals are not included.

One of the Canadian fixed plants indicates (UNEP, 2004):

PCB contaminated mineral oil: CAN \$ 0.15 /L

PCB contaminated capacitors: CAN \$ 5.10 /kg

PCB contaminated fluorescent light ballast waste: CAN \$ 1.10 /kg

1. Installation and commissioning costs [US Dollars]:

2. Site preparation costs [US Dollars]:

3. Energy & Telecom installation costs:

4. Monitoring costs:

Amount of monitoring dependent on regulatory requirements

5. Complying costs:

Amount of compliance testing, oversight, etc., will depend on regulatory requirements

6. Reporting costs:

Amount of reporting dependent on regulatory requirements

7. Running costs with no waste:

8. Running costs with waste:

9. Decommissioning costs:

10. Landfill costs:

Depending on the local situation – Should be filled in by the concerned country

11. Transport costs of residues:

Depending on the local situation – Should be filled in by the concerned country

C. Impact:

1. Discharges to air:

The PCB concentration at the vent must be less than 1 ug/m³ in Canada.

In France, so far, no analysis at the exhaust of the electrofilter has been required by the customers

2. Discharges to water:

less than 2 ppm in solid and liquid residues (to less than 0.5 ppm in Japan; the North American target most often used for chemical dechlorination of oil is 2 ppm, but the process has the ability to reach 0.5 ppm in most cases

In France, no water analyses have been required, because the machine has its own retention: the components are in no way in contact with the ground. Additionally, a plastic sheet is placed under the installation before deployment for the projects listed in Annex, Table 2.

3. Discharges to land:

See under 2.

4. Soil impact (noise etc):

D. Risks

A French technology supplier working with the Sodium Hydride process involves Na H instead of sodium in its metallic form. The reductive element is here the H- ion, which is also very reactive, but claim that there is no chance of flames or explosions claims a much more safe system.

1. Risks of reagents applied:

a. Dispersed metallic sodium can react violently and explosively with water, presenting a major hazard to operators. Metallic sodium can also react with a variety of other substances to produce hydrogen – a flammable gas that is explosive in admixture with air.

→ *Measures taken: reagent handling and decontamination in the reactors is performed under nitrogen atmosphere.*

b. Naphthalene has a flash point 174 degrees F and does not really react with oxidizers. Naphthalene only to be used in a well-ventilated area. Since the vapor is heavier than air, a potential asphyxiant hazard exists when stored or used in confined spaces. In contrast to Naphthalene, sodium naphthalide is one of the chemical reagents used to treat PCB contaminated oil, and does react violently with oxidizer. Naphthalene enters in the preparation of the reagent

--> no measure needed!

c. Another reagent used in the process is a member of the glycol ether family. Polyethylene glycol has a flash point of about 470 F and is not flammable, and can form organic peroxides when combined with water under certain conditions.

→ No measures needed

d. Hydrogen gas is a by-product of the sodium process. It is created as the sodium encounters and reacts with waters and/or alcohols in the oil. Main cause of concern is it's flammable nature, however since it much lighter than air it dissipates rapidly.

e. Sodium hydroxide is produced as another by-product of the treatment process. It is corrosive and destroys human tissue at a rate based upon concentration, and may be fatal if swallowed. Waste sodium hydroxide is a regulated waste material that requires special storage, handling, and disposal in both US and Canada.

→ No further measures needed

2. Risks of technology:

Overall several hazards exist with operating the process like most environmental and/or chemical processes. The risk for fire and explosion is well above the norm for chemical processes due to the use of sodium metal. The environmental risk is above the norm due to the handling of PCB oils and fluids.

The worst-case scenarios associated with this process are fire, explosion, injury/fatality, and environmental release. The worst case of all would involve all of these at once. In the history of the PPM process only three instances of fire have occurred (A facility in Delfzijl, The Netherlands, has been severely damaged by a fire) and in each case they were related to operator error. On the other hand one of the Canadian companies declared that since the plant began commercial operation in 1987, there had not been a single safety incident from the plant. Another Canadian company stated also no accidents after 20 years of experience (UNEP, 2004)

However through planning, worker training, engineering controls, and the use of personal protective equipment these risks and hazards are reduced to acceptable levels.

3. Operational risks: Main information is drawn from Canadian mobile units

a. Water contact. Great care must be taken in process design and operation to (please, be aware of the fact that some water in the ppm range is needed in the reaction) exclude water (and certain other substances, e.g. alcohols) from the waste and from any other contact with the sodium.

b. Electricity. The mobile treatment unit is equipped with a transformer and a power panel to operate the various pump motors, mixer motors, sensors, and alarms. The panel is a high voltage source and must be kept closed when not being maintained.

All wiring is 480 V, three phase and designed to the applicable electrical code:

Design and construction depending on the standards of the country where the unit is used, for example 575 V in Canada)

If the mobile unit will be operated inside a building or in a confined area, the wiring, motors, and conduit must be upgraded to explosion proof due to the potential presence of hydrogen gas.

Measures taken: In such a case, any hydrogen by-product would be vented outside of the building)

Safety is a priority and is highly controlled during operation of the mobile system:

The mobile unit is also equipped with gas detection and fire prevention equipment.

Operational parameters are automated for fail safe modes from a control panel in the laboratory area.

Safety features include :

- A spill tray on the container floor capable of holding more than the entire system's oil capacity.
- A separate reagent preparation area with a nitrogen injection system.
- A flammable gas LEL detector (lower explosion limit) that automatically controls the unit ventilation and shuts off the operations in case of abnormal conditions.
- Smoke and heat detectors with automatic shut-off of the decontamination unit.
- Controls interrupting the processing in the case of abnormal pressure or temperature conditions in the reactors.

E. Constructability:

1. Ease of installation/construction of plant:

Example smallest model:

- Two 3000 L insulated reactors, with mixers.
- A dehydrator / degassifier unit.
- Oil heating units.
- Cooling and condensation unit, with vacuum pump and GAC filter.
- Process and auxiliary pumps.
- Instrumentation, control and automation system.
- A laboratory module.
- Reagent handling and injection system.
- Inert gas blanketing system.
- Ventilation system with built-in safety features.

Example middle model:

- All equipment of smallest model.
- Fuller's earth filters with accessories.
- Anti-oxidant injection system.

Example largest Model:

- All equipment of smaller models.
- A centrifuge with accessories.
- A refrigeration unit.
- Additional heat exchanger for cooling of oil.

Optional Process Equipment

The mobile units can be adapted to the specific needs of customers with optional equipment. A partial list of the main optional equipment available follows :

- The regeneration package including two Fullers earth filters and an antioxidant module.
- A centrifuge for on-line separation of by-products.
- A chiller to enhance off gas condensation.
- A HDS injection system for treatment of mixed wastes.
- A gas chromatograph for PCB analysis in oil.
- Dielectric measuring equipment.
- Trailer mounted system.

2. Ease of shipping/transit:

For example the mobile units are installed in a 12 meter (40') container.

3. Ease of operation:

All operators of the process must complete a training class in health and safety, environmental management, and on-the-job operation.

The Canadian system has a large operating experience, and has operated units in a mobile fashion (for about two hundred different customers over 20 years) and in two fixed facilities in Canada, receiving oil from many customers. All work was performed with mobile units between 1985 and 1995. Most of the oil is now treated in fixed facilities nowadays because very few clients remain who have a sufficient quantity of oil to justify mobilisation/demobilisation of a mobile unit. This is a dying market in Canada and in the United States as most of the PCB contaminated oil has been treated. Most of the PCB contaminated oil we treat nowadays contains less than 50 ppm because only a bit more than 50 ppm oil is left.

4. Ease of processing :

In terms of operation, in Canada one uses continuous processing units to treat transformer oil (this represents about 97% of the work done) and has used a batch processing unit to treat waste oil with miscellaneous junk and contaminants (oil contaminated with solvents, fuels, aqueous wastes, radioactive elements, paint, dioxins and furans, etc.). In the latter cases, one conducts laboratory scale treatment to develop the proper recipe and methodology to carry out treatment in the full scale. One has carried out this second type of treatment mostly between 1994 and 1999. Of particular interest is a full scale treatment which was performed to decontaminate residues from a magnesium plant; the residues contained HCB, PCDFs and PCDDs (all POPs) as well as many other organochlorinated contaminants (about 75 drums or 15,000 litres).

F. Output/generation waste

1. Generated waste (% of input waste)

The estimate waste production is about 120 kg of solid waste per 1000 l of treated oil. Those wastes are not contaminated by PCB, because of the complete chemical destruction of the product. However, they have to be treated as hazardous industrial waste, due to a possible presence of remains of Sodium Hydride.

One Canadian fixed installation quotes (UNEP, 2004):

Sludge (NaCl, NaOH, Biphenyls) 20 kg/t waste treated

Another Canadian fixed plant (UNEP, 2004):

Waste water: 80 L/t waste treated

Sludge: 1kg /t waste treated

For the waste water which is a caustic oil, the oil is removed and the water is neutralized by a waste contractor

2. Deposited waste at landfill (% of input waste)

For both fixed plants, it cannot be stated if the waste is landfilled. Companies indicate that sludges and waste waters are disposed of by waste management contractors and/or waste disposal companies (UNEP, 2004)

(UNEP, 2004)

3. Waste quality properties (pH, TCLP)

No liquid effluent generated.

**Note: This Technology Specification and Data Sheet (TSDS) does not certify any particular technology, but tries to summarise the state of the art of the concerned technology on the basis of data delivered by the companies or other sources, which have been made available to the author and refers the reader to original documents for further evaluation. Without the efforts below listed technology suppliers it would not have been possible to set up this TSDS. Date: 08.05.2005*

1. Technology suppliers that have contributed to this TSDS:

Powertech Labs Inc., Canada

Sanexen Environmental Services Inc., Canada

TREDI - Groupe S  ch  , France

References:

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Weber, Roland, 2004, Relevance of PCDD/PCDF Formation for the Evaluation of POPs Destruction Technologies – Necessity and Current Status. Organohalogen Cpd 66: 1282-1288.

ALKALI-METAL-REDUCTION – ANNEX TO POPS TECHNOLOGY SPECIFICATION AND DATA SHEET

2. Table 1: Technology Overview – Summary Technical Details

TECHNOLOGY PROVIDER	TECHNOLOGY	SCALE+	COMP. TREATED	RELATED COMP TREATED	VALIDATION PROJECT EXPERIENCE*	APPLICABILITY RANKING++	ADDITIONAL REMARKS	OTHERS
SANEXEN ENVIRONMENTAL SERVICES INC., CANADA	ALKALI-METAL-REDUCTION	F	PCB in various contaminated materials, mostly from electrical supply equipments	PCBS	OVER 25 YEARS OF EXPERIENCE	DA	COMMERCIAL OPERATION OF PCB'S SINCE 1985. CLEANED 25 000 METRIC TONNES BY MEANS OF DCR MOBILE SYSTEMS	
POWERTECH LABS INC., CANADA	SODIUM REDUCTION	F	PCB IN OIL, PCB IN FLUORESCENT BALLAST WASTE	PCBS	SINCE 1987	DA		
TREDI - GROUPE SÉCHÉ, FRANCE	DE-HALOGENATION AND REGENERATION OF MINERAL OIL CONTAMINATED WITH CHLORINE AND SULPHUR COMPOUNDS (SODIUM HYDRIDE)	F	PCB-CONTAMINATED OILS CONTAINING CONCENTRATIONS UP TO 20,000 PPM AND FOR ASKAREL TRANSFORMERS (>10,000 MG/KG OF PCBS)	PCB'S	SINCE 1995	DA	SINCE 1995 AROUND 600 TONS HAVE BEEN TREATED.	
+KEY: F - FULL-SCALE APPLICATIONS COMPLETED					++KEY: APPLICABILITY RANKING FOR PESTICIDES			
P - PILOT/DEMONSTRATION SCALE COMPLETED; NO F-APPLICATIONS					DA – DIRECT APPLICABLE			
B - BENCH/LABORATORY SCALE COMPLETED; NO P OR F-APPLICATIONS					FS 1 – FULL SCALE WITHIN REASONABLE PERIOD POSSIBLE 0-2 YEARS			
T - THEORETICAL APPLICABLE, NO B, P, F APPLICATIONS					FS 2 – FULL SCALE WITHIN CONSIDERABLE PERIOD POSSIBLE 2-5 YEARS			
* VENDOR CLAIMS PERFORMANCE OF DEMONSTRATION, BUT NO DATA PROVIDED					**VALIDATION ON THE BASIS OF INFO PROVIDED IN TABLE 2 AND 3			

2.1.
2.2.

ALKALI-METAL-REDUCTION – ANNEX TO POPS TECHNOLOGY SPECIFICATION AND DATA SHEET

2.3. Table 2: Overview Project Experience per Technology Supplier

TECHNOLOGY PROVIDER	CONTAMINANTS	AMOUNT TREATED IN TONS	RESULTS INCL. DRE, PRE-TREAT, POST TREAT EMISSIONS, ENERGY CONSUMPTION, COSTS*	CLIENT REFERENCES NAME, ADDRESS, CONTACT PERSON PHONE, EMAIL, FAX
Sanexen - Canada	PCB MATERIALS CONSIST. OF OIL, ASKAREL, AND ELECTRICAL EQUIPMENT	25 000 METRIC TONNES	DE VARIES TYPICALLY BETWEEN 99% AND 99.9% IN MOST APPLICATIONS	Hydro-Québec's "Bout-de-l'Île" site in Montréal, 1985-2000
Powertech Labs Inc	PCB CONTAMINATED TRANSFORMER OIL	~14 000 T (SINCE 1987)	RESIDUAL < 2 PPM	Commercial plant operated since 1987 at BC Hydro Power Authority Surrey Oil Business Unit plants Canada)
TREDI – Séché	PCB'S	DIELECTRIC MASS 16 000 KG	98.7 % ON PCB	ENEL SPA, BUCINE (AR), ITALY, 1999
TREDI – Séché	PCB'S	22 600 KG	98.5 % ON PCB	ENEL SPA, PARMA, ITALY, 1999
TREDI – SÉCHÉ	PCB'S	17 500 KG	98.9 % ON PCB	ENEL SPA, FIGLINA VALDARNO (FI), 2001
TREDI – SÉCHÉ	PCB'S	15 600 KG	99.6 % ON PCB	ENEL SPA, FOLANO DELLA CHIANA (AR), 2001
TREDI – SÉCHÉ	PCB'S	15 000 KG	99.3 % ON PCB	ENEL SPA, BOSSANO (VI), 2002
TREDI – Séché	PCB'S	13 000 KG	97.7 % ON PCB	CELESTICA ITALIA SPA, VIOMERCATO (MI), 2002

ALKALI-METAL-REDUCTION – ANNEX TO POPS TECHNOLOGY SPECIFICATION AND DATA SHEET

2.4. Table 3: Overview detailed project information per project – Project name (from Table 2):

LOCATION PROJECT	PRE-TREAT MG/KG	POST-TREAT MG/KG	DRES	EMISSIONS 1. AIR (HCL, DIOXINS & FURANS ETC) 2. WATER, 3. WASTE (SLAGS)	ENERGY CONSUMPTION	COSTS(CAPITAL, OPERATING COSTS)	OTHERS, REMARKS
ENEL SPA, BUCINE (AR)	315 PPM OF PCB	4 PPM OF PCB TRANSFORMER READY FOR RE - USE	98.7 % ON PCB				
ENEL SPA, PARMA	330 PPM OF PCB	5 PPM OF PCB TRANSFORMER READY FOR RE - USE	98.5 % ON PCB				
ENEL SPA, FIGLINA VALDARNO (FI)	190 PPM OF PCB	2 PPM OF PCB TRANSFORMER READY FOR RE - USE	98.9 % ON PCB				
ENEL SPA, FOLANO DELLA CHIANA (AR)	285 PPM OF PCB	1 PPM OF PCB TRANSFORMER READY FOR RE - USE	99.6 % ON PCB				
ENEL SPA BOSSANO (VI)	450 PPM OF PCB	3 PPM OF PCB TRANSFORMER READY FOR RE - USE	99.3 % ON PCB				
CELESTICA ITALIA SPA VIOMERCATO (MI)	155 PPM OF PCB	3.5 PPM OF PCB TRANSFORMER READY FOR RE - USE	97.7 % ON PCB				

ALKALI-METAL-REDUCTION – ANNEX TO POPS TECHNOLOGY SPECIFICATION AND DATA SHEET

TABLE 4: UTILITIES REQUIRED FOR PCB CAPACITORS TREATMENT

(EXAMPLE OF CANADIAN FIXED PLANT)

UTILITY	3. Units	QUANTITY REQUIRED PER TONNE OF WASTE INPUT	4. Quantity required per month 5. (Semi-mobile plant)	6. Quantity required per month 7. (Full-scale plant)
ELECTRICITY	MWH	1.0		10
NITROGEN	NM ³	192		1,920
CO2	KG	100		1,000
NATURAL GAS	NM ³	768		7,680
PROCESSING RATE	KG/MIN			0.4
	TONNES/MONTH			10.4
	TONNES/YR			130

Cement Kiln Co-Processing (High Temperature Treatment)

Name of Process:

Cement Kiln Co-Processing
(High Temperature Treatment)

Applicable Pesticides and related POPs wastes:

Cement kilns are in principle capable of treating wastes consisting of, or contaminated with, any POP.

Cement kilns can be designed to accept wastes in any concentration or physical form (Chadbourne, 1997)

Status:

Portland cement was invented in the late 18th century and is manufactured in huge high temperature kilns (Roy, 1985). The cement industry is today widely distributed throughout the world and produced in 2003 approximately 1.940 million tons of cement (Cembureau, 2004); i.e. many thousands of kilns are in operation in most countries of the world.

Cement kiln co-processing of hazardous wastes provides high temperatures, long residence time, surplus oxygen, good mixing and an alkaline environment, as well as efficient recovery of any energy and raw material substitutes in the hazardous waste.

Co-processing of hazardous wastes in cement kilns has been practiced for more than 30 years and is acknowledged to be feasible for sound hazardous waste treatment in both EU and US regulation, as well as in numerous other countries (Council Directive, 2000; Federal Register, 1999). The US Environmental Protection Agency (EPA) has done numerous studies on the influence of co-processing hazardous wastes in cement kilns. Cement kiln operators in the US began recovering energy from organic waste materials, including hazardous chlorinated compounds, as early as 1974. That practice became commonplace by 1987 and since 1991 US cement kilns have used roughly 1,000,000 tons per year of hazardous waste as fuel. Some of these kilns replace up to 100% of their conventional fuels with waste-derived fuels (Branscome et al., 1985; Garg, 1990; Gorman et al., 1986; Cement Kiln Recycling Coalition Comments CKRC, 2002).

Testing of cement kiln emissions for the presence of organic chemicals during the burning of hazardous materials has been undertaken since the 1970s, when the practice of co-processing hazardous wastes in cement kilns was first considered. Lauber (1982), Ahling (1979) and Benestad (1989) describe some of these early tests on US, Swedish and Norwegian kilns, which confirmed the ability of cement kilns to destroy the organic component of a waste feed in an environmentally sound manner. Numerous tests around the world have demonstrated that there is essentially no difference in the emissions or the product quality when hazardous waste materials are used to replace the fuels and ingredients needed to produce cement clinker (Chadborne, 1997; Karstensen, 1994).

Technology description:

Portland cement is made by heating a mixture of limestone, silica, alumina and iron materials to a temperature of about 1450°C. In this process, partial fusion occurs and nodules of so-called cement clinker are formed. The cooled clinker is mixed with a few percent of gypsum and ground into a fine meal – cement (Duda, 1985). In the clinker burning process it is essential to maintain kiln charge material temperatures of approximately 1450°C and gas temperatures of up to 2000°C. Also, the clinker needs to be burned under oxidising conditions (IPPC, 2001).

Fuel and wastes fed through the main burner of a cement kiln will be decomposed under oxidising conditions in the primary flame burning zone at temperatures up to 2,000°C and a retention time up to 8 seconds. Fuel and waste fed to the secondary burner, preheater or precalciner will be burnt at temperatures up to 1,200°C. Cement kilns are equipped with either electro static precipitator (ESP's) or fabric filters, or both, for particulate matter control. Acid gas pollution control devices are not used at cement kilns (except for SO₂ in some instances) since the raw materials are highly alkaline and provide acid gas control. In preheater kilns, the finely ground alkaline raw material acts as a huge dry lime scrubber as it is fed counter-currently to the exit gas from the kiln (Environment Agency, 2001).

Studies on PCDD/F emissions have come to the conclusion that co-processing of hazardous wastes doesn't influence the emissions (Branscome et al, 1985; Lauber, 1987; Garg, 1990). In a study performed for the World Business Council for Sustainable Development data from more than 1,700 PCDD/F measurements from wet and dry kilns, performed under normal and worst case operating conditions, and with the co-processing of a wide range of hazardous wastes fed to both the main burner and to the precalciner shows that most cement kilns can meet an emission limit of 0.1 ng TEQ/Nm³ (Karstensen, 2004a).

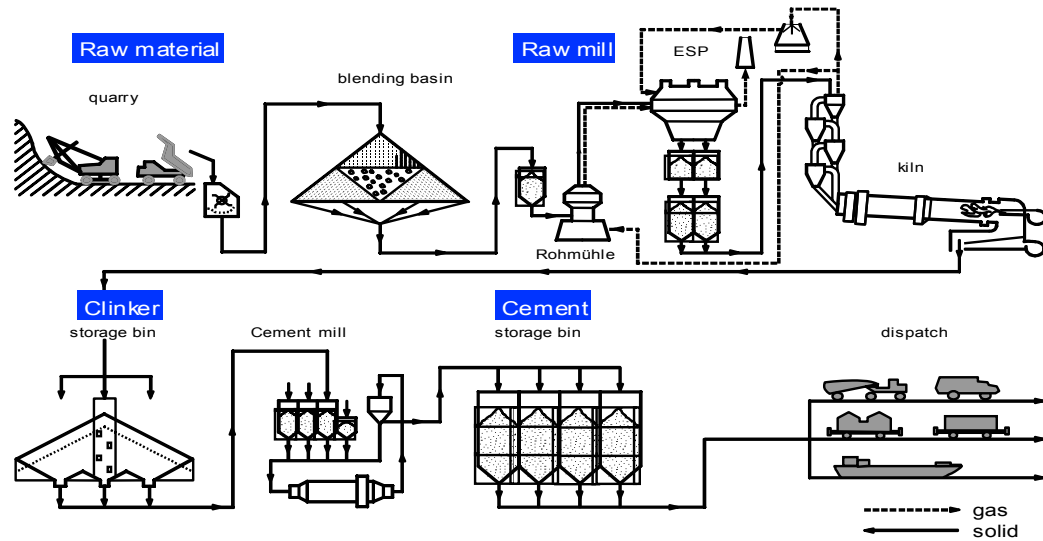
These findings are confirmed by the UNEP Standardized Toolkit (UNEP, 2003) which has developed three classes of default emission factors for cement production, differentiating between type of kiln and ESP temperature. The Toolkit also acknowledges the US EPA statement from 1999 "that hazardous waste burning does not have an impact on PCDD/F formation, PCDD/F is formed post combustion" (Federal Register, 1999). The Toolkit emphasizes that the more detailed investigations of the US EPA study has suggested that provided combustion is good, the main controlling factor is the temperature of the dust collection device in the gas cleaning system, and says further "the plants equipped with low temperature electrostatic precipitators appear to have well controlled emissions with or without waste fuels".

In a recent sampling and analysis program of different industrial sources for UPOP's emissions in Thailand (UNEP, 2001), the cement plant investigated had the lowest emissions among the industrial sources investigated and the results demonstrated that the addition of tyre and/or liquid hazardous waste had no effect on the emissions results. The concentrations measured were all below 0.02 ng I-TEQ/m³ and as low as 0.0001 ng I-TEQ/m³; the means were 0.0105 ng I-TEQ/m³ and 0.0008 ng I-TEQ/m³ for the normal operation conditions and 0.003 ng I-TEQ/m³ and 0.0002 ng I-TEQ/m³ for the test performed with substitute secondary fuels, respectively (UNEP, 2001).

Cement Kiln Co-Processing (High Temperature Treatment)

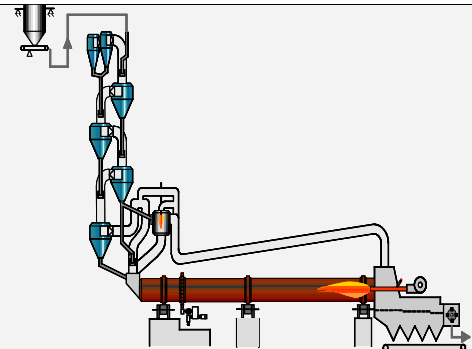
For new cement plants and major upgrades the best available technique for the production of cement clinker is a short dry process kiln with multi-stage preheating and precalcination (IPPC, 2001; Environment Agency, 2001). A smooth and stable kiln process, operating close to the process parameter set points, is beneficial for all kiln emissions as well as the energy use. Quick cooling of kiln exhaust gases to a temperature lower than 200°C is considered to be the most important measure to avoid PCDD/F formation and emissions in wet kilns (process inherent in suspension preheater and precalciner kilns), as well as careful selection and control of substances entering the kiln through the raw material feed. Primary measures have been shown to be sufficient to comply with an emission level of 0.1 ng TEQ/Nm³ in existing suspension preheater and precalciner kilns under normal operating conditions (Karstensen, 2004a; and http://www.pops.int/documents/meetings/bat_bep/2nd_session/egb2_followup/draftguide/default.htm)

Process diagram for dry preheater process (example Germany):



Temperature and residence time during cement production

Characteristics	Value
Temperature at main burner	>1450°C: material >1800°C: flame temperature.
Residence time at main burner	>12-15 sec > 1200°C >5-6 sec > 1800°C
Temperature at precalciner	> 850°C: material >1000°C: flame temperature
Residence time at precalciner	> 2 - 6 sec > 800°C
Residence time at precalciner	> 2 - 6 sec > 800°C



Cement Kiln Co-Processing (High Temperature Treatment)

PART I: Criteria on the Adaptation of the Technology to the Country

A. Performance

1. Minimum pre-treatment:

Some waste categories have to be pre-treated in order to comply with the technical specifications of cement production and to guarantee that environmental standards are met. This can involve grinding, blending, mixing and homogenization processes. High concentration POPs should always be fed to the high temperature burning zone, i.e. main burner or precalciner burner -The method of introducing liquid and solid hazardous waste into the kiln is a key factor to the complete consumption of the waste during the combustion of the primary fuel. Liquid hazardous waste is either injected separately or blended with the primary fuel (coal). Solid waste is mixed and burned along with the primary fuel. Fuel and wastes fed through the main burner will be decomposed under oxidising conditions in the primary flame burning zone at temperatures up to 2,000°C and long residence times. Fuel and waste fed to the secondary burner, preheater or precalciner will be burnt at temperatures between 900°C and 1,200°C. The US TSCA PCB incineration criteria require a temperature of 1,200°C and 2 seconds retention time at 3% oxygen (Lee et al., 2000; Dempsey and Oppelt, 1993; Federal Register, 1999); the EU Directive 2000/76/EU require a temperature of 850°C for at least 2 seconds for the incineration of non-chlorinated hazardous waste and 1,100°C and 2 seconds retention time for organic substances containing more than 1% halogen at 2% oxygen (Council Directive, 2000).

Different feed points can be used to insert wastes into the cement production process. The most common ones are:

- via the main burner at the rotary kiln outlet end;
- via a feed chute at the transition chamber at the rotary kiln inlet end (for lump fuel);
- via secondary burners to the riser duct;
- via precalciner burners to the precalciner;
- via a feed chute to the precalciner (for lump fuel);
- via a mid kiln valve in the case of long wet and dry kilns (for lump fuel).

The feed point selected must ensure that a complete and irreversible destruction is achieved.

2. Destruction efficiency (DE):

The choice of acceptable compounds depends primarily on potential occupational exposures and material-safety criteria. Virtually any organic compound can be completely destroyed at the elevated temperatures in a properly operating cement kiln. Process operating constraints may become significant when certain compounds are present in excessive quantities (Chadbourne, 1997).

A wide variety of hazardous wastes containing organic compounds, including aldehydes, esters, alcohols, ketones, phthalates, alcohol ethers, aromatic compounds, phenols, amines, amides, ethers, nitriles, freons and other halogenated organic compounds are commonly found in hazardous waste fuel mixtures used in the cement industry. More than 250 organic compounds have been approved for use in hazardous waste fuel in the US (Chadbourne, 1997).

Two typical examples are given below:

One older performance example from Sweden (Ahling, 1979):

In 1978, various chlorinated chemical wastes were burned at a test in the Stora Vika Cement plant, near Stockholm in Sweden. The kiln was a 620 ton/day coal-fired wet process cement kiln, where chlorinated aliphatics and aromatics like PCB, chlorophenols and phenoxyacids were burned during these tests. The average chlorine concentration of these chemical wastes, was 17%. Chlorine addition averaged 0.35% of clinker weight. At up to 0.6-0.7% chlorine input, there were no kiln operational problems; at an input of 0.8-0.9% a chlorine clinker ring was formed, which later disappeared when chlorine feed rates were reduced. Waste destruction efficiencies of chlorinated aliphatics was measured to be better than 99.995-99.9998%. The Destruction and removal efficiency (DRE) of PCB was greater than 99.99998%. Analyses were also conducted for dioxins and furans but no detectable quantities of dioxins or furans containing four or six chlorines were found.

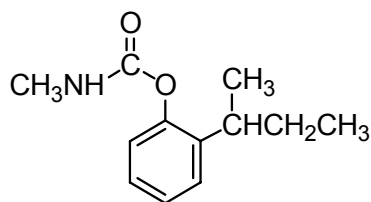
One recent performance example from a developing country (Karstensen, 2005):

In a recent test burn done in a developing country with two obsolete insecticides the destruction and removal efficiency was measured to be better than 99.999997% and 99.999985% for Fenobucarb and Fipronil respectively and showed that the destruction had been complete and irreversible, i.e. no new formation of dioxins, furans or PCB's i.e. all analysis result for PCDD/F's, HCB and dioxin like PCB's were below the detection limit. Raw meal, the product clinker, fine coal, electro static precipitator dust and by-pass dust was analysed for both insecticide compounds and was found to be less than the detection limit for all samples, i.e. <2.0 parts per billion – All electro static precipitator dust are fed back to the process, i.e. only the product and the emissions are outputs from the process and this makes DRE equivalent with the DE, or to be 100% exact: DRE 99.99999719 and DE 99.99999692 for Fenobucarb and DRE 99.99998531 and DE 99.99998321 for Fipronil. This will very often be the case for the cement kilns since they usually don't produce waste or exit gas residues or

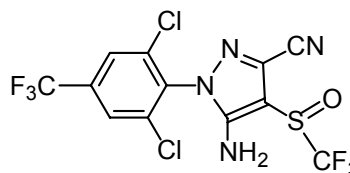
Cement Kiln Co-Processing (High Temperature Treatment)

slags.

Cement Kiln Co-Processing (High Temperature Treatment)



Fenobucarb



Fipronil

The insecticides were fed to the main burner of the kiln at a rate of 2,000 litres per hour and approximately 40,000 litres were co-processed and safely destroyed in less than 20 hours. The insecticides were solved in a mix of aromatic solvents and the energy content of the mix substituted the equivalence of 2.5 tonnes of coal; i.e. the destruction also reversed the energy in the toxic waste.

3. Toxic By-products:

Some cement plants produce cement kiln dusts (CKD) which cannot be reintroduced to the process due to process or quality constraints; usually the CKD are reused as a mineral-substitute but some plants landfill their CKD's. Potential contamination needs to be checked.

4. Uncontrolled releases:

Cement kilns are known to release dusts, CO₂, NO_x and SO₂. Modern plants usually comply with emission limit values with good margins. Plants who co-process hazardous waste must comply with the stringent emission limit values for hazardous waste incinerators.

5. Capacity to treat all POPs:

Numerous tests around the world have demonstrated no difference in the emissions or the product quality when waste materials are used to replace the fuels and ingredients needed to produce cement clinker (Branscome et al., 1985; Chadbourne, 1997; Garg, 1990; Lauber, 1982 and 1987). Comprehensive emission studies have been performed when hazardous waste was introduced, and these have generally concluded that no significant differences could be measured between usages of the two fuels). Already in 1975 Mac Donald et al (1977) carried out test burns with hazardous chlorinated hydrocarbons containing up to 46% chlorine in a wet cement kiln in Canada and concluded that "all starting materials, including 50% PCB's, were completely destroyed to at least 99.98 percent efficiency in all cases" and emissions of high molecular weight chlorinated hydrocarbons were not detected.

Similar tests with chlorinated and fluorinated hydrocarbons conducted in a wet kiln in Sweden showed that the DRE of PCB's were better than 99.99998% and that there were no change in product quality or any influence on process conditions with a chlorine input up to 0.7% of the clinker production (Ahling, 1979). Also, "no TEQ dioxins or furans could be detected". Viken and Waage (1980) carried out test burns in a wet kiln in Norway feeding 50 kg PCB's per hour, showing a DRE better than 99.9999% and no traces of PCB in clinker or dusts could be detected and "PCDD and PCDF have not been detected". Benestad (1989) carried out studies in a dry preheater cement kiln in Norway in 1983 and 1987 and concluded that the "type of hazardous used as a co-fuel" does not influence the emissions and that the destruction of PCB's were better than 99.9999%. "0.2 ng PCDD/Fs TEQ/m³ and 0.1 ng PCDD/Fs TEQ/m³ were measured when feeding hydrocarbon waste (fatty acid esters, solvents and paint residues) and PCB-waste respectively".

Seen from a process technical and chemistry viewpoint it is easier to dispose liquid POP's like PCB contaminated oils than solid materials. Independent of the state of the material, pre-treatment, analysis and control, and cautious feeding of POP's material is necessary. The chlorine tolerance of the process needs to be known

5.1 Capacity to treat hazardous wastes

Cement kilns are a versatile alternative for the management of a wide variety of hazardous wastes. The raw materials used to produce cement often contain trace quantities of virtually every natural element, including alkali chlorides and sulfates; heavy metals, such as lead, cadmium, chromium and arsenic; and organic materials. Many of these constituents are also contained in fossil fuels, such as coal, oil and petroleum coke, and in the water used to prepare slurry for wet-process kilns (Chadbourne, 1997).

Materials present in the feed, fuels or hazardous waste introduced into the kiln become part of the cement product and a waste material known as cement-kiln dust is formed, or they are converted to other forms within the kiln. With few exceptions, materials introduced into cement kilns will be oxidized and stabilized, requiring no further treatment (Chadbourne, 1997).

Cement Kiln Co-Processing (High Temperature Treatment)

5.2 Capacity to treat POPs

The potential for using cement kilns to incinerate PCBs has been investigated in several countries (Lauber, 1982 and 1987). Since PCBs are such stable compounds, the ability of a cement kiln to destroy these compounds indicates the overall ability to destroy organic constituents in hazardous wastes. The DRE's determined from several trial burns conducted in many countries indicate that cement kilns are effective at destroying PCBs (Lauber, 1987; KarstensenB, 2004: http://www.chem.unep.ch/pops/pcb_activities/PCB_proceeding/pcb_proceeding.htm , see also Annex, Table 2 and 3)

Many cement kilns burning hazardous waste as fuel have chosen not to burn PCB wastes for the reasons of perception, bad mention and fear for market implications (Chadbourne, 1997).

6. Throughput:

6.1 Quantity [t/day, L/day]

Cement kilns produces from a few tons cement clinker per hour and up to several hundred tons per hour, which means that the fuel-firing requirements vary from a few tons to several tens of tons of fuel per hour. Yearly capacities vary from a few thousand to more than 10 million tonnes per year (in Thailand). Usually fine coal is used as the primary fuel.

6.2 POPs throughput: [POPs waste/total waste in %]

The waste throughput will be dependent on the total mass flow of fuel: there are kilns which are licensed to substitute 100% of its conventional fuel with organic hazardous wastes. For POP's waste a responsible throughput from a few tens of kg per hour to several thousand kg per hour can be expected. As rule of thumb, chlorine should usually be limited to 350 to 500 g/t cement clinker for a kiln without by-pass and 400 to 750 g/t for a kiln with by-pass. See also under 2, 3 and 5. Important is that the process owner needs to know the chlorine tolerance of the process in question.

7. Wastes/Residuals:

7.1 Secondary waste stream volumes:

In the cement industry levels of alkalis, sulphur and chlorides (volatile components) in the product clinker are controlled to achieve the required quality of the product cement. In some cases, construction standards impose an alkali specification of 3 kg/m³ of concrete because of the risk of alkali-aggregate reactions and thus the alkali content of the cement is limited. Volatile components can also be a problem in the kiln system, as high levels can cause blockages in pre-heater cyclones or form rings in the in the rotary kiln inlet zone.

The cement industry has several options to control clinker alkali content. The control of the alkali content of the input raw materials can be used but the practicality of this depends on the availability of low alkali raw materials.

7.2 Off gas treatment

In wet cement kilns, some of the volatile components evaporate in the sintering section but condense in the drying zone on the fine particulate matter. Hence, if an electro static precipitator (ESP) is used for particulate arrestment, the finer proportion of the cement kiln dust (CKD) containing the highest concentration of volatile components can be removed whilst the remaining dust is recycled. Complete recycling can be achieved by introducing CKD into the rotary kiln by using specially designed scoops in the cylindrical walls of the kiln or, more frequently by injecting CKD into the burning zone of the kiln (insufflations). In dry process kilns, CKD is usually reintroduced into the raw meal or may be fed directly to the cement mill.

The inherent absorption capacity of pre-heater dry cement kilns can cause problems with blockages in the cyclone systems caused mainly by build-ups of volatile components. One option to curtail volatile component levels is by bypassing part of the particulate laden gas stream out of the kiln back end away from the cyclone system and condensing the volatiles by cooling. Bypasses of 10-30% of the kiln gas flow are typical. This bypass stream can be high in pollutants (particulates and sulphur oxides) and must be treated separately.

Both kiln dust and bypass dust are in most cases returned to process providing clinker alkali levels are controlled. When this is not possible dust is sent to controlled landfills or sold as binder for waste stabilisation or other purposes.

7.3 Complete elimination:

See under 2, 3 and 5.

Reliability:

Cement production is a continuous process and a cement kiln is normally shut down a few weeks per year due to

Cement Kiln Co-Processing (High Temperature Treatment)

maintenance.

Limitations:

The feasibility of a cement kiln for treatment of POP's should be investigated by experts on a case by case basis. There are kilns which are not recommended to use for POP's treatment, for example vertical shaft kilns or kilns with improper environmental performance. The chlorine tolerance of a kiln differs widely due to process constraints, but as rule of thumb, chlorine should usually be limited to 350 to 500 g/t cement clinker for a kiln without by-pass and 400 to 750 g/t for a kiln with by-pass.

Transportability:

Cement kilns are fixed constructions.

Detailed information:

See for example World Business Council for Sustainable Development, Cement Sustainability Initiative, which has links to the major companies:

<http://www.wbcsd.ch/templates/TemplateWBCSD1/layout.asp?type=p&MenuId=MTI2&doOpen=1&ClickMenu=LeftMenu>

Full Scale treatment examples:

See under Performance

Conclusion:

POP's can be destroyed safely and environmentally sound in technical and chemical feasible cement kilns with trained staff.

Detailed information and treatment examples:

In the separate Annex the following information is given:

8. Table 1: Technology Overview – Summary Technical Details

Table 2: Overview Project Experience per Technology Supplier

Table 3: Overview detailed project information per project – Project name (from Table 2)

Cement Kiln Co-Processing (High Temperature Treatment)

PART II: Criteria on the Adaptation of the Country to the Technology

Note: This part or any present gaps have to be filled in every time the "suitability" of the technology has to be examined for a certain country situation!!

Part II is not applicable for cement kilns for the following reasons:

A cement plant is already in place and the purpose of the plant is to produce cement, but by coincidence rotary cement kiln possess many inherent features which makes it ideal for hazardous waste treatment; high temperatures, long residence time, surplus oxygen during and after combustion, good turbulence and mixing conditions, thermal inertia by high flows of high temperature materials, counter currently dry scrubbing of the exit gas by alkaline raw material in dry preheater and precalciner kilns, fixation of the traces of heavy metals in the clinker structure, no production of slag, ashes or liquid residues from exit gas cleaning and complete recovery of energy and raw material components in the waste.

A cement plant can be used beneficially if found **suitable** and sound, preferably by independent experts. Together with sufficient competence and personal protective equipment, this is the key question.

The factors listed part II are already present for the production of cement and cannot be changed anymore if it is investigated at a certain stage if hazardous waste and POPs can be treated or not.

Questions on energy use or water consumption are not relevant in this case. Investigations are commonly made by authorities or companies for existing cement kilns if they are suitable to treat certain hazardous wastes. The cement kiln has to be investigated further because raw material conditions, technology, chemistry etc will be site specific.

Therefore only a limited number of issues have been dealt with in this part.

A. Resource needs:

1. Power requirements :

2. Water requirements:

3. Fuel volumes:

4. Reagents volumes:

No reagents

5. Weather tight buildings:

6. Hazardous waste personnel requirement:

7. Sampling requirements/facilities:

8. Peer sampling:

These requirements are covered in the permits

9. Laboratory requirements:

10. Communication systems:

On site requirements:

Mobile network:

Requirements in country:

Fixed network:

As the plant is co-processing Hazardous waste, it is obligatory that all materials going into the plant are analyzed and a laboratory is necessary

11. Number of personnel required:

11.1 Number of Technicians required (skilled labour):

11.2 Number of Labourers required (unskilled labour):

B. Costs:

The reason that cement plants are taking waste is usually to save costs. In general the cement plants are cheaper, but this may not be the case with POPs because the monitoring and control requirements will add to the costs significantly. If a plant decides to go in hazardous waste co-processing, the owner will do these investments themselves. The listed experience in Vietnam for example and the prices offered by the cement plant need to be competitive to the market, independent of the investment.

1. Installation and commissioning costs [US Dollars or EUROS]:

2. Site preparation costs [US Dollars or EUROS]:

See above

3. Energy & Telecom installation costs:

4. Monitoring costs:

Must be covered by the owner and will be specified in the permit

5. Complying costs:

6. Reporting costs:

7. Running costs with no waste:

8. running costs with waste:

Cement kilns run in principle always without waste as their objective is to produce cement.

Not relevant for cement kilns

9. Decommissioning costs:

10. Landfill costs:

Not applicable

Depending on local situation – should be filled in for the concerned country

11. Transport costs of residues:

Depending on local situation – should be filled in for the concerned country

Cement Kiln Co-Processing (High Temperature Treatment)

C. Impact:

1. Discharges to air:

Cement plant emit CO₂, NO_x, SO₂ and dusts, but these emissions have to comply with emission limit values which are different from country to country, but the emission limits have always to be met independently of the fact if waste co-processing takes place or not.

Normally there are no materials disposed. One has to think that a cement plant is a production plants and most of the materials are fed back into the process instead. If disposal is needed then this is regulated in the permit.

3. Discharges to land:

CKD's are in some plants disposed in landfill (secure)

4. Soil impact (noise etc):

2. Discharges to water:

None

D. Risks

1. Risks of reagents applied:

2. Risks of technology:

3. Operational risks:

E. Constructability:

Cement kilns are already available in the concerned country

1. Ease of installation/construction of plant:

Not applicable here. Plants are in the country when one starts looking for treatment options

3. Ease of operation:

A cement kiln co-processing hazardous waste has its own staff and department for this.

2. Ease of shipping/transit:

Not applicable

4. Ease of processing :

A cement kiln co-processing hazardous waste has its own staff and department for this. They will produce the fuel blend which is proper for the process and the chemistry.

F. Output/generation waste:

1. Generated waste (% of input waste)

Sometimes CKD are disposed.

3. Waste quality properties (pH, TCLP)

2. Deposited waste at landfill (% of input waste)

See under C.1.

**Note: This Technology Specification and Data Sheet (TSDS) does not certify any particular technology, but tries to summarise the state of the art of the concerned technology on the basis of data delivered by the organisations or other sources, which have been made available to the author and refers the reader to original documents for further evaluation. Without the efforts below listed technology suppliers it would not have been possible to set up this TSDS. Date: 20.04.2005*

3. Technology suppliers that have contributed to this TSDS:

Kare Helge Karstensen, Foundation for Scientific and Industrial Research, SINTEF, Norway

Web sites:

See for example World Business Council for Sustainable Development, Cement Sustainability Initiative, which has links to the major companies:

<http://www.wbcds.ch/templates/TemplateWBCSD1/layout.asp?type=p&MenuId=MTI2&doOpen=1&ClickMenu=LeftMenu>

The European Cement Association Cembureau: <http://www.cembureau.be/>

The American Cement Association: <http://www.cement.org/>

The Cement Association of Canada:

<http://www.cement.ca/cement.nsf>

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CEMENT KILN CO-PROCESSING (HIGH TEMPERATURE TREATMENT) – ANNEX TO POPS TECHNOLOGY SPECIFICATION AND DATA SHEET

9. Table 1: Technology Overview – Summary Technical Details

TECHNOLOGY PROVIDER	TECHNOLOGY	SCALE +	COMP. TREATED	RELATED COMPOUND TREATED	VALIDATION PROJECT EXPERIENCE **	APPLICABILITY RANKING++	ADDITIONAL REMARKS	OTHERS
ST. LAWRENCE CEMENT PLANT (CANADA)	WET PROCESS CEMENT KILN HIGH TEMPERATURE TREATMENT	F	VARIOUS CHLORINATED WASTE STREAMS			DA	SERIES OF TESTS	
STORA VIKÅ CEMENT PLANT (SWEDEN)	WET PROCESS CEMENT KILN HIGH TEMPERATURE TREATMENT	F	VARIOUS CHLORINATED WASTE STREAMS SUCH AS PCB'S, CHLOROPHENOLS, AND PHENOXYACIDS			DA	TEST BURN IN 1978	
UNIDENTIFIED	ONE WET AND ONE DRY PROCESS CEMENT KILN HIGH TEMPERATURE TREATMENT	F	ORGANIC CONSTITUENTS SUCH AS METHYLENE CHLORIDE, 1,1,2-TRICHLORO-1,2,2-TRIFLUOROETHANE (FREON 113), METHYL ETHYL KETONE, 1,1,1-TRICHLOROETHANE, TOLUENE			DA	TRIAL BURNS IN THE 1980S	
UNIDENTIFIED	DRY PROCESS EQUIPPED WITH PREHEATER	F	CARBONTETRACHLORIDE, TRICHLOROBENZENE				TRIAL BURNS IN THE 1990S	
TWIGA CEMENT FACTORY, TANZANIA	TRIAL BURN	F	4,6-DINITRO-O-CRESOL (DNOC)				TRIAL BURN 1993-1996 (W. SCHIMPF, 1999)	
United Cement		F					DRE TESTING IN 1990S	
Colombia	DRY PROCESS KILN	F					TEST BURN IN 2001	
Vietnam		F	FENOBUCARB FIPRONIL				TEST BURN AT A RATE OF 2 T/H. IN TOTAL 40,000 LITRES IN LESS THAN 20 HOURS	
+KEY: F - FULL-SCALE APPLICATIONS COMPLETED P - PILOT/DEMONSTRATION SCALE COMPLETED; NO F-APPLICATIONS					++KEY: APPLICABILITY RANKING FOR PESTICIDES DA – DIRECT APPLICABLE			

***CEMENT KILN CO-PROCESSING (HIGH TEMPERATURE TREATMENT) – ANNEX TO POPS
TECHNOLOGY SPECIFICATION AND DATA SHEET***

B - BENCH/LABORATORY SCALE COMPLETED; NO P OR F-APPLICATIONS	FS 1 – FULL SCALE WITHIN REASONABLE PERIOD POSSIBLE 0-2 YEARS
T - THEORETICAL APPLICABLE, NO B, P, F APPLICATIONS	FS 2 – FULL SCALE WITHIN CONSIDERABLE PERIOD POSSIBLE 2-5 YEARS
* VENDOR CLAIMS PERFORMANCE OF DEMONSTRATION, BUT NO DATA PROVIDED	**VALIDATION ON THE BASIS OF INFO PROVIDED IN TABLE 2 AND 3

- 9.1.
- 9.2.

CEMENT KILN CO-PROCESSING (HIGH TEMPERATURE TREATMENT) – ANNEX TO POPS TECHNOLOGY SPECIFICATION AND DATA SHEET

9.3. Table 2: Overview Project Experience per Technology Supplier

TECHNOLOGY PROVIDER	CONTAMINANTS	AMOUNT TREATED IN TONS	RESULTS INCL. DRE, PRE-TREAT, POST TREAT EMISSIONS, ENERGY CONSUMPTION, COSTS*			CLIENT REFERENCES NAME, ADDRESS, CONTACT PERSON PHONE, EMAIL, FAX
ST. LAWRENCE CEMENT PLANT (CANADA)	VARIOUS CHLORINATED WASTE STREAMS	UNKNOWN	99.986 % FOR THE CHLORINATED COMPOUNDS			Executed in mid 70s (Karstensen, 2004)
STORA VIKA CEMENT PLANT (SWEDEN)	VARIOUS CHLORINATED WASTE STREAMS SUCH AS METHYLENE CHLORIDE, PCB'S, CHLOROPHENOLS, AND PHENOXYACIDS	UNKNOWN	99.995 % FOR METHYLENE CHLORIDE 99.9998 % FOR TRICHOETHYLENE 99.99998 % FOR PCB'S NO TEQ DIOXINS OR FURANS COULD BE DETECTED			Executed in 1978 (Karstensen, 2004)
Unidentified	ORGANIC CONSTITUENTS SUCH AS METHYLENE CHLORIDE, 1,1,2-TRICHLORO-1,2,2-TRIFLUOROETHANE (FREON 113), METHYL ETHYL KETONE, 1,1,-TRICHLOROETHANE, TOLUENE	UNKNOWN		WET PROCESS KILN	DRY PROCESS KILN	EXECUTED IN THE 1980S (KARSTENSEN, 2004)
			METHYLENE CHLORIDE FREON 113 METHYL ETHYL KETONE 1,1,TRICHLOROETHANE TOLUENE	99.983 % >99.999% 99.988% 99.995% 99.961%	99.96 % 99.999% 99.998% >99.999% 99.995%	
Unidentified	CARBONTETRACHLORIDE, TRICHLOROBENZENE	UNKNOWN	99.999% FOR CARBONTETRACHLORIDE 99.995% FOR TRICHLOROBENZENE			Executed in 1990s (Karstensen, 2004)
United Cement	SULPHUR HEXAFLUORIDE	UNKNOWN	99.9998% FOR SULPHUR HEXAFLUORIDE			Executed in 1990s (Karstensen, 2004)
Twiga Cement Factory, Tanzania	4,6-DINITRO-O-CRESOL (DNOC)	57,000 LITRES	ALL SAMPLES IN DUST: <0.25 MG/KG DNOC ALL SAMPLES IN CLINKER: <0.25 MG/KG DNOC 0.25 MG/KG = DETECTION LIMIT			
Colombia	PESTICIDE CONTAMINATED SOIL	UNKNOWN	>99.9999%			Executed in 2001 (Karstensen, 2004)
Vietnam	EXPIRED CHLORINATED INSECTICIDE COMPOUNDS		FENOBUCARB FIPRONIL	DRE 99.9999719 99.99998531	DE 99.99999692 99.99998321	(Karstensen, 2004, see also TSDS part I under A. Performance)

CEMENT KILN CO-PROCESSING (HIGH TEMPERATURE TREATMENT) – ANNEX TO POPS TECHNOLOGY SPECIFICATION AND DATA SHEET

9.4. Table 3: Overview detailed project information per project – Project name (from Table 2):

LOCATION PROJECT	PRE-TREAT MG/KG	POST-TREAT MG/KG	DRES	EMISSIONS 1. AIR (HCL, DIOXINS & FURANS ETC) 2. WATER, 3. WASTE (SLAGS)	ENERGY CONSUMPTION	COSTS(CAPITAL, OPERATING COSTS)	OTHERS, REMARKS
TWIGA CEMENT FACTORY, TANZANIA	20% DNOC IN DIESEL MIXTURE	ALL SAMPLES IN DUST <0.25 MG/KG DNOC ALL SAMPLES IN CLINKER <0.25 MG/KG DNOC 0.25 MG/KG = DETECTION LIMIT		1. AIR: CO (MG/M ³)=271-280 NOX (MG/M ³)=594-1115			
	PCB'S, CHLOROPHENOLS, AND PHENOXYACIDS AVERAGE CHLORINE CONCENTRATION 17%			NO DETECTABLE QUANTITIES FOR DIOXINS AND FURANS CONTAINING 4 OR 6 CHLORINES WERE FOUND			
VIETNAM		RAW MEAL, THE PRODUCT CLINKER, FINE COAL, ELECTRO STATIC PRECIPITATOR DUST AND BY-PASS DUST WAS ANALYSED FOR BOTH INSECTICIDE COMPOUNDS AND WAS FOUND TO BE LESS THAN THE DETECTION LIMIT FOR ALL SAMPLES, I.E. <u><2.0 PARTS PER BILLION</u>	>99.99999% (SEE ALSO TABLE 2)	ALL ANALYSIS RESULTS FOR PCDD/F'S, HCB AND DIOXIN LIKE PCB'S WERE BELOW THE DETECTION LIMIT			

CEMENT KILN CO-PROCESSING (HIGH TEMPERATURE TREATMENT) – ANNEX TO POPS TECHNOLOGY SPECIFICATION AND DATA SHEET

9.5. Table 4: Client References Overview project experience per technology suppliers in Canada

THIS TABLE MAKES REFERENCES TO THE CONCERNING CEMENT COMPANIES AND NOT TO THE INDIVIDUAL PLANTS. THE KNOW HOW AND EXPERIENCE IS WITH THE CEMENT COMPANIES.

Organization	Description/Notes
HOLCIM	HOLCIM, LARGEST COMPANY IN THE WORLD WITH PLANTS IN 70 COUNTRIES) WHICH IS THE MOST ADVANCED ON CO-PROCESSING OF HAZARDOUS WASTE
OTHERS ARE LAFARGE, HEIDELBERG, TAIHEYO, CEMEX	SEE FOR EXAMPLE WORLD BUSINESS COUNCIL FOR SUSTAINABLE DEVELOPMENT, CEMENT SUSTAINABILITY INITIATIVE, WHICH HAS LINKS TO THE MAJOR COMPANIES: HTTP://WWW.WBCSD.CH/TEMPLATES/TEMPLATEWBCSD1/LAYOUT.ASP?TYPE=P&MENUID=MTI2&DOOPEN=1&CLICKMENU=LEFTMENU
IN EUROPE	THE EUROPEAN CEMENT ASSOCIATION CEMBUREAU: HTTP://WWW.CEMBUREAU.BE/
IN USA	THE AMERICAN CEMENT ASSOCIATION: HTTP://WWW.CEMENT.ORG/
IN CANADA	THE CEMENT ASSOCIATION OF CANADA: HTTP://WWW.CEMENT.CA/CEMENT.NSF

Hazardous Waste Incineration

Name of Process:

Hazardous waste incineration

4. Vendors include:

A number of existing hazardous waste incineration facilities are identified within the inventory of worldwide PCB destruction capacity. (UNEP, 2001 and Draft 2004)

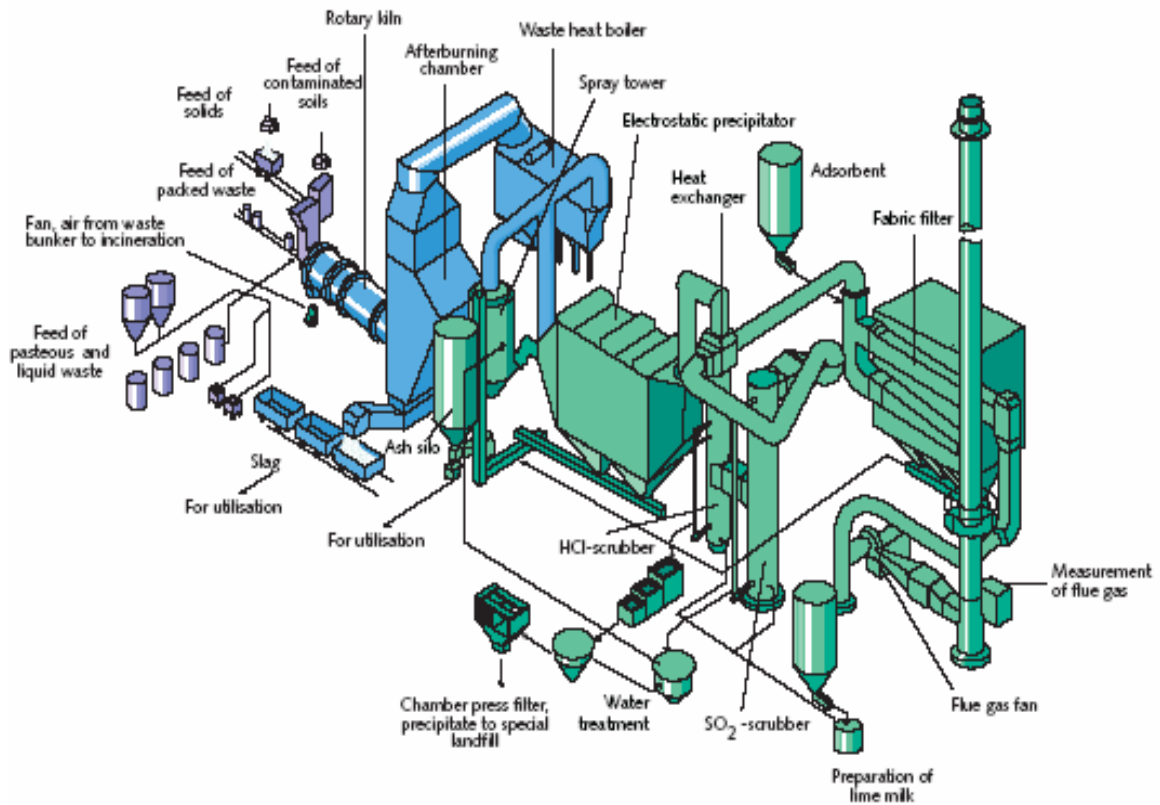
Applicable POPs wastes:

hazardous waste incinerators are capable of treating wastes consisting of, containing or contaminated with any POP. Incinerators can be designed to accept wastes in any concentration or any physical form, i.e., gases, liquids, solids, sludges and slurries. (UNEP, 1995c)

Status:

There is a long history of experience with hazardous waste incineration. (UNEP, 2001, UNEP Draft 2004)

Technology description: Hazardous waste incineration uses controlled flame combustion to treat organic contaminants mainly in rotary kilns. Typically a process for treatment involves heating to a temperature greater than 850 °C or, if the chlorine content is above 1 %, greater than 1,100 °C, with a residence time greater than 2 seconds, under conditions that assure appropriate mixing. Dedicated hazardous waste incinerators are available in a number of configurations including rotary kiln incinerators, static ovens (for liquids only). High-efficiency boilers and light-weight aggregate kilns are also used for the co-incineration of hazardous wastes (See Brunner, 2004).

Process diagram:

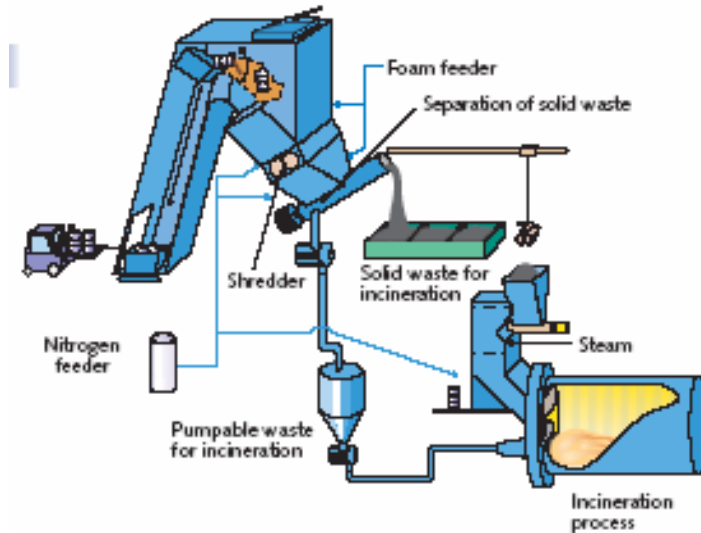
Example: Incineration plant in Finland

PART I: Criteria on the Adaptation of Technology to the Country

A. Performance:

1. Minimum pre-treatment:

Depending upon the configuration, pre-treatment requirements may include blending, dewatering, screening and shredding of wastes (UNEP, 1995c; UNEP, 1998b, UNEP, 2004c)



Example: Pre-treatment in Finland

2. Destruction efficiency (DE):

DREs of greater than 99.9999 percent have been reported for treatment of wastes consisting of, containing or contaminated with POPs. (FRTR) 2002; Rahuman et al., 2000; UNEP, 1998b and UNEP, 2001) DEs of greater than 99.999 and DREs of greater than 99.9999 per cent have been reported for chlordane and HCB (Ministry of the Environment of Japan, 2004, HIM, 2004), while DEs between 83.15 and 99.88% have been reported for PCBs (U.S. Environmental Protection Agency, 1990) and > 99,999 % in Germany (HIM, 1983-84) and > 99,99992 % (HIM, 1995)

3. Toxic by-products:

4. Uncontrolled releases:

5. Capacity to treat all POPs:

Capable of treating wastes consisting of, containing or contaminated with any POP and can be designed to accept wastes in any concentration or any physical form, i.e., gases, liquids, solids, sludges and slurries.(UNEP, 1995c)

Compounds treated:

6. Throughput:

6.1 Quantity [tons/day, L/day]

Hazardous waste incinerators can treat between 30,000 and 100,000 tons per year.

Full-Scale Plants Example Germany: 2 rotary kilns with a total capacity of 110 000 t/year for solid, fluid, paste, gaseous and in drums packed hazardous wastes

Semi-Mobile Plants:

Portable Plants: are applied in Poland with a capacity of 300 kg/h for a calorific value of waste 24 MJ/kg and at present in Latvia a container-based Incineration system (CIS) with a capacity of 2000-4000 t/y depending on calorific value of waste. Waste can contain to 2.5 % Sulphur and to 10% halogen (mostly chlorine).

6.2 POPs throughput : [POPs waste/total waste in %]

max 10% Chlorines or halogens

7. Wastes/Residuals:

7.1 Secondary waste stream volumes:

very low PCDD and PCDF discharges to water.(UNEP, 1995c; UNEP, 1998b; UNEP, 2004c) PCDDs and PCDFs are mainly found in fly ash and salt, and to some extent in bottom ash and scrubber water sludge

Example German installation: ashes 237 kg/t, filter ashes, filter dust 51 kg/t

Emissions include carbon monoxide, carbon dioxide, HCB, hydrogen chloride, particulates, PCDDs, PCDFs and PCBs and water vapour. Incinerators applying BAT, i.e., inter alia, designed for high temperature and equipped with prevention of reformation of PCDD/F and dedicated PCDD and PCDF removal (e.g., activated carbon filters), have led to very low PCDD and PCDF emissions to air (UNEP, 1995c; UNEP, 1998b; UNEP, 2004c).

7.2 Off gas treatment:

Process gases may require treatment to remove hydrogen chloride and particulate matter and to prevent the formation of and remove unintentionally produced POPs. This can be achieved through a combination of types of post-treatments, including cyclones and multi-cyclones, electrostatic filters, static bed filters, scrubbers, selective catalytic reduction, rapid quenching systems and carbon adsorption (UNEP, 2004c). Depending upon their characteristics, bottom and fly ashes may require disposal within a specially engineered landfill (US Army. 2003).

7.3 Complete elimination:

Detailed information and treatment examples:

Table 1: Technology Overview – Summary Technical Details

Table 2: Overview Project Experience per Technology Supplier

9.6. Table 3: Client References Overview project experience per technology suppliers

Table 4: Utilities Required for Hazardous Waste Treatment

See UNEP, 2001 and Draft 2004

PART II: Criteria on the Adaptation of the Country to the Technology

Part II is not applicable for Hazardous Waste Incineration (HWI) Plant is not specifically designed for POPs and under normal circumstances present in a country. Its presence is based on national or regional waste management plans and deals with the issue of hazardous waste management and only marginally with POPs. Therefore the data given in this Annex cannot simply be compared with the data for technologies which are specifically designed to treat POPs! This typical and state of the art Hazardous Waste Incineration (HWI) Plant with the combination of rotary kiln and secondary combustion chamber, followed by a boiler and sophisticated effective flue gas cleaning installations is able to dispose of continuously all kinds of hazardous waste: solid, liquid, gaseous, pasteous and materials in drums. The part of pesticides, packed in drums, is normally less than 1 %. Together with other POPs waste like PCB it can be sometimes up to 5 % and are often negligible compared to the total waste treated.

Questions on energy use are not relevant, as most of the plants have energy recovery and deliver energy to the public network. Therefore only a limited number of issues have been dealt with in this part.

Note: This part has to be filled in every time the "suitability" of the technology has to be examined for a certain country situation!!

A. Resource needs: Example Germany: 2 rotary kilns with a total capacity of 110 000 t/year taken per year

All numbers are given per tonne

1. Power requirements :

170 KWh/t. The installation produces in one turbine the energy itself. One part is supplied to the public Electricity network, being ca 15 % of the generated energy

3. Fuel volumes:

Only 4.4 kg/t combustion oil is used during heating up of installation after standstill. Normally the installation runs completely by means of the waste provided

2. Water requirements:

1.7 m³/t/year and the water is drawn from its own water supply well

4. Reagents volumes:

40 kg/t of 50% NaOH is used for the neutralisation of acid gases in the wet scrubber and is very much dependent on the Halogen and sulphur content of the wastes.

Activated carbon/chalk mixture is 1.5 kg/t (in the last step of the gas cleaning for traces of Dioxins and mercury

5. Weather tight buildings:

Yes

6. Hazardous waste personnel requirement:

Plant workers have been required to be trained in hazardous waste operations

7. Sampling requirements/facilities:

8. Peer sampling:

Continuous flue gas monitoring according to air pollution regulations and drainage water sampling. In some cases samples from the stack gas are taken in a discontinuous mode and analyzed by independent laboratories. In case of POPs/PTS releases it is possible to return components to the process. Fly ash tests and slag tests. All sampling according to regulations.

Some facilities monitor their gaseous releases monthly/annually to verify compliance with air discharge permit and some facilities hold and test solids and effluents prior to discharge for total organic chlorine (TOCl), total organic carbon (TOC), pH, temperature, turbidity, and heavy metals concentration.(UNEP, 2004)

9. Laboratory requirements:

A broad variety of spectroscopic, colorimetric and chromatographic techniques are used for monitoring, such as gas chromatography (GC), mass spectrometry (MS), GC/MS, inductively coupled plasma spectrometry (ICP), ion chromatography (IC), poly urethane foam (PUF) air monitoring, infra red (IR) spectroscopy, standard dust monitors, fly ash tests, slag tests, wipe tests, titrimetric methods, and mass balance analysis (UNEP, 2004).

10. Communication systems:

Mobile network:

Fixed network:

On site requirements:

11. Number of personnel required:

11.1 Number of Technicians required (skilled labour):

11.2 Number of Labourers required (unskilled labour):

B. Costs:

Rough calculation of a new plant in a country based on existing standards in Germany:

-throughput 2 x 50,000 t/Year treating solid, liquid, pastes, drums

- thermal capacity (with boiler) 2 x 22 MW

-buffer capacity for waste 5 days

would require investment ca. 50 mio US \$

plus 85 people personnel

1. Installation and commissioning costs [US Dollars]:

2. Site preparation costs [US Dollars]:

3. Energy & Telecom installation costs:

4. Monitoring costs:

Amount of monitoring dependent on regulatory

Hazardous Waste Incineration

<p>5. Complying costs: Amount of compliance testing, oversight, etc., will depend on regulatory requirements</p> <p>7. Running costs with no waste:</p> <p>9. Decommissioning costs: Not applicable</p> <p>11. Transport costs of residues: Depending on the local situation – Should be filled in by the concerned country</p>	<p>requirements</p> <p>6. Reporting costs: Amount of monitoring dependent on regulatory requirements</p> <p>8. running costs with waste:</p> <p>10. Landfill costs: Depending on the local situation – Should be filled in by the concerned country</p>
<p>C. Impact:</p>	
<p>1. Discharges to air: See Table 2 of Annex</p> <p>3. Discharges to land: See under F.2.</p>	<p>2. Discharges to water: The incinerator data listed here has an effluent free process. Others often have a specific treatment of the effluents. See Table 4 of Annex</p> <p>4. Soil impact (noise etc):</p>
<p>D. Risks</p>	
<p>1. Risks of reagents applied: 50% NaOH applied is corrosive but does not create a specific risk</p> <p>3. Operational risks:</p>	<p>2. Risks of technology: Risk are well-known and many safety reports have been made conform the Seveso II Directive</p> <p>4.</p>
<p>E. Constructability:</p>	
<p>1. Ease of installation/construction of plant: Installation of the plants is complex works which only can be done by real specialists, having in-depth experience in the construction and installation of these plants. What is your opinion about that?</p> <p>3. Ease of operation:</p>	<p>2. Ease of shipping/transit: Not applicable</p> <p>4. Ease of processing :</p>
<p>F. Output/generation waste</p>	
<p>1. Generated waste (% of input waste): ca. 30% (ashes, filter dust and active carbon)</p> <p>3. Waste quality properties (pH, TCLP): See under 2.</p> <p><i>*Note: This Technology Specification and Data Sheet (TSDS) does not certify any particular technology, but tries to summarise the state of the art of the concerned technology on the basis of data delivered by the company or other source, which have been made available to the author and refers the reader to original documents for further evaluation. Without the efforts below listed technology suppliers it would not have been possible to set up this TSDS. Date: 20.05.2005</i></p>	<p>2. Deposited waste at landfill (% of input waste) 28.8 % (consisting of ashes, filter dust and active carbon) is deposited at special landfill (Saltmines) with max dioxin content 33ng TEQ/kg for ashes and 1200 ng TEQ/kg filter dust (Recovery operation R5).</p>

5. Technology suppliers that have contributed to this TSDS:

HIM GmbH, Germany
SAVA GmbH, Germany.

References:

Brunner, C. R., Van Epp, T. D., 2004. *Plasma Arc and Other Thermal Destruction Technologies Applied to Persistent Organic Pollutants*. Incinerator Consultants Incorporated. Available at <http://members.aol.com/iciengineers>

FRTR, 2002. *Remediation Technologies Screening Matrix and Reference Guide, Version 4.0*. Available at www.frtr.gov/matrix2/top_page.html

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Rahuman, M.S.M. Mujeebur; L. Pistone; F. Trifirò and S. Miertu, 2000. *Destruction Technologies for Polychlorinated Biphenyls (PCBs)*. Available at www.unido.org

Hazardous Waste Incineration

UNEP, 1998b. Inventory of World-Wide PCB Destruction Capacity. Available at www.chem.unep.ch

UNEP, 2004. Inventory of Worldwide PCB Destruction Capacity, September 2004,

UNEP, 2001. Destruction and Decontamination Technologies for PCB and Other POPs Wastes Part III. Technology Selection Process. Available at www.basel.int

UNEP, 1995c. Technical Guidelines on Incineration on Land (D10). Available at www.basel.int

UNEP, 2004c. Draft Guidelines on Best Available Techniques and Provisional Guidance on Best Environmental Practices. Available at www.pops.int

United States Army Corps of Engineers, 2003. Safety and Health Aspects of HTRW Remediation Technologies. Available at www.usace.army.mil

INCINERATION– ANNEX TO POPS TECHNOLOGY SPECIFICATION AND DATA SHEET

10. Table 1: Technology Overview – Summary Technical Details

IMPORTANT NOTE: THE DATA GIVEN IN THIS ANNEX CANNOT SIMPLY BE COMPARED WITH THE DATA FOR TECHNOLOGIES WHICH ARE SPECIFICALLY DESIGNED TO TREAT POPS!

THIS TYPICAL AND STATE OF THE ART HAZARDOUS WASTE INCINERATION (HWI) PLANT WITH THE COMBINATION OF ROTARY KILN AND SECONDARY COMBUSTION CHAMBER, FOLLOWED BY A BOILER AND SOPHISTICATED EFFECTIVE FLUE GAS CLEANING INSTALLATIONS IS ABLE TO DISPOSE OF CONTINUOUSLY ALL KINDS OF HAZARDOUS WASTE: SOLID, LIQUID, GASEOUS, PASTEUS AND MATERIALS IN DRUMS. THE PART OF PESTICIDES, PACKED IN DRUMS, IS NORMALLY LESS THAN 1 %. TOGETHER WITH OTHER POPS WASTE LIKE PCB IT CAN BE SOMETIMES UP TO 5 % AND ARE OFTEN NEGLIGIBLE COMPARED TO THE TOTAL WASTE TREATED.

For the incineration process there is no difference by treating POPs or other kinds of hazardous wastes, which also can content higher concentrations of sulfur, chlorine, bromine, fluorine or heavy metals. Starting with checking the inventory, analyzing and the correct packaging regarding the weight of the single drums, filled with POPs in different concentrations, together with the daily incineration menu of the incinerator emission peaks are avoided. Thus you cannot see any difference in the continuous emission monitoring during POPs incineration. One reason is the big buffer capacity in the flue gas treatment installations.

TECHNOLOGY PROVIDER	TECHNOLOGY	SCALE +	COMP. TREATED	RELATED COMP TREATED	VALIDATION PROJECT EXPERIENCE **	APPLICABILITY RANKING++	ADDITIONAL REMARKS	OTHERS
SAVA, GERMANY	HIGH TEMPERATURE INCINERATION IN A ROTARY KILN WITH EFFICIENT FLUE GAS CLEANING SYSTEM	F	PESTICIDES AND PCBS			DA	RUNS SINCE 1997	
EKOEM, FINLAND	HIGH TEMPERATURE INCINERATION IN A ROTARY KILN	F	PESTICIDES AND PCBS			DA	SINCE 1987 3 UNITS	
TREDI, SAINT VULBAS, FRANCE	ONE ROTARY KILN AND ONE STATIC KILN (FOR LIQUID)	F	PESTICIDES AND PCBS			DA		
AVG ABFALL-VERWERTUNGSGESELLSCHAFT MBH, GERMANY	HIGH TEMPERATURE INCINERATION PLANT	F	PESTICIDES AND PCBS			DA	SINCE 1971 WITH 2 UNITS	
SHANKS, UNITED KINGDOM	VARIOUS HIGH TEMPERATURE INCINERATION	F	PESTICIDES AND PCBS			DA		

INCINERATION– ANNEX TO POPS TECHNOLOGY SPECIFICATION AND DATA SHEET

	PLANTS							
HIM, GERMANY	ROTARY KILN AND SECONDARY COMBUSTION CHAMBER, FOLLOWED BY A BOILER AND FLUE GAS CLEANING INSTALLATIONS	F	PESTICIDES AND PCBS			DA		
+KEY: F - FULL-SCALE APPLICATIONS COMPLETED					++KEY: APPLICABILITY RANKING FOR PESTICIDES			
P - PILOT/DEMONSTRATION SCALE COMPLETED; NO F-APPLICATIONS					DA – DIRECT APPLICABLE			
B - BENCH/LABORATORY SCALE COMPLETED; NO P OR F-APPLICATIONS					FS 1 – FULL SCALE WITHIN REASONABLE PERIOD POSSIBLE 0-2 YEARS			
T - THEORETICAL APPLICABLE, NO B, P, F APPLICATIONS					FS 2 – FULL SCALE WITHIN CONSIDERABLE PERIOD POSSIBLE 2-5 YEARS			
* VENDOR CLAIMS PERFORMANCE OF DEMONSTRATION, BUT NO DATA PROVIDED					**VALIDATION ON THE BASIS OF INFO PROVIDED IN TABLE 2 AND 3			

INCINERATION– ANNEX TO POPS TECHNOLOGY SPECIFICATION AND DATA SHEET

10.1. Table 2: Overview Project Experience per Technology Supplier

Note: There are hardly any data available of direct monitoring of POPs destruction. Mostly 1 or 2 times per year are only the legally obligatory data available and these are independent of POPs treatment

TECHNOLOGY PROVIDER	CONTAMINANTS	AMOUNT TREATED IN TONS	RESULTS INCL. DRE, PRE-TREAT, POST TREAT EMISSIONS, ENERGY CONSUMPTION, COSTS*	CLIENT REFERENCES NAME, ADDRESS, CONTACT PERSON PHONE, EMAIL, FAX																								
SAVA SONDERABFALLVERBRENNUNGS ANLAGEN GMBH, GERMANY	PCBS CONTAMINATED METALLIC EQUIPMENT ALL KINDS OF PCB MATERIALS. 100% PCB OILS, MINERAL OILS, WASTE OILS AND AQUEOUS WASHING LIQUIDS CONTAMINATED BY PCB	OBSOLETE PESTICIDES 4,100 T RELATED WASTES PCB'S, PAINTS, SOLVENTS PHARMACEUTIC AL WASTE 1999- 2004 23,000 T/Y	RESIDUES IN GENERAL: 200 KG/T SLAG 75 KG/T FILTER DUST DISPOSED QUANTITY IS < 5% OF TOTAL WASTE TREATED. IT IS NOT POSSIBLE TO FIGURE OUT THESE AMOUNTS FOR PCB TREATMENT DE'S >99.99% IN GENERAL (SUPPLIED BY SAVA, UNEP 2004))	30,000 UN approved drums with solids and 1,200 tons of liquids units per year (PCB questionnaire, UNEP, 2004)																								
EKOKEM, OY AB, FINLAND	AS ABOVE		DE>99.9999% (SUPPLIED BY EKOKEM, UNEP 2004)) CONTINUOUS FLUEGAS MONITORING	Since 1987 (UNEP, 2004)																								
Tredi, Saint Vulbas, France	AS ABOVE		RESIDUES IN GENERAL: ASH AND DUST: FEW PPM KG /T WASTE TREATED DE=99.999999% INCINERATION (SUPPLIED BY TREDI, UNEP 2004)	CAPACITY 10,000 T/Y PCB WASTE 100% PCB OILS 6,000 T/Y PERMITTED (UNEP, 2004)																								
AVG Abfall-Verwertungsgesellschaft mbH	AS ABOVE		RESIDUES IN GENERAL: 33% OF INCINERATED WASTE IS FLY ASH, SLAG AND GYPSUM DE=100% (SUPPLIED BY AVG, UNEP 2004))	Total capacity of plant 100,000 t /y																								
HIM, Germany	APRIL/MAY 2005 PESTICIDES IN DRUMS ARE DELIVERED FROM THE MINISTRY OF ENVIRONMENT OF VENEZUELA TO THE INCINERATION PLANT AND DISPOSED OF IMMEDIATELY WITHOUT ANY PROBLEM.	APPROX. 400 TONS	<table border="1"> <thead> <tr> <th>PARAMETER</th> <th>HWI 1 [MG/M³ N.DRY, 11 VOL% O₂]</th> <th>HWI 2 [MG/M³ N.DRY, 11 VOL% O₂]</th> </tr> <tr> <th></th> <th>YEARLY AVERAGE</th> <th>YEARLY AVERAGE</th> </tr> </thead> <tbody> <tr> <td>DUST</td> <td>0.24</td> <td>0.59</td> </tr> <tr> <td>CO</td> <td>20.36</td> <td>23.97</td> </tr> <tr> <td>SO₂</td> <td>1.19</td> <td>1.45</td> </tr> <tr> <td>HCL</td> <td>0.82</td> <td>0.2</td> </tr> <tr> <td>HG</td> <td>0.0013</td> <td>0.0003</td> </tr> <tr> <td>TOC</td> <td>0.82</td> <td>0.5</td> </tr> </tbody> </table>	PARAMETER	HWI 1 [MG/M ³ N.DRY, 11 VOL% O ₂]	HWI 2 [MG/M ³ N.DRY, 11 VOL% O ₂]		YEARLY AVERAGE	YEARLY AVERAGE	DUST	0.24	0.59	CO	20.36	23.97	SO ₂	1.19	1.45	HCL	0.82	0.2	HG	0.0013	0.0003	TOC	0.82	0.5	Total capacity of plant 110,000 t /y
PARAMETER	HWI 1 [MG/M ³ N.DRY, 11 VOL% O ₂]	HWI 2 [MG/M ³ N.DRY, 11 VOL% O ₂]																										
	YEARLY AVERAGE	YEARLY AVERAGE																										
DUST	0.24	0.59																										
CO	20.36	23.97																										
SO ₂	1.19	1.45																										
HCL	0.82	0.2																										
HG	0.0013	0.0003																										
TOC	0.82	0.5																										

INCINERATION– ANNEX TO POPS TECHNOLOGY SPECIFICATION AND DATA SHEET

			NO _x	128.26	130.34	
HIM, Germany	PCB INCINERATION CAMPAIGN		DESTRUCTION EFFICIENCY FOR PCB HAS BEEN CHECKED DURING PCB CAMPAIGN. THE RESULT HAS BEEN > 99.99992 %.			

INCINERATION– ANNEX TO POPS TECHNOLOGY SPECIFICATION AND DATA SHEET

10.2. Table 3: Client References Overview project experience per technology suppliers

NOTE: THESE DATA DO NOT CLAIM TO BE COMPLETE FOR ALL INCINERATION PLANTS. ONLY SOME EXAMPLES RECEIVED FROM 2 COMPANIES HAVE BEEN INCLUDED IN THE LIST

TECHNOLOGY PROVIDER	COUNTRY, EMPLOYER REFERENCES	CONTACT	COMP. TREATED	PERIOD TREATMENT	TREATMENT DATA	DESCRIPTION/NOTES
SAVA SONDERABFALLVERBRENNUNGSANLAGEN GMBH, GERMANY	EU PHARE, CONTRACT AND FINANCE UNIT, BUCHAREST, ROMANIA RAMBØLL, DENMARK SITE SUPERVISION AND ASSESSMENT INCINERATION PLANT	MS. BETTINA KAMUK	OBSOLETE PESTICIDES 300 TILL END OF APRIL 2005 (TOTAL CONTRACT 1,409 T)	2005-UNDER EXECUTION		ANALYSIS OF WASTE BEFORE TREATMENT HAS BEEN MADE
SAVA SONDERABFALLVERBRENNUNGSANLAGEN GMBH, GERMANY	SENEGAL, MAURETANIA AND CAPE VERDE	DUTCH EMBASSY, DAKAR, SENEGAL MR. FRANKE TOONSTRA, PH: +221-8490360 NIRAS, DENMARK, MR. PREBEN KNUDSEN, PH: +45 96306421	783 TONS OF OBSOLETE PESTICIDES	2003-2004		
SAVA SONDERABFALLVERBRENNUNGSANLAGEN GMBH, GERMANY	SERETARIO DE AMBIENTE Y DESARROLLO SUSTENABLE, BUENOS AIRES, ARGENTINA		200 TONS OF LINDANE CONTAMINATED SOIL	2003		
SAVA SONDERABFALLVERBRENNUNGSANLAGEN GMBH, GERMANY	EU PHARE, MANAGEMENT UNIT	GRIGOR GJECI, PH:+355 4223818 COWI: PH: +45 29254494	362 TONS OF OBSOLETE PESTICIDES	2002		
SAVA SONDERABFALLVERBRENNUNGSANLAGEN GMBH, GERMANY	HYDROGEOTECHNIKA, POLAND	JAROSLAV SURMA, FORMER MANAGER AT HYDROGEOTECHNIKA, PH:+49 1702346853	1,300 TONS OF OBSOLETE PESTICIDES	2001 – 2002		
SAVA SONDERABFALLVERBRENNUNGSANLAGEN GMBH, GERMANY	S.T.E. (SUBSIDIARY OF RWE), ITALY	PH: +390108311591	200 TONS OF OBSOLETE PESTICIDES FROM GALIATE	2000		
SAVA	S.T.E. (SUBSIDIARY	PH: +390108311591	130 TONS OF DDT	2000		

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SONDERABFALLVERBRENNUNGSANLAGEN GMBH, GERMANY	OF RWE), ITALY		SLUDGE			
HIM	VENEZUELA					

INCINERATION– ANNEX TO POPS TECHNOLOGY SPECIFICATION AND DATA SHEET

TABLE 4: UTILITIES REQUIRED FOR HAZARDOUS WASTE TREATMENT
(DATA ARE GENERAL REPRESENTATIVE FOR THE YEAR 2003, BUT NOT SPECIFICALLY FOR HIGH STRENGTH PESTICIDES WASTE)

Utility	11. Units	QUANTITY REQUIRED PER TONNE OF WASTE INPUT	12. Quantity required per year 13. (110,000 t Full- scale plant)
ELECTRICITY	KWH	170	18,700,000
ELECTRICITY PRODUCED AND SUPPLIED TO PUBLIC NET	MWH		1,700
(50%) NAOH	KG	40	4,400,000
CO2 PRODUCTION	KG	820	90,000,000
OIL	KG	4	440,000
ACTIVE CARBON /CALCIUM HYDROXIDE MIX	KG	1.4	150,000
COOLING AND SCRUBBING WATER (OWN SUPPLY WELL)	M ³	1.7	187,000
SLAG PRODUCTION	KG	215	23,600,000
FILTER DUST AND SPRAY DRYER RESIDUE	KG	46	5,100,000
PROCESSING RATE		KG/MIN	
		TONNES/MONTH	9,170
		TONNES/YR	110,000

- L CONSUMPTION: ONLY USED FOR START-UP OF THE INSTALLATION AFTER STANDSTILL, OTHERWISE THE INSTALLATION RUNS AUTARQUE ONLY WITH THE WASTE
- NAOH IS ONLY USED TO NEUTRALISE ACID GAS IN THE WET SCRUBBER, STRONGLY DEPENDING ON HALOGEN AND SULFUR CONTENT OF THE WASTE
- ACTIVE CARBON /CALCIUM MIX IS OCCURRING IN THE LAST STEP OF THE FLUEGAS CLEANING, FOR TRACES OF DIOXINE AND MERCURY)

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Base Catalyzed Decomposition (BCD)

Name of Process:

Base Catalyzed Decomposition (BCD) formerly called Base Catalyzed Dechlorination

Applicable POPs wastes:

DDT, HCB, PCBs, PCDDs and PCDFs.

BCD should be applicable to other POPs in addition to the waste types listed before (UNEP, 2004; Vijgen, 2002). BCD should be capable of treating wastes with a high POP concentration, with demonstrated applicability to wastes with a PCB content of above 30 % (Vijgen, 2002). Applicable waste matrices include soil, sediment, sludge and liquids. The owners of the process claim that it has been demonstrated to destroy PCBs in wood, paper and metal surfaces of transformers.

Status:

BCD has been used at two commercial operations within Australia, with one still operating. Approx. 8-10,000 t of PCB's and PCB contaminated oils, 25 t of Pesticide chemicals and pesticide waste, 15 t of pesticide concentrates collected from soil remediation

Another commercial system has been operating in Mexico (from 1998 till present treated 1400 tons of liquids and solids with PCB's. BCD systems have been used for short-term projects in Australia, Spain and the United States of America.

A BCD unit for the treatment of both PCDD- and PCDF- contaminated soil and pesticide wastes is tested at pilot scale and now under full scale construction within the Czech Republic. The plant will treat 35,000 t of soil and building rubble contaminated with PCDD/F, HCB & HCH. In addition to treating more than 1000 t of contaminated concentrate from the first stage thermal desorption process more than 200 t of waste pesticide intermediates will also be treated.

BCD has been successfully applied in US in the combination with thermal desorption for soil remediation. In Basque Country, Spain another system has been operating from 2000 to 2002 by IHOBE S. A. where 3500 tons of pure HCH waste has been destructed to TCB, which was used by the industry. In the US the BCD system has been successfully applied in combination with thermal desorption at the beginning of the 90's.

In Japan, a continuous process for oils with low contamination of PCB's has been developed.

The patent owners of this technology sell licences to operate the technology. Currently, licences are held by companies based in Australia, Czech Republic, Japan, Mexico and the United States of America.

Technology description:

Based on patents developed at the Cincinnati Risk Reduction Research Laboratory by C. Rogers, A. Kornel and their group from the US EPA, there have been given licenses to various vendors. Initially, the technology was developed for the destruction of halogenated compounds. With the improved chemistry, all heteroatoms other than just chlorinated (Halogenated) compounds are destroyed. For this reason the term Dechlorination in BCD has been modified to "Decomposition".

The BCD process involves treatment of liquid and solid wastes in the presence of a reagent mixture consisting of a high boiling point hydrocarbon such as number 6 fuel oil, sodium hydroxide and a proprietary catalyst. When heated to about 300° C, the reagent produces highly reactive atomic hydrogen, which cleaves chemical bonds that confer toxicity to compounds.

The residues produced from decomposition of heteroatomic compounds are carbon, and sodium salts of anions liberated during the complete decomposition reactions. After the thermal treatment reaction, the inorganic and carbonaceous solids are separated from the unreacted oil by gravity or centrifugation. The oil and catalyst may be recovered for reuse in other treatment cycles. If it is desired to further separate the solids residues, the salts and excess base can be removed from carbon residue by washing with water. The carbon residue is non-toxic, has no heteroatoms attached and can be disposed of as any non-toxic material. The BCD process has the advantages of not requiring very high temperatures, high pressure, or energetic reagents.

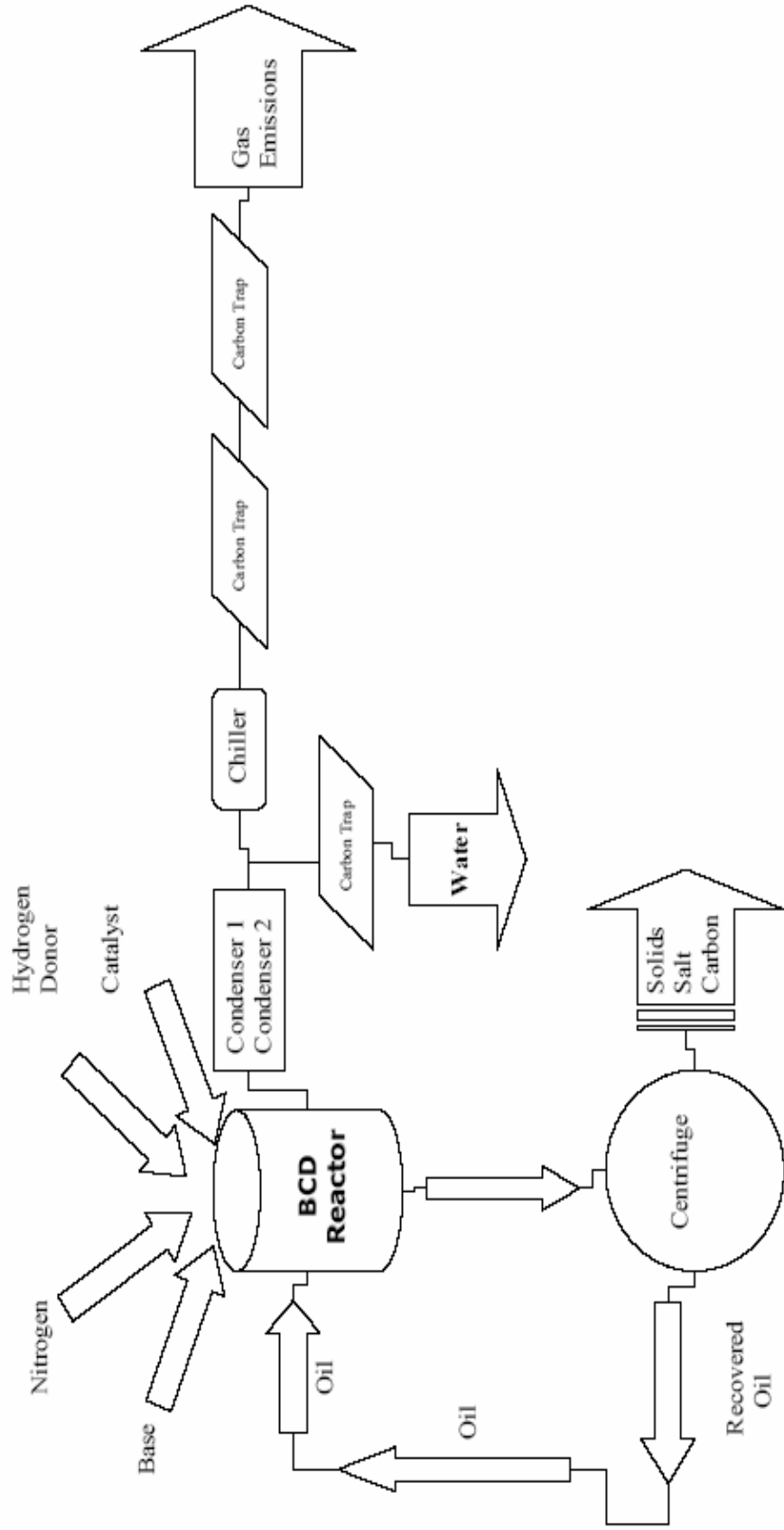
Alternatively, when pesticides or other pollutants are contaminants in soil, sediment or other solid matrices, the BCD process is linked with a pre-treatment step such as thermodesorption to remove and collect contaminants. The collected contaminates can be destroyed on-site in a mobile BCD vessel designed to treat liquids (CMPS&F, 1997, HCB Communication, 2000).

In 1997 the BCD inventors C. Rogers and A. Kornel discovered a new more effective BCD catalyst while working as visiting scientists at the USEPA Laboratory in Cincinnati, Ohio. When PCBs in 10% concentrations were treated with the original BCD catalyst, it required up to three hours to effect complete destruction of all PCB congeners. When the newly discovered BCD catalyst is employed, PCBs in 20% concentrations are destroyed within 20-30 minutes (see following Table) and 30% PCB concentrations are destroyed within 60-90 minutes.

In 2004 at the Spolana site in Czech Republic at the trial in the pilot plant, HCB waste with an organic chlorine content of 55%, dioxins in dust up to a level 1,620,000 ng/kg I-TEQ has been successfully destroyed (see under DE).

Process diagram:

BCD Process Flow



Base Catalyzed Decomposition (BCD)

PART I: Criteria on the Adaptation of the Technology to the Country

A. Performance:

Details on performance can be found in the Annex to this sheet in Tables 1-6

1. Minimum pre-treatment:

Soils may be treated directly. Different types of soil pre-treatment may be necessary:

- (a) Larger particles may need to be removed by sifting and crushed to reduce their size; or
- (b) pH and moisture content may need to be adjusted.

Thermal desorption has also been used in conjunction with BCD to remove POPs from soils prior to treatment. In these situations, the soil is premixed with sodium bicarbonate prior to being fed into the thermal desorption unit (CMPS&F, 1997). Water will need to be evaporated from aqueous media, including wet sludge, prior to treatment. Capacitors can be treated following size reduction through shredding (CMPS&F, 1997). Volatile can be presently treated in pressure reactors.

2. Destruction efficiency (DE):

DEs of 99.99–99.9999 % have been reported for DDT, HCB, PCBs, PCDDs and PCDFs. (UNEP, 2004b). DEs of greater than 99.999 % and DREs of greater than 99.9999 percent have also been reported for chlordane and HCB (Ministry of the

Base Catalyzed Decomposition (BCD)

Environment of Japan, 2004). It has also been reported that reduction of chlorinated organics to less than 2 mg/kg is achievable. (UNEP, 2001), however the vendors claim DE's achievable down to levels below analytical detection.

Latest results of the pilot-scale demonstration at Spolana (M. Kubal et al, 2004)

The efficiencies of destruction of polychlorinated dibenzodioxines and dibenzofuranes (which are the most toxic contaminants monitored) during each run of the BCD reactor were extraordinary high

Dioxin Destruction.

Material:	Inlet ng/kg I-TEQ	Outlet Oil Matrix ng/kg I-TEQ
Chemical waste	209,000	0 (Reported value)
Chemical waste	200,000	4.3
Chemical waste	11,000	0.23
Chemical waste	47,000	0
Chemical waste	35,000	0
Dust	1,620,000	0.52
Chemical waste	78,000	0
Concentrate Aqueous	96,000	0
Concentrate Organic	876,000	0

Destruction of HCB & Lindane.

Material	Inlet mg/kg		Outlet Oil Matrix mg/kg	
	HCB	Lindane	HCB	Lindane
Chemical waste	29,000	1,500	< 1.0	< 1.0
Chemical waste	200,000	900	< 2.0	< 2.0
Chemical waste	550,000	1,000	< 2.0	< 2.0
Chemical waste	270,000	1,000	< 2.0	< 2.0
Chemical waste	160,000	1,000	< 2.0	< 2.0
Dust	7,600	7	< 2.0	< 2.0
Chemical waste	1,598	19,000	< 2.0	< 2.0
Concentrate Aqueous	630	<2.0	< 2.0	< 2.0
Concentrate Organic	11,000	<2.0	< 2.0	< 2.0

The conclusions of the tests in Spolana have been formulated as follows (Kubal et al., 2004):

"The solid waste treatment strategy directed to processing of waste showing extremely high contents of polychlorinated compounds (including dioxins) was successfully presented within the pilot-scale demonstration project at former pesticides producing plant in Spolana Neratovice. The treatment system consisting of thermal treatment unit and a BCD reactor proved its capability to effectively detoxicate soil, concrete, bricks, plaster, steel and dust contaminated by polychlorinated compounds as well as to provide more than satisfactory destruction of these chemicals in their concentrated form. The demonstration results confirmed the ability of these technological processes to clean up the solid waste with extraordinary high efficiency thus providing an effective remediation tool for this heavily polluted site."

3. Toxic by-products:

The by-products are salt containing excess caustic soda and carbon. This material is disposed of to secure landfill without significant toxic properties. In addition there are small amounts of donor oil, free of both organic and inorganic chlorine recycled as fuel to licensed users. USEPA tested extensively for the formation of toxic by-products. None were detected.

4. Uncontrolled releases:

Modern plants are designed with a high degree of intrinsic safety. Vapour release pass through double condensers, chillers and double activated carbon filters before release. Pressure safety valves are routed to a containment tank.

5. Capacity to treat all POPs:

Capacity to treat all POPs. The process is not selective all organically bonded halogen groups are attacked and degraded. An extensive list of pesticides was tested. Direct treatment of capacitors is not possible and solvent extraction is required. Although some facilities shred the capacitors and treat the material with sodium hydroxide. The shredded material can be treated with the BCD process

Compounds treated:

The following have been treated on an industrial scale: all types of PCB's, PCDD/Fs, HCH, including Lindane wastes, HCB, DDT, PCP and other chlorinated phenols.

6. Throughput:

6.1 Quantity [tons/day, L/day]

Latest information in 2004, quoted that both in Mexico and in the Czech republic the BCD reactor has been sized at 10 m³

Base Catalyzed Decomposition (BCD)

volume and equipped with thermo-oil heating as against the original small electric heating. The result has been to greatly improve the relative heat up times to increase productivity so that 3 batches per 24 hours are now easily achievable and the overall productivity and throughput of such BCD units now are improved such that up to 1000 t/y of high chlorine content PCB's or pesticides (50%) can now be treated in a single line. The reactor can also treat 2000 t/y of contaminated filter dust and up to 7000 t/y of oils with moderate to low contamination of PCB's

In case larger capacities are required more reactors can be added.

Low contaminated oils can be treated at up to 5000 t/a.

Transportable plants are available with 2-5 m³ reactors. 10 m³ reactors relocatable in stead of transportable.

6.2 POPs throughput : [POPs waste/total waste in %]

30% and recently in Spolana upto 55%

7. Wastes/Residuals:

7.1 Secondary waste stream volumes:

Air emissions are expected to be relatively minor. The potential to form PCDDs and PCDFs during the BCD process is relatively low. However, it has been noted that PCDDs can be formed from chlorophenols under alkaline conditions at temperature as low as 150°C (Weber, 2004). It should be mentioned that in the Olympic site project in Australia chlorophenols and PCDD/F were treated at the same time. PCDD/F's were similarly destroyed. The operating temperature was 350 °C.

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. For further details, users are referred to the literature produced by BCD Group, Inc.

Latest development in 2004 is that the process has the choice of using low cost heavy fuel oils or refined paraffinic oils as the donor oil in the process. Heavy fuel oils can be used once only, with the used oil being fed to cement kilns after destruction of POP's. Where this option is not used it is now possible to recover and re-use 90-95% of the donor oil which greatly improves the economics of the process and reduces the production of wastes virtually to a solids stream of sodium chloride and carbon from the breakdown of the POP molecule.

Latest results at Spolana (Kubal et al., 2004):

Treatment of Solid Matrices in Upstream Desorber:

Dioxin Removal:

Material	Inlet ng/kg I-TEQ	Outlet ng/kg I-TEQ
Soil	46,500	2.9
Brick&Concrete	2,420,000	6.3
Concrete	4,780,000	66.0
Plaster	3,800	5.6

HCB & Lindane Removal:

Material	Inlet mg/kg		Outlet mg/kg	
	HCB	Lindane	HCB	Lindane
Soil	2,643	1.34	< 1.0	< 1.0
Brick&Concrete	49,000	11	< 1.0	< 1.0
Concrete	5,100	18	< 1.0	< 1.0
Plaster	270	< 1.0	< 1.0	< 1.0

Since the BCD process involves stripping chlorine from the waste compound, the treatment process may result in an increased concentration of lower chlorinated species. This can be of potential concern in the treatment of PCDDs and PCDFs, where the lower congeners are significantly more toxic than the higher congeners. It is therefore important that the process be appropriately monitored to ensure that the reaction continues to completion. In the past, it has been reported that the BCD process was unable to treat high concentration wastes because of salt build-up (CMPS&F, 1997). More recently, however, it has been reported that this problem has been overcome (Vijgen, 2002).

7.2 Off gas treatment:

Base Catalyzed Decomposition (BCD)

In addition, BCD plants are equipped with activated carbon traps to minimize releases of volatile organics in gaseous emissions.

7.3 Complete elimination:

Detailed information and treatment examples:

In the separate Annex the following information is given:

Table 1: Technology overview-Summary Technical Details

Table 2 - Part 1: Overview project experience per technology suppliers in Australia

Table 2 - Part 2: Overview project experience per technology suppliers in US and Mexico

Table 3: Overview detailed Project Information per Project – Project Name (from Table 2)

Table 4: Emissions Summary, BCD Plant in Basque Country, June 1999 – February 2001 (4)

Table 5: Brine control summary – BCD plant in Basque Country June 1999 – February 2001 (4)

Table 6: Limits set by authorities as per European Directive (90/415/EEC)

Base Catalyzed Decomposition (BCD)

PART II: Criteria on the Adaptation of the Country to the Technology

Note: This part or any present gaps have to be filled in every time the "suitability" of the technology has to be examined for a certain country situation!!

A. Resource needs:

BCD process occupies a relatively small space and so is suitable for deployment near e.g. pesticide stockpiles, provided that the local infrastructure is adequate to support the technology. Some data for the large BCD reactor system of 1000 t/y and oil recovery have been included.

1. Power requirements :

100-125 kWh/h

Energy requirements are relatively low owing to low operating temperatures associated with the BCD process.

The example for the Spolana project is taken: Here is a very reliable E-net available. For emergency back up, a diesel generator is used, namely to be able to shut down the plants safely in the rare event of a power failure.

Requirement: about 60 kWh/h emergency back up for the BCD reactors and 45 kWh/h for the ITD (Indirect Thermal Desorption).

2. Water requirements:

cooling water 10-15 m³/h

3. Fuel volumes:

Fuel gas 40 m³/h

4. Reagents volumes:

a. Hydrogen donor oil, such as No. 6 fuel oil or Sun Par oils No. LW-104, LW-106 and LW-110; → 150-200 t/year

b. Alkali or alkali earth metal carbonate, bicarbonate or hydroxide, such as sodium bicarbonate. The amount of alkali required is dependent on the concentration of the halogenated contaminant contained in the medium (CMPS&F, 1997)

Amounts range from 1 % to about 20 % by weight of the contaminated medium. Here: NaHCO₃ in soil 1-3 %. NaOH: 1.1-1.2 stoichiometric ratio to org. chlorine → for each Cl-atom 1.1 to 1.2 NaOH atoms are needed.

c. Proprietary catalyst amounting to 1 per cent by volume of the hydrogen donor oil: here 0.5 t/year

5. Weather tight buildings:

Building requirements are acc. to project and location.

Process itself has no special requirements other than rain shelter.

7. Sampling requirements/facilities:

9. Laboratory requirements:

Mainly depending on agreements and requirements of the local authorities.

It is also depending upon the target species.

On site requirements:

For PCB's or OCP's (e.g., Lindane, DDT etc.) one can install on-site GC &/or GCMS and so one can do the main QC work. Depending on agreement with authorities this could suffice before we export any materials off-site after treatment, and spot checks by external labs can be made.

For Dioxins for QC one works with a system from USA, using enzymes. Analysis time is perhaps 4 - 6h, but it is still quite expensive and not recognised by authorities. It is useful for internal QC where a local lab for dioxins does not exist.

Requirements in country:

For Dioxin, using a local lab one has a turnaround of 24 h for low resolution and within 3 days for high resolution.

By recycling the oil now one has much smaller quantities to be exported. Hence waiting time is not a problem. The reactors do not stop to wait for an answer. Only material for off-site disposal needs a regulatory analysis. This is stored in containers until cleared. One can afford to wait for a week, even longer if needed.

In the Czech Rep. one will make use of an accredited lab for all work.

11. Number of personnel required:

11.1 Number of Technicians required (skilled labour):

Operator skilled 1 per shift. This operator must be a skilled chemical operator.

11.2 Number of Labourers required (unskilled labour):

1 semi-skilled operator per shift

B. Costs:

BCD (Spolana) status mid 2004: 1400-1700 €/t for org. Chlorine cont 50% for a throughput of 150 t/month.

Operating costs will be € 850-1200/t of pure chemical waste and depreciation € 500/t of chemical waste

1. Installation and commissioning costs [US Dollars]:

2. Site preparation costs [US Dollars or EUROS]:

3. Energy & Telecom installation costs:

4. Monitoring costs:

Base Catalyzed Decomposition (BCD)

<p>5. Complying costs:</p> <p>7. Running costs with no waste:</p> <p>9. Decommissioning costs:</p> <p>11. Transport costs of residues: Depending on local situation - should be filled in for the concerning country</p>	<p>6. Reporting costs:</p> <p>8. running costs with waste:</p> <p>10. Landfill costs: Depending on local situation – should be filled in for the concerning country</p>
C. Impact:	
<p>1. Discharges to air: 2-5 m³/h, average 3.5 m³/h. 90% nitrogen and rest H₂</p> <p>3. Discharges to land: Since 2004 is that the process has the choice of using low cost heavy fuel oils or refined paraffinic oils as the donor oil in the process. Heavy fuel oils can be used once only, with the used oil being fed to cement kilns after destruction of POP's. It is now possible to recover and re-use 90-95% of the donor oil which greatly improves the economics of the process and reduces the production of wastes virtually to a solids stream of sodium chloride and carbon from the breakdown of the POP molecule. Discharge to landfill: Salt carbon residue, approx 900-1100t for 1000 t of 50% chlorine pesticides etc.</p>	<p>2. Discharges to water: none</p>
4. Soil impact (noise etc): Treated soil is usually back-filled at site	
D. Risks	
<p>1. Risks of reagents applied: (a) Hydrogen donor oil, such as No. 6 fuel oil or Sun Par oils No. LW-104, LW-106 and LW-110 (b) Alkali or alkali earth metal carbonate, bicarbonate or hydroxide, such as sodium bicarbonate can be handled with normal procedures (c) Proprietary catalyst is non hazardous and is applied in cosmetics. Working with pesticides workers wear Tyvek, gloves contained face mask and breathing filter when handling</p> <p>2. Risks of technology: In general the health and safety risks associated with operation of this technology are thought to be low (CMPS&F, 1997, Rahuman et al., 2000 in annex IV, References) although a BCD plant in Melbourne, Australia, was rendered inoperable following a fire in 1995. The fire is thought to have resulted from the operation of a storage vessel without a nitrogen blanket (CMPS&F, 1997). Some associated pre-treatments such as alkaline pre-treatment of capacitors and solvent extraction have significant fire and explosion risks, although they can be minimized through the application of appropriate precautions.(Ibid) At the present stage the risk of fire is very limited as only at one point in the process is oil above flash point in a pressure vessel under N₂ atmosphere.</p> <p>3. Operational risks: Feed to plant is automatic. Plant comes fully constructed with control unit. All skids for large plants are conform EU road transport limits. Processing is easy as operation follows with fixed recipes. Heating and pressure control are fully automatic and intrinsically safe</p>	
E. Constructability:	
<p>1. Ease of installation/construction of plant: Processing is easy as operation follows with fixed recipes. Heating and pressure control are fully automatic and intrinsically safe</p> <p>3. Ease of operation: See under 1</p>	<p>2. Ease of shipping/transit: Virtually all containerized sizes.</p> <p>4. Ease of processing :</p>
F. Output/generation waste	
<p>1. Generated waste (% of input waste) Spolana Case: for a site remediation job with an input of 35,000 t we will produce 450 t of waste either from the BCD process or material BCD cannot treat, that is less than 1.5%</p>	<p>2. Deposited waste at landfill (% of input waste) For treatment of chemicals, pesticide wastes PCB's; with about 50% organic chlorine one cannot avoid producing about 1.5 times the input of chemicals. However this material is POP's and hydrocarbons free and can be deposited in low cost landfill. pH is high due to excess NaOH. OCP's etc. are below analytical detection. Any other process claiming differently is ignoring the fact that the carbon is then going to the atmosphere and salt going away in large volumes of dilution water.</p>
3. Waste quality properties (pH, TCLP)	

Base Catalyzed Decomposition (BCD)

**Note: This Technology Specification and Data Sheet (TSDS) does not certify any particular technology, but tries to summarise the state of the art of the concerned technology on the basis of data delivered by the companies or other sources, which have been made available to the author and refers the reader to original documents for further evaluation. Without the efforts below listed technology suppliers it would not have been possible to set up this TSDS. Date: 11.03.2005*

6. Technology suppliers that have contributed to this TSDS:

BCD International, Inc., United States
Thermal and Chemical Soil Remediation Ltd (TCSR), Czech Republic
BCD Technologies Pty Ltd, Australia
S.D. Myers de Mexico

References:

CMPS&F - Environment Australia. Appropriate Technologies for the Treatment of Scheduled Wastes, Review Report Number 4 – November 1997, Canberra, Australia

HCB Communication Information Systems Documents, Background Document HCB Destruction Facility, URS Australia, Pty Ltd, 13 December 2000

Kubal¹ M., J. Fairweather², P. Crain² and M. Kuraš^{1 1)} *Department of Environmental Chemistry, Institute of Chemical Technology in Prague, Czech Republic* ²⁾ *BCD CZ, Prague, Czech Republic*, Treatment of solid waste polluted by polychlorinated contaminants (pilot-scale demonstration), presented at the 2nd International Conference held in Rhodes (Greece) from 29Sept. to 1 Oct. 2004 and published in the Proceedings from this Conference (pp.13-24).

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UNEP, 2004a. Review of the Emerging, Innovative Technologies for the Destruction and Decontamination of POPs and the Identification of Promising Technologies for Use in Developing Countries. Available at www.unep.org/stapgef/

Vijgen, John. New, emerging and/or less expensive solutions for the destruction of land contaminated with pesticides, State-of-the-Art, December 2002. Available at <http://www.ihpa.info/libraryNATO.htm>

Weber, Roland, Relevance of PCDD/PCDF Formation for the Evaluation of POPs Destruction Technologies. – PCB destruction by Super Critical Water Oxidation (SCWO)", in ORGANOHALOGEN COMPOUNDS – Volume 66 (2004)

BCD – ANNEX TO POPS TECHNOLOGY SPECIFICATION AND DATA SHEET

14. Table 1: Technology overview technology – Summary-Technical Details

TECHNOLOGY PROVIDER	TECHNOLOGY	SCAL E+	PEST COMP. TREATED	RELATED COMP TREATED	VALIDATION PROJECT EXPERIENCE **	APPLIC A-BILITY RANKIN G++	ADDITIONAL REMARKS
THERMAL AND CHEMICAL SOIL REMEDIATION LTD, (TCSR), CZECH REPUBLIC	BCD + THERMAL DESORPTION	PS + FS	HCB, LINDANE	PCDDS AND PCDFS		DA	TREATMENT OF ONE OF WORLD MOST CONTAMINATED SITES WITH DIOXINS, 2003 AND 2004 UNDER EXECUTION
BCD TECHNOLOGIES	BCD	FS	??	PCB'S		DA	PERMANENT TREATMENT FACILITY IN BRISBANE
ENTERRA (ADI)	ADOX/BCD	FS	CHLORINATED BENZENES, CHLOROPHENOLS, PESTICIDES WASTE?	DIOXINS, FURANS WASTE		DA	NORTH HOMEBUSH OLYMPIC SITE. ONLY MADE TRIALS ON CHLORO-ORGANICS (NOT PESTICIDES). ADOX/BCD BATCH PLANT UPGRADED TO 2 M3 EFFECTIVE CAPACITY TO ALLOW TREATMENT OF QUANTITY OF CHLORINATED BENZENE PRESENT
SOILTECH ATP SYSTEM	MOBILE ANAEROBIC THERMAL PROCESSOR (ATP) SYSTEM IN CONJUNCTION WITH ALKALINE POLYETHYLENE GLYCOL (APEG) DECHLORINATION	FS		PCB'S /ARACHLOR SOIL		DA	FULL SCALE 42000 T WIDE BEACH, 1991 SUPERFUND SITE IN. 2 M3 CAP. PLANT
SOILTECH ATP SYSTEM		FS		PCB'S IN SOIL		DA	OUTBOARD MARINE CORP.(OMC), 1992, SUPERFUND SITE, WAUKEGAN, ILLINOIS, IN 12,755 T CONTAMINATED SOIL & SEDIM.
ETG (THERM-O-DETOX SYSTEM) IT CORPORATION		FS		PCP IN SOIL		DA	SITE DEMONSTRATION AT KOPPERS COMPANY SUPERFUND SITE IN MORRISVILLE, NORTH CAROLINA
ETG		FS		PCB-CONTAMINATED SOIL		DA	AT U.S. NAVY FACILITIES IN GUAM 10,000 TONS OF SOIL (1994-96).
ETG		FS		SOIL CONTAMINATED WITH DIOXIN AND PESTICIDES		DA	NEW YORK STATE DEPT OF ENVIRON. CONSERV. CLEANUP SITE BINGHAMTON, NEW YORK (1997) 2,500 TONS
ETG	BCD IN CONJUNCTION WITH THERM-O-DETOX® SYSTEM	P		PCBS, DIOXIN/FURAN IN		DA	WARREN COUNTRY LANDFILL. STATE OF CAROLINA DEPT. OF

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				SOIL			ENVIRONMENT AND NATURAL RESOURCES
S.D. MYERS DE MEXICO	BCD	FS	PCB'S	PCB'S			PERMANENT TREATMENT FACILITY
+KEY: F - FULL-SCALE APPLICATIONS COMPLETED				++KEY: APPLICABILITY RANKING FOR PESTICIDES			
P - PILOT/DEMONSTRATION SCALE COMPLETED; NO F-APPLICATIONS				DA – DIRECT APPLICABLE			
B - BENCH/LABORATORY SCALE COMPLETED; NO P OR F-APPLICATIONS				FS 1 – FULL SCALE WITHIN REASONABLE PERIOD POSSIBLE 0-2 YEARS			
T - THEORETICAL APPLICABLE, NO B,P, F APPLICATIONS				FS 2 – FULL SCALE WITHIN CONSIDERABLE PERIOD POSSIBLE 2-5 YEARS			
* VENDOR CLAIMS PERFORMANCE OF DEMONSTRATION, BUT NO DATA PROVIDED				**VALIDATION ON THE BASIS OF INFO PROVIDED IN TABLE 2 AND 3			

BCD – ANNEX TO POPS TECHNOLOGY SPECIFICATION AND DATA SHEET

14.1. Table 2- Part 1:

14.2. Overview project experience per technology suppliers in Australia

14.3. BCD Technologies, Enterra-Australia

LOCATION/PROJECT	CONTAMINANTS	AMOUNT TREATED IN TONS	RESULTS INCL DRE, PRE-TREAT, POST TREAT, EMISSIONS, ENERGY CONSUMPTION, COSTS*	CLIENT REFERENCES NAME, ADDRESS, CONTACTPERSON PHONE, EMAIL , FAX
BCD TECHNOLOGIES TREATMENT PLANT, BRISBANE				
THERMAL AND CHEMICAL SOIL REMEDIATION LTD, (TCSR), CZECH REPUBLIC	HCB, LINDANE, PCDDS AND PCDFS	TO BE TREATED 200 T OF WASTE PESTICIDE CHEMICALS AND 1200-1500 T OF DIOXIN AND PESTICIDE CONCENTRATE FROM SOIL REMEDIATION	TESTS DES OF 99.99–99.9999% FOR DIOXINS	CZECH MINISTRY OF ENVIRONMENT
ADI'S ST. MARYS SITE (SYDNEY)				ADI (AUSTRALIAN DEFENCE INDUSTRY)
ADI'S FOOTSCRAY SITE (VICTORIA)				ADI (AUSTRALIAN DEFENCE INDUSTRY)
ADI MARYBYRNONG SITE (VICTORIA)				ADI (AUSTRALIAN DEFENCE INDUSTRY)
NORTH HOMEBUSH OLYMPIC SITE	CHLORINATED BENZENES, CHLOROPHENOLS, PESTICIDES, DIOXINS, FURANS WASTE	400 T TEST RUNS PCB TREATMENT: 1,06 – 4.432 T/H	PERFORMANCE TESTS DE>99.9999% FOR DDT, DIELDRIN, LINDANE AND PCP	OLYMPIC CO-ORDINATION AUTHORITY (OCA) ENTERRA, BALA KATHIRAVELU BALA.K@COMPUSERVE.COM PH: + 03 9819 0284

*IN CASE OF MORE DETAILS PER PROJECT TABLE 3 SHOULD BE USED

14.4.

14.5.

14.6.

BCD – ANNEX TO POPS TECHNOLOGY SPECIFICATION AND DATA SHEET

14.7. Table 2 – Part 2:

14.8. Overview project experience per technology suppliers in US and Mexico

14.9. SoilTech ATP System, Therm-o-Detox system and S.D. Myers de Mexico

LOCATION/PROJECT	CONTAMINANTS	AMOUNT TREATED IN TONS	RESULTS INCL DRE, PRE-TREAT, POST TREAT, EMISSIONS, ENERGY CONSUMPTION, COSTS*	CLIENT REFERENCES NAME, ADDRESS, CONTACTPERSON PHONE, EMAIL , FAX
WIDE BEACH SUPERFUND SITE	PCB'S IN SOIL	42,000		
OUTBOARD MARINE CORPORATION (OMC), SUPERFUND SITE	PCB'S IN SOIL AND SEDIMENT	12,755		
SITE DEMONSTRATION AT THE KOPPERS COMPANY SUPERFUND SITE	PCP		TREATED SOIL MET THE CLEANUP GOAL OF 95 PPM PCP AND 7 UG/ KG 2,3,7,8-TETRACHLORODIBENZO-P-DIOXIN EQUIVALENTS IN ALL TEST RUNS LTR BATCH TESTS REDUCED PCP CONCENTRATIONS BY 96.89% OR BETTER, AND TOTAL DIOXIN AND TOTAL FURAN CONCENTRATIONS BY 99.97% OR BETTER	
SMITH FARM, LOUISVILLE, KENTUCKY	PCBS, PESTICIDES AND SOLVENTS IN SOIL	30,000		
U.S. NAVY FACILITIES IN GUAM	PCBS IN SOIL	10,000		US NAVY
SITE IN BINGHAMTON, NEW YORK (1997)	DIOXIN AND PESTICIDES IN SOIL	1500 CUBIC YARDS		NEW YORK STATE DEPARTMENT OF ENVIRONMENTAL CONSERVATION
INACTIVE WOOD PRESERVING FACILITY, KALAMAZOO, MICHIGAN	PCP	220 CUBIC YARDS		
WARREN COUNTY PCB LANDFILL	PCB, DIOXIN/FURAN IN SOIL	PILOT SCALE TEST FULL SCALE UNDER EXECUTION 40,000 TONS AT PRESENT	PCB LEVELS IN SOIL WERE REDUCED FROM 259-853 PPM TO 0-2.55 PPB. DIOXIN LEVELS WERE REDUCED FROM 147-238 PPT TEQ TO 0-3 PPT TEQ. NO DATA YET	STATE OF CAROLINA DEPT. OF ENVIRONMENT AND NATURAL RESOURCES

BCD – ANNEX TO POPS TECHNOLOGY SPECIFICATION AND DATA SHEET

S.D. MYERS DE MEXICO	PCB'S	2,500-3,000 T TO DATE OF PCB CONTAMINATED OIL AND PURE PCB'S	PERMANENT TREATMENT FACILITY 2,600 GALLON BCD PLANT
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*IN CASE OF MORE DETAILS PER PROJECT TABLE 3 SHOULD BE USED

14.10. Table 3: Overview detailed project information per project – Project name (from Table 2):

LOCAT PROJECT	PRE-TREAT MG/KG	POST-TREAT MG/KG	DRE'S	EMISSIONS 1. AIR (HCL, DIOX/FURANS ETC) 2. WATER, 3. WASTE (SLAGS)	ENERGY CONSUMPTION	COSTS(CAPITAL , OPERATING COSTS)	OTHERS, REMARKS
WIDE BEACH SUPERFUND SITE	10 TO 5,000 MG/KG PCB	< 0.5 MG/KG	NR	PCB'S 1X10-5 (REQUIR. 3.3X10-5) LB/HR PEG 4.0X10-5 (REQUIR. 4.16X10-5 LB/HR PARTICULATES 0.04 (REQUIR 0.05GR/DSCF)			
OUTBOARD MARINE CORPORATION (OMC), SUPERFUND SITE	SOIL AND SEDIMENT 2,400 TO 23,000 MG/KG PCB'S	SOIL AND SEDIMENT 0.4 MG/KG TO 8.9 MG/KG PCB'S	SOIL AND SEDIMENT; AVERAGE PCB REMOVAL EFFICIENCY OF 99.98% MOST SAMPLES LESS THAN 2 MG/KG	REGULATORY REQUIREMENTS AIR - PCB'S: DESTRUCTION AND REMOVAL EFFICIENCY (DRE) OF 99.9999%, DIOXINS/FURANS: 30 NG/DSCM MET FOR DIOXINS/FURANS AFTER SYSTEM MODIFICATIONS		109 US /T + 900.000 US COSTS BEFORE TREATMENT (INCL. MOBILISATION ETC)	
SITE DEMONSTRATION AT THE KOPPERS COMPANY SUPERFUND SITE	OCDD and total HpCDD 15000 mg/kg and 2000 mg/kg resp. (1)	PCP'S 0.14 - 1.06 MG/KG (0.49MG/KG AVERAGE); OCDD AND TOTAL HPCDD CONCENTRATION S TO BELOW DETECTION LIMITS (APPROX. 20 MG/KG) (1)	PCP> 8000 MG/KG AND LESSER CONCENTRATION OF DIOXINS AND FURANS IN THE SOIL.(1) REMOVAL EFFICIENCIES OF 99.97% OR BETTER FOR PCP AND 99.56% OR BETTER FOR TOTAL DIOXINS AND TOTAL FURANS				
SMITH FARM, LOUISVILLE, KENTUCKY							

BCD – ANNEX TO POPS TECHNOLOGY SPECIFICATION AND DATA SHEET

U.S. NAVY FACILITIES, GUAM								
BINGHAMTON, NEW YORK								
WARREN COUNTY PCB LANDFILL	PCB LEVELS IN SOIL FROM 259-853 PPM DIOXIN LEVELS FROM 147-238 PPT TEQ	PCB 0-2.55 PPB DIOXIN 0-3 PPT TEQ			AIR EMISSION STANDARDS (A THE PROPERTY LINE) OF 8X10-4 UG/DSCM FOR PCBs AND 5X10-8 UG/DSM FOR DIOXINS WERE MET			
S.D. MYERS DE MEXICO	UP TO100% PCB							

TABLE 4: EMISSIONS SUMMARY, BCD PLANT IN BASQUE COUNTRY, JUNE 1999 – FEBRUARY 2001

	HCH STORE EMISSIONS				PROCESS PLANT EMISSIONS				NUMBER OF SAMPLES
	HCH CONCENTRATION MG/NM ³		TCB CONCENTRATION MG/NM ³		HCH CONCENTRATION MG/NM ³		TCB CONCENTRATION MG/NM ³		
	MEDIUM	MAXIMUM	MEDIUM	MAXIMUM	MEDIUM	MAXIMUM	MEDIUM	MAXIMUM	
1999	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	2,5	5,1	6
JULY	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	4,5	8,9	42
AUGUST	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.		44
SEPTEMBER	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.		42
OCTOBER	N.D.	N.D.	N.D.	1,3	N.D.	N.D.	<1	5,0	38
NOVEMBER	N.D.	N.D.	N.D.	N.D2,3.	N.D.	N.D.	1,5	8,7	42
DECEMBER	N.D.	N.D.	N.D.	1,1	N.D.	N.D.	N.D.	1,0	28
JANUARY 2000	N.D.	N.D.	N.D.	2,5	N.D.	N.D.	N.D.	2,4	40
FEBRUARY	N.D.	N.D.	<1	2,0	N.D.	N.D.	1	3,0	42
MARCH	N.D.	N.D.	1,8	3,6	N.D.	N.D.	2	3,8	46
APRIL	N.D.	N.D.	<1	1,9	N.D.	N.D.	1,2	2,0	16
MAY	N.D.	N.D.	N.D.	1,4	N.D.	N.D.	1,1	1,2	6
JUNE	N.D.	N.D.	1,5	1,8	N.D.	N.D.	1,2	1,3	4
JULY	N.D.	N.D.	1,1	1,2	N.D.	N.D.	1,9	2,7	4

BCD – ANNEX TO POPS TECHNOLOGY SPECIFICATION AND DATA SHEET

AUGUST	PLANT STOP FOR MAINTENANCE								
SEPTEMBER	N.D.	N.D.	1,3	1,5	N.D.	N.D.	1,5	1,5	4
OCTOBER	N.D.	N.D.	0,7	1,3	N.D.	N.D.	0,7	1,4	4
NOVEMBER	N.D.	N.D.	1,4	2,4	N.D.	N.D.	0,7	1,1	6
DECEMBER	N.D.	N.D.	1,8	1,9	N.D.	N.D.	3,7	5,9	4
JANUARY 2001	N.D.	N.D.	0,7	1,4	N.D.	N.D.	1,7	2	4
FEBRUARY	N.D.	N.D.	1,2	2,4	N.D.	N.D.	1,2	2,3	4
									426
EMISSION LIMITS FOR TCB = 20 MG/NM ³ ; HCH = 20 MG/NM ³									

14.11. Table 5: Brine control summary – BCD plant in Basque Country June 1999 – February 2001

Brine Control Summary

TCB		HCH	
Data >0	154	Data >0	1
Data = N.D.	178	Data = N.D.	353
Total data	332	Total data	354
Maximum value (mg/l)	1,4	Maximum value (mg/l)	0,15
15% of maximum value	0,21	99,7 from total data = N.D.	
81 % from total data <0,21			

ECOTOX		pH	
Total data	158	pH	6,5-9,5
Minimum value (mg/l)	127 000	PCB (mg/l)	N.D.
Maximum value (mg/l)	450 000	% Salinity	15-26%
45% of maximum value	202 500		
70 % from total data >202.500			

BCD – ANNEX TO POPS TECHNOLOGY SPECIFICATION AND DATA SHEET

TABLE 6: LIMITS SET BY AUTHORITIES AS PER EUROPEAN DIRECTIVE (90/415/EEC)

European Directive (90/415/EEC)

Medium value	TCB	HCH
Monthly (g/ Tm)	10	5
Monthly (mg/l)	1	2
Daily (g/ Tm)	20	10
Daily (mg/l)	2	4

Gas-Phase Chemical Reduction (GPCR)

Name of Process: Gas-Phase Chemical Reduction (GPCR)

Applicable Pesticides and related POPs wastes: Pesticides such as Lindane, Hexachlorobenzene, DDT, Aldrin, Dieldrin, HCBs, DDT, PCBs, dioxins and furans and other POPs.

Status: A commercial GPCR system operated in Australia for more than 5 years, treating more than 2,500 t of PCBs, DDT and other POPs. In 1999 a full-scale test on HCB was conducted using the commercial plant.

GPCR technology licensees in Japan have built and operated a semi-mobile GPCR plant for the treatment of PCB wastes.

The technology was tested as part of the ACWA (Assembled Chemical Weapons Assessment) Program for the destruction of chemical warfare agents. Through this testing the GPCR technology was proven to be effective for treatment of chemical warfare agents.

The GPCR technology can be used in conjunction with thermal desorption technologies for treatment of soil and sediment at rates of up to 10 t per hour.

The GPCR technology was selected by UNIDO for a pilot project for treatment of up to 6,000 t of PCB wastes in the Slovak Republic.

Additional approvals received:
 -for PCB and dioxin waste in Japan
 -for PCB's TSCA permit in USA
 -for PCB's and other toxic compounds in the Province of Ontario (Canada)

Technology description:

GPCR involves the reduction of organic compounds by hydrogen and some steam (which acts as a heat transfer agent and another source of hydrogen) at temperatures of 850°C or greater. Organic compounds are ultimately reduced to methane, hydrogen chloride (if the waste is chlorinated), 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, or can be taken off in acid form for reuse, if desired. Cooled, scrubbed gas from the reactor ("Product Gas") is compressed and analyzed. Product gas can then be reused as a fuel for plant components, or consumed in a burner.

The GPCR technology can be broken down into three basic unit operations: the front-end system (where the contaminants are rendered into a suitable form for destruction in the reactor), the reactor (which reduces the contaminants, now in gas phase, using hydrogen and steam), and the gas scrubbing and compression system (Figure 1). The front-end units will differ depending on the waste matrix. For example, bulk solids such as drummed chemicals, electrical equipment, spent carbon, etc., are placed into a Thermal Reduction Batch Processor (TRBP), which desorbs the contaminants from the solid material, and then conveys them to the reactor for destruction. Watery wastes and high-strength oily wastes are injected into a preheater that vaporises the liquids in an indirectly fired heat exchanger. The gases are mixed with hydrogen and steam to a temperature of 600°C prior to introduction to the GPCR reactor.

In the case of soil and sediment treatment, contaminants are first desorbed from the solids using a thermal desorption device (of which there are many proven and available worldwide). The gas containing the contaminants is then condensed, the water removed, and the remaining concentrated contaminant liquid fed to the preheater and GPCR reactor as a contaminant-concentrated liquid waste feed.

Process diagram: Block Flow Schematic:

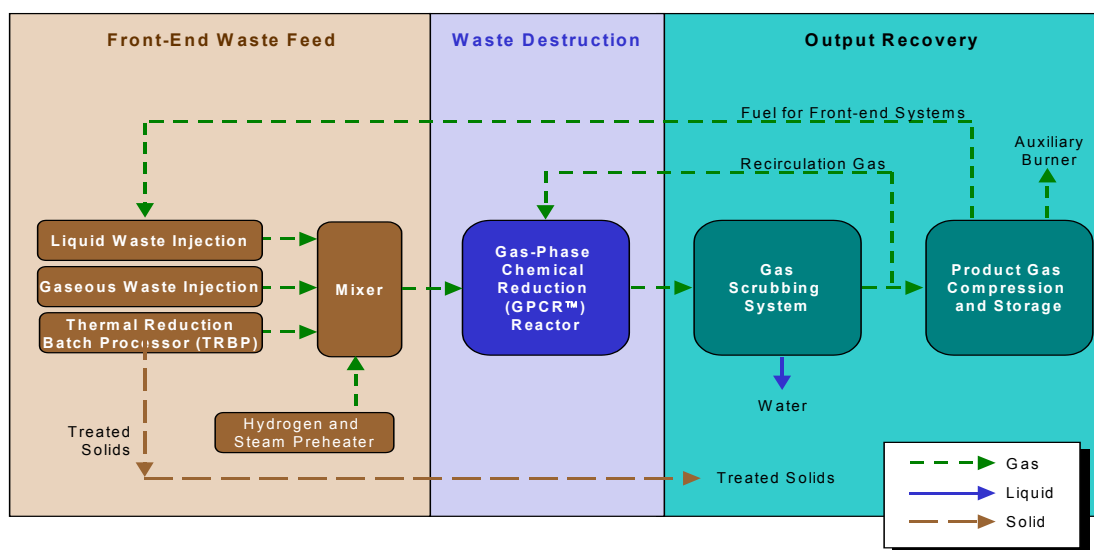


Figure 1

PART I: Criteria on the Adaptation of the Technology to the Country

A. Performance:

1. Minimum pre-treatment:

Contaminants must be in a gaseous form in order to be reduced in the GPCR reactor. While liquid wastes can be preheated and injected directly into the reactor on a continuous basis, contaminants on solids must first be volatilized from the solid. Bulk solids and drummed chemicals are placed in a TRBP, which is then heated to approximately *650°C in a hydrogen-rich (oxygen deficient) atmosphere*. In this environment the contaminants are desorbed (leaving a hazard-free solid) and are then conveyed directly to the GPCR reactor for destruction.

Because the TRBP involves minimal handling (i.e., material need not be removed from drums and does not require sorting or segregation by type), worker exposure to the chemicals is minimal.

An evaluation for the US Department of Energy (DOE) (Schwinkendorf, 1997) noted that the front-end components for introducing solids and large equipment was a limiting factor. A more recent assessment of the applicability of GPCR for chemical weapons destruction noted that the TRBP should be "completely effective in decontaminating metal components" to the stringent requirements of the ACWA program (Bizzigotti, 1999) and that "[a]n advantage of the GPCR process with regard to solids treatment is that the solids would not have to be size-reduced or shredded before being treated. Treatment could be as simple as removing the lids from the solids waste drums and treating the drums in the TRBP."

2. Destruction efficiency (DE): (See Table 2 and 3 in separate Annex)

The GPCR has treated HCBs and PCBs and DDT, other chlorinated pesticides and POPs related wastes such as dioxins and furans. The Annex provides a complete list of contaminants treated. Generally Destruction Efficiencies (DE's) of 99.999% and mostly more have been proven.

Commercially the system operated more than 5 years at Kwinana in Western Australia, treating PCBs, HCBs and DDT. Here efficiencies of at least 99.9999 % (Kummling, Gray, et al, February 2002), (Woodland, February 1999), (Eco Logic, June 8, 1998) were demonstrated. In commercial-scale performance tests in Canada, the gas-phase reduction process achieved DE and Destruction and Removal Efficiencies (DRE) with high-strength PCB oils and chlorobenzenes as shown below in Table 2 (See Annex). Dioxins that were present as contaminants in the PCB oil were destroyed with efficiencies ranging from 99.999 to 99.9999 percent (Kummling, Festarini, et al., 1997), (Kümmling, Kornelsen, 1997).

Engineering testing on batches of 3, 9 and 27 drums (205 litre size) of HCB wastes showed that, "Results of the trials indicated that the system effectively desorbed approximately 98 percent of the waste input to the TRBP. In excess of 99.9999 percent of the HCB and chlorobenzene present in the waste was volatilized in the TRBP and swept to the reactor for destruction."

Destruction efficiencies for the desorbed HCB and chlorobenzenes in the GPCR reactor were reported to be 99.99999% and 99.99999% respectively (Kümmling, Gray, et al., 2001).

3. Toxic by-products:

There are no toxic by-products produced by the technology. An evaluation for the US Department of Energy (DOE) (W. E. Schwinkendorf, 1997) noted that contaminants are "completely destroyed in the process" and that the process, "features a high degree of internal waste recycle and has no waste generating side streams."

4. Uncontrolled releases:

There have been no uncontrolled releases during use of the technology. The GPCR technology has a process control system in place that provides rigorous monitoring of all stages of the system. The necessary controls are in place such that in an upset event, the system goes into recirculation mode and no untreated waste is released

5. Capacity to treat all POPs:

The GPCR technology has treated HCBs and PCBs and DDT, other chlorinated pesticides and POPs related wastes such as dioxins and furans. In addition to more recent treatment of Lindane and 2,4-Dichlorophenoxyacetic Acid (2,4-D), the following Table provides a complete list of contaminants treated.

Gas-Phase Chemical Reduction (GPCR)

Industrial Chemicals and Manufacturing By-products				
PCBs	Dioxin and Furans	Hexachlorinated Wastes	Pentachlorophenol	
Polyaromatic Hydrocarbons				
Acenaphthene	Benzo(a)Pyrene	Chrysene	Indeno(123-cd)Pyrene	
Acenaphthylene	Benzo(b)Fluoranthene	Dibenzo(ah)Anthracene	Naphthalene	
Anthracene	Benzo(ghi)Perylene	Fluoranthene	Phenanthrene	
Benzo(a)Anthracene	Benzo(k)Fluoranthene	Fluorene	Pyrene	
Organochlorine Pesticides				
o,p'-DDE	Chlorodimeform	Endosulfan I	Mecoprop	Pirimphos ethyl
p,p'-DDE	Chlorofenviphos	Endosulphan	Metalaxyl	Procymidone
o,p'-DDD	Chloroprotham	Endosulphan II	Methiocarb	Procynidone
p,p'-DDD	Chloropyrifos	Endrin	Methomyl	Propachlor
o,p'-DDT	cis-Chlordane	Endrin Ketone	Methoxychlor	Propargite
p,p'-DDT	Coumoiphos	Ethephon	Metoxuron	Propazine
2,4,5-T	Crotoxyphos	Ethion	Metribuzin	Propoxur
a-BHC	Dieldrin	Fenamiphos	Mevinphos	Quinomethionate
a-chlordane	Diazinon	Fenitrothion	Naproamide	Quintozone
Alachlor	Dicambamethyl	Fenoprop	Nicotine	Rotenone
Aldrin	Cyanthoate	Fenthion	Nornicotine	Seccumeton
Atrazine	Dacthal	Folpet	Oxydisulfoton	Simazine
Azinphos ethyl	d-BHC	g-BHC	Parathion	SWEP
b-BHC	DCPA	g-chlordane	Pendimethalin	Technazene
Bendiocarb	DDMU	Glyphosate	Permethrin I	Terbufos
Bis-2-chloroethylether	Dichlorfuanid	Heptachlor	Phenolthiazine	Terbutryn
Bupirimate	Dichlorobenil	Heptachlor Epoxide	Phorate	Tetrachloro-m-xylene
Captan	di-Chlorovos	Hexachloroethane	Phorate Sulfone	Thiabendazole
Carbaryl	Dicloran	Lindane	Phosmet	Trans-chlordane
Carbofenthion	Dicofol	Linuron	Phosphorodithioic Acid	Triadimefon
Carbophenothion	Dimethoate	Malathion	Piperonyl butoxide	Triallate
Carboxin	Disulfoton	Manoczeb	Pirimicarb	Tridimefon
Chemical Warfare Agents and other Military Wastes				
VX	HD (Distilled Sulphur Mustard)	GB (Sarin)	DPE Suit Material (Plastic, Teflon)	
Napalm	Chemical Agent Neutralents			
Other Compounds Treated				
Benzene	Toluene	Mineral oil	Vegetable oil	

6. Throughput:

6.1 Quantity [t/day, etc]:

Throughput of the technology will depend on the scale of GPCR plant that is deployed, and the type of waste being treated. The following table gives the rough throughput estimates for different waste types. A general description of the different plant sizes follows the Table.

Waste Type	Plant	Capacity (Tonnes/yr)
PCB Oil	Semi-Mobile	840
	Full Scale	3360
CFCs and Halons	Semi-Mobile	1680
	Full Scale	6720
PCB Capacitors	Semi-Mobile	1400
	Full Scale	5600
Chlorinated Pesticides (solid and/or liquid)	Semi-Mobile	840
	Full Scale	3360

Gas-Phase Chemical Reduction (GPCR)

Full-Scale Plants:

- Full-scale plants in operation since 1995 (Kwinana: 1995 to 2000; GMCL: 1996 to 1997)
- For use at sites with large waste stockpiles, or where waste can be brought in from surrounding area
- Footprint: 4,000 m² (approximately 8 to 10 trailers)

Semi-Mobile Plants:

- Semi-Mobile plant recently constructed in Japan
- For use at sites or in regions with smaller waste stockpiles, or where mobility is important
- Footprint: 1,000 m² (approximately 4 trailers)

Portable Plants

- Small size (fits into single sea container or gooseneck trailer; 800 ft² footprint)
- Highly mobile
- First developed as a unit for conducting treatability tests
- Commercial applications are on-site, in-process treatment of manufacturing wastes and carbon filter material
- Throughput: 50 - 250 (or greater) t/year, depending on reactor configuration, chemical concentration and waste matrix

Table 5 in the Annex provides a summary of the utility requirements per tonne of pesticide waste treated. These utility requirements can be applied to any scale of plant.

6.2 POPs throughput: [POPs waste/total waste in %]

Most GPCR experience has been with the treatment of chlorinated POPs wastes (PCBs, pesticides) and to a lesser degree fluorinated wastes (chemical warfare agents and chlorofluorocarbon refrigerants). The technology has also been used to treat a small quantity of iodine waste. In general the technology is well suited and well proven for halogenated waste streams.

Of particular benefit is the fact that the waste streams do not require dilution prior to destruction using GPCR. For example, in April 1999 the technology was used to treat almost 84 percent pure hexachlorobenzene crystals using the commercial-scale GPCR plant in Kwinana; no dilution or specialized pre-treatment was required. Similarly, the refrigerant R-12 (dichlorodifluoromethane) was treated in pure form (100% strength) using the GPCR demonstration plant. This robustness is an advantage over other technologies that may require dilution of the material to accommodate the high halogen content.

Summary of high-strength POPs treated:

- Commercial testing at Kwinana, Australia: 30.3% DDT, 5.6% DDT, 96% PCBs (1995/1996)
- Commercial testing at General Motors with 50% PCBs and 30% Chlorobenzenes (1996)
- Commercial demonstration at Kwinana, Australia: 84% Hexachlorobenzene crystals (April 1999)
- Demonstration with portable plant at Rockwood, Canada: 100% dichlorofluoromethane gas (2002)
- Demonstration with portable plant at Rockwood, Canada: 100% Lindane powder (2003)

7. Wastes/Residuals:

7.1 Secondary waste stream volumes:

System outputs generated during waste treatment activities are treated solids, water and product gas, all of which are clean, reusable or disposal products. All process and waste residuals are contained and can be tested and reprocessed as necessary. No uncontrolled releases in normal operation. The USEPA recently noted that, "All outputs are stored and analyzed for regulatory compliance prior to off-site disposal or reuse." and that "The principal waste stream is the scrubber residuals which include decant water (which is recycled into the process) and scrubber particulate (which is stored and analyzed and then retreated or shipped off-site for disposal)" (US EPA, 2000). An evaluation for the US Department of Energy (DOE) (W. E. Schwinkendorf, 1997) noted that contaminants are "completely destroyed in the process" and that the process, "features a high degree of internal waste recycle and has no waste generating side streams."

The system does not produce slag or ash – the only solid process residual (other than the treated steel and other treated waste inputs) is carbon filter media, which are not a system output. When the filters are "spent", they are placed in the TRBP, which heats them to desorb contaminants, and the contaminated gas goes to the GPCR reactor for destruction. The carbon is now ready for reuse, as is common practice at GPCR commercial operations (Kümmling, 2004)

For Approximately 500 t pesticides and 1500 t PCBs in Kwinana; no PCBs or DDT detected in gaseous, liquid and solid outputs. Further during Regulatory testing Waste-specific compounds non-detected in air, solid and liquid outputs; no slag created (See Table 2 and 3 of Annex).

Gas-Phase Chemical Reduction (GPCR)

7.2 Off gas treatment:

Contaminants entering the GPCR reactor are reduced using hydrogen, heat and steam, resulting in a gas that is comprised of primarily methane, acid gases and hydrogen. This gas leaving the GPCR reactor is scrubbed in two caustic scrubber towers to cool the gas and to remove acid, water, heat and fine particulate. The acid in the gas (HCl, in the case of chlorinated wastes) can be neutralized with a caustic solution (to create a salty scrubber water), or recovered for subsequent refinement/concentration to recyclable specifications for industrial reuse.

The cooled and scrubbed product gas is a mixture of hydrogen, methane, carbon monoxide and other light hydrocarbons. Some of the product gas is reheated and recirculated back to the reactor, or through the TRBP as sweep gas. Excess product gas is removed from the system, compressed and temporarily stored. This stored product gas is chemically tested with on-line instruments and then used as fuel to heat system components such as the boiler, and as an input stream to a catalytic steam reformer as heating fuel for hydrogen generation (in situations where piped hydrogen gas is not readily available at the site). This gas meets the BIF standards for use as a fuel in the United States.

7.3 Water treatment:

During conventional hazardous waste treatment operations (PCBs, pesticides, etc.), it was permitted to dispose of scrubber water. After carbonfiltering removing any residual organics, the water could be disposed in a variety of ways, including discharge to a local irrigation system, discharge to a surface water body, and discharge to a municipal sewer. Alternatively the water can be reused as cooling water.

7.4 Complete elimination:

An evaluation for the US Department of Energy (DOE) (Schwinkendorf, et al, 1997) noted that contaminants are "completely destroyed in the process". The technology has been subjected to regulatory testing during treatment of high-strength PCB oil at a General Motors of Canada facility in Ontario, Canada. Data from this testing (provided below) was audited by the Provincial Government (the Ministry of the Environment). Data from other projects in the accompanying table has also been verified by third-party review, such as cognizant regulatory authorities in Australia and the US National Research Council. All of the data demonstrates complete destruction of the contaminants in the wastes, and safe disposal of the byproducts.

EFFICIENCY OF HALOGENATED WASTE TREATMENT USING GPCR

15. Project	15.1. Contaminant	Destruction Efficiency (%)*	Target Criteria (%)
Bay City (oily water – 3 tests)	Tetrachloroethene	> 99.99	99.99
Bay City (oil – 3 tests)	Tetrachloroethene	> 99.99	99.99
General Motors of Canada Limited (PCB Oil - 3 tests)	PCBs	99.9999996	99.9999
	PCBs	99.9999985	
	PCBs	99.9999808	
	Chlorobenzenes	99.9999836	None
	Chlorobenzenes	99.9999972	
	Chlorobenzenes	99.9999971	
PCB Oil (Kwinana Regulatory Testing)	PCBs	99.999998	99.9999
DDT in Toluene (Kwinana Regulatory Testing)	DDT	99.999984	99.9999
PCB Oil (Japanese Regulatory Testing)	PCBs	99.99998098	99.9999
	PCBs	99.9999977	99.9999
HCB Treatment Trials (HCB crystals - 3 Tests)	HCB	99.999999	99.9999
	HCB	99.999999	99.9999
	HCB	99.99999	99.9999
Refrigerant Treatment (CFC R-12 - 1 Test)	Dichlorodifluoromethane	> 99.999	99.99

*Note that these destruction efficiencies take into account contaminants in the solid and liquid outputs in addition to the stack gas. The exception may be the Japanese Regulatory Testing where we are unsure of whether solid and liquid outputs were included in the calculation.

Detailed information and treatment examples:

In the separate Annex the following information is given:

- Table 1: Technology overview-Summary Technical Details
- Table 2: Overview of Project Experience per Technology Supplier
- Table 3: Overview detailed Project Information per Project – Project Name (from Table 2)
- Table 4: Client References for GPCR Plant in Australia
- Table 5: Utilities required for High-strength Pesticides Waste Treatment
- Table 6: Comparison of Worldwide Incinerator Air Emission Standards with GPCR-Results

Gas-Phase Chemical Reduction (GPCR)

Gas-Phase Chemical Reduction (GPCR)

PART II: Criteria on the Adaptation of the country to the Technology

Note: This part has to be filled in every time the "suitability" of the technology has to be examined for a certain country situation!!

Example on basis of pesticide waste treatment at 840 t per year (semi-mobile plant) and 3,360 t per year (full-scale plant). Quantities are provided per tonne of waste treated, so that utility requirements at different scales and throughput rates can be more easily calculated. A table of utility requirements is provided in Table 5 of the Annex.

A. Resource needs:

1. Power requirement :

Power (peak) demand: 1,000 kW
2.5 MWh required per tonne of waste input to plant

3. Gas volumes (per tonne of waste input to plant):

Natural gas: 600 Nm³

2. Water requirements (per tonne of waste input to plant):

Steam: 1,500 kg
Cooling water: 500 m³

4. Reagents volumes (per tonne of waste input to plant):

Nitrogen: 75 Nm³
Carbon Dioxide: 20 kg
Caustic: 1.4 t
Hydrogen: 1,000 Nm³

5. Weather tight buildings:

GPCR plants have been run effectively in out-door environments (e.g. GMCL and Kwinana). Nevertheless, installing the equipment inside a building or portable structure is preferred, so as to minimize the amount of pad water (from rain or snow) that would require monitoring and possible treatment, and to make the working conditions more comfortable for site employees.

6. Hazardous waste personnel requirement:

For all GPCR projects to date, plant workers have been required to be trained in hazardous waste operations (e.g. 40-hour HAZWOPER training).

7. Sampling requirements/facilities:

Dependent on the specific country's regulatory requirements. For the Kwinana and GMCL full-scale operations, a portable laboratory trailer was installed on site so that rapid analysis of process samples could be carried out. Regular subsamples (e.g. 1 in 10) were sent to the regulatory authority's laboratory for confirmatory analysis.

8. Peer sampling:

See 7.

9. Laboratory requirements:

Dependent on the specific country's regulatory requirements. See 7 above.

10. Communication systems:

Dependent on the specific country's regulatory requirements. The GPCR process control system can be accessed remotely, for monitoring and troubleshooting purposes. For example, head office personnel in Canada are able to monitor systems operating in other locations, through internet access.

11. Number of personnel required:

Solids Feed (2 TRBPs)

Semi-mobile Plant: 4 people per shift
Full-Scale Plant: 6 people per shift

11.1 Number of Technicians required (skilled labour):

Solids Feed (2 TRBPs)

Semi-mobile Plant: 2 people per shift
Full-Scale Plant: 3 people per shift

Liquid/Gas Feed (1 TRBP)

Semi-mobile Plant: 2 people per shift
Full-Scale Plant: 3 people per shift

Liquid/Gas Feed (1 TRBP)

Semi-mobile Plant: 3 people per shift
Full-Scale Plant: 5 people per shift

11.2 Number of Labourers required (unskilled labour):

Solids Feed (2 TRBPs)

Semi-mobile Plant: 2 people per shift
Full-Scale Plant: 3 people per shift

Liquid/Gas Feed (1 TRBP)

Semi-mobile Plant: 1 people per shift
Full-Scale Plant: 2 people per shift

B. Costs:

1. Installation and commissioning costs [US Dollars]:

2. Site preparation costs [US Dollars]:

Estimated Capital Costs (unburdened design labour, no licensing/royalties, includes installation and commissioning, site preparation)

Two-TRBP Plant Estimate (solid feed)

Full-Scale: \$10,800,000
Semi-Mobile: \$ 5,000,000

One-TRBP Plant Estimate (liquid and gaseous feed)

Full-Scale: \$10,300,000
Semi-Mobile: \$ 4,750,000

3. Energy & Telecom installation costs:

Unknown

4. Monitoring costs:

Amount of monitoring dependent on regulatory requirements

5. Complying costs:

Amount of compliance testing, oversight, etc., will depend on regulatory requirements

6. Reporting costs:

Amount of reporting dependent on regulatory requirements

7. Running costs with no waste:

If system were to remain running but no waste input to the system, then the major cost would be that of natural gas and labour for monitoring the system (see the Annex Table 5 for a list of utility requirements – if no waste is run, then

Gas-Phase Chemical Reduction (GPCR)

hydrogen and caustic are not needed). If waste were unavailable over a long period of time, the system would be shut down. Costs would therefore vary depending on how many staff are retained, etc.

8. Running costs with waste:

Estimate of Utility and Labour Costs for Pesticide Treatment (estimates based on 2004 US utility prices)

Waste Type	Plant	Capacity (Tonnes/yr)	Estimated GPCR cost per tonne of waste feed (US\$)*	
			Utilities	Labour
Chlorinated Pesticides (solid or liquid)	Semi-Mobile	840	\$1,317	\$593
	Full Scale	3360	\$1,317	\$222

* Utility and Labour costs are marginal only; no allocation has been made for overhead or profit

9. Decommissioning costs:

Estimated at \$750,000

10. Landfill costs:

Depending on the local situation – Should be filled in by the concerned country

11. Transport costs of residues:

Depending on the local situation – Should be filled in by the concerned country

C. Impact:

1. Discharges to air: Estimate of stack gas generated

Semi-mobile Plant (70 t/month waste treated): 1.75 million m³/month
 Full-scale Plant (280 t/month waste treated): 7 million m³/month

Stack gas is comprised of 16% H₂O, 4% CO₂, 72% N₂ and 8% O₂. Stack gas is the result of the burning of product gas; product gas is tested to ensure compliance before it is burned.

2. Discharges to water: Estimate of scrubber water generated

Semi-mobile Plant (70 t/month waste treated): 140,000 kg/month
 Full-scale Plant (280 t/month waste treated): 560,000 kg/month

Scrubber water is carbon filtered to remove any residual organics, and then tested prior to discharge or reuse as cooling water. In the past, GPCR plants have been permitted to discharge scrubber water to open water bodies, municipal sewers, and irrigation systems.

3. Discharges to land:

There are no uncontrolled discharges to land. All site-generated waste is treated in the TRBP to ensure it is free of waste-specific contaminants.

Small amounts of residual carbon that may remain in the TRBP are tested and then disposed of in a landfill. During full-scale HCB treatability testing in Kwinana, full drums of HCB crystals were treated in the TRBP. Only 2% of the input mass was present following treatment. This material was tested and found to be silicon and carbon residue.

Carbon filter media is used at various locations throughout the plant, including the effluent water treatment system. Once saturated with organics, the carbon filter media is treated in the TRBP and then reused as part of regular operations. Internal and third-party testing has confirmed the viability of the TRBP for carbon regeneration.

4. Soil impact (noise etc):

D. Risks:

1. Risks of reagents applied:

GPCR reactor must be operated in a closed, contained environment. As a result, fugitive hydrogen emissions can be a serious hazard (National Research Council, 1999). The monitoring and control system on the GPCR units must ensure that no oxygen or other oxidants are present before oxygen is admitted into the system (National Research Council, 1999).

Measures to counter hydrogen risks:

In order to ensure safe use of hydrogen the company has several procedures to avoid that hydrogen becomes explosive. These procedures are carried out during waste processing to ensure safe operation:

1. Prior to any hydrogen being introduced into the system, all vessels that may contain hydrogen-rich gas are pressure tested to well above normal operating pressure, to ensure they are leak-proof. This testing includes a final test of the entire system with all vessels connected

2. All vessels which might contain hydrogen-rich gas are electrically grounded through the main power transformer on site. This ensures that even in the unlikely event that the hydrogen combines with oxygen and becomes explosive; there is no potential for spark ignition.

3. All gasketed pipeline joints that may contain hydrogen-rich gas are connected by conducting straps or structural conductors, and grounded.

4. The technology operates as a sealed, close loop system, at nominal atmospheric pressure (less than 0.4 psig).

Gas-Phase Chemical Reduction (GPCR)

Therefore, the possibility of the system rupturing due to over-pressure is extremely unlikely. Also, the low system operating pressure means that any small leaks which may occur would release very small amounts of hydrogen – too small to become explosive.

5. Rigorous procedures are followed for plant operations to ensure that hydrogen-rich gas never mixes with oxygen or air. For example, all sealed vessels in the system are completely purged and filled with nitrogen before any hydrogen enters the vessel. The vessels are monitored and hydrogen is only introduced when the levels of oxygen are well below the safe limit for a hydrogen/oxygen mixture.

6. The procedure described under 5. is also followed at the end of each waste processing cycle, when vessels full of hydrogen-rich gas need to be opened. Nitrogen gas is used in the system as a "buffer" gas between hydrogen and oxygen.

7. Once a sealed vessel is filled with hydrogen-rich gas, the system is continuously monitored for oxygen content by process operators, to ensure that any increase of oxygen in the system is immediately detected. Special actions are taken by the system operators which will correct the condition well before an explosive mixture is created. The special actions are detailed in a rigorous response procedure for operators that forms part of the Standard Operating Procedures.

8. As part of standard system operations, the air around the system is continuously monitored at numerous strategic locations for explosive conditions due to hydrogen release. Warning alarms will sound at levels well below an explosive mixture, which gives the system operators ample time to take the appropriate corrective actions

9. No open flames are permitted

2. Risks of technology:

A primary design criteria of GPCR plants is the prevention of any releases of hazardous materials that would put environmental and public safety at risk. It is for this reason that Product Gas is compressed and stored prior to test and release to the Product Gas Burner. Product Gas must meet specific contaminant level criteria otherwise it is re-circulated back to the reactor for reprocessing or further reduction. Another example is that the entire system is designed to be a low pressure (2-8 kPa normal operating pressure) system. Operating at slightly above atmospheric pressure ensures that any potential leaks have a minimal impact.

The design features that protect against the release of hazardous materials can be divided into three categories: physical systems, procedural systems and process control systems. Physical systems are actual physical controls or barriers that prevent final release to the environment (i.e. the pad). The procedural systems are standard industry practices for both operators and management that ensure that environmental and public safety are an integral part of operations and design (i.e. HAZOPs). The process control systems are the instrumentation and interlocks that ensure that process limits are not exceeded (i.e. ESD routine).

3. Operational risks:

Operational risks are minimized by the process control system. The process control system that forms part of the general system safety and control for GPCR plants includes all the instrumentation, measurement devices, computers and software that are used to observe and control the operation of the facility. The entire system that consists of the electronic eyes, ears and fingers of the facility contribute greatly to the general safety and control of each facility. In the following section the Process Control Systems currently in place to ensure that the system operates with the critical ranges is described. Conditions outside the ranges will cause the process control system to alert the operator, so that corrective action can be taken. These are the standard operating conditions of the full-scale unit, and have been fully evaluated and tested as part of routine operations over the past 9 operating years.

In addition, Hazards and Operability reviews of the system have been conducted on GPCR plants during their development to identify areas that require redundancy for safety purposes. Redundant instrumentation is in place to measure temperature and pressure for key components (e.g. oxygen analyzer, process gas monitoring). The gas scrubbing system is equipped with redundant pumps to ensure that there is adequate cooling water at all times. Throughout the system there are isolation valves, block and bleed valves as well as several redundant valves and pipes. These valves and pipes allow facility operators to change equipment while on-line, drain lines, fix measurement devices and conduct regular maintenance activities without risk. Process controlled valves have "back-up" hand valves that can be manually operated in the event of a process control problem. Valve and pipe redundancies allow operators to re-route product gas should a blockage or equipment failure require it.

In the event of a fire, all sources of flammable gas to the process (i.e. hydrogen, propane, etc.) are shut off via the Emergency Shutdown Devices (ESDs), and the process is put into automatic shutdown mode. ESDs are located at key positions throughout the site.

Process Control System

15.2. Safety and Control Benefit

Process Control Computer

Each GPCR facility is automatically controlled through a process control system and computer. This system

Gas-Phase Chemical Reduction (GPCR)

ensures that the operators can control the plant from a computer in the Process Control trailer. Facility instrumentation and measuring equipment are directly linked to the process control computer and allow the operator to view the performance of the plant in its entirety. Process control valves and "enable" switches throughout the facility as well as the burner control systems allow the operators to adjust flows, motor speeds, burner settings, pressures and temperatures directly from the process control computer. All automatic systems have back-up manual valves. The process control computer is linked to the alarm system described below.

In the event of an emergency shutdown, the process computer automatically activates a shutdown routine by means of the Emergency Shutdown Devices (ESD) located throughout the facility.

Facility instrumentation

Throughout each facility, temperature, pressure and flow elements are linked directly to the process control computer. This instrumentation provides the operators and the process control computer with the raw data necessary to run the facility safely and effectively. This data is stored historically within the process control computer for future analysis and review.

Many facility instruments have a redundant, "stand alone" instrument not connected to the process computer. This allows for system verification and safe facility shutdown in the event of process control computer failure.

System measuring equipment

Product Gas is measured in two key locations: after the scrubber system and off the product gas storage tank. Measurement is done by on-line micro GCs that are linked to the process control computer. This allows for continuous monitoring of product gas (both immediately after processing and in compressed storage) for specific compounds indicative of incomplete destruction of waste. Product gas that is outside normal operating maximums is re-routed to the reactor for reprocessing.

Measurement data is stored historically within the process control computer for future analysis and review.

Alarm system

Automatic process alarm for pressure outside pre-set normal operating range, oxygen content in system gas outside normal operating range, temperatures outside of normal operating ranges, concentration of indicator compound in exceedance of normal operating maximum.

All alarms are recorded both within the process control computer and on an on-line printer. In this way, all alarm situations can be reviewed and compared with the trend and recording system.

E. Constructability:

1. Ease of installation/construction of plant:

2. Ease of shipping/transit:

See also under Throughput under Semi mobile and portable plants. The DOE review of the full-scale plant (Schwinkendorf, 1997) noted that, "The process is offered commercially as an integrated transportable (7-10 trailers) system for on-site hazardous waste treatment." And Bizzigotti et al commented, "The GPCR is a robust system that should be able to withstand transportation and other motion- or vibration-induced stresses. In addition, system integrity checks that will be performed prior to operation should detect leaks and other minor damage caused by transportation." (Schwinkendorf, 1997).

3. Ease of operation:

The GPCR technology is not very different than any other chemical process. The process design includes many parameters that must be measured and controlled and the process control computer ensures that all parameters stay within their appropriate ranges. From the operators point of view the system is easy to operate because the actual control of the system occurs seamlessly in the background.

4. Ease of processing:

Processing of the waste is very straightforward but the pre and post processing can vary depending on the type of waste. Liquid wastes are easily handled and often no post processing is required. For bulk solids such as capacitors, they must be punched, drained, and loaded into the TRBP. After processing they must be unloaded and sampled to prove they are clean before final disposal.

F. Output/generation waste

1. Generated waste (% of input waste):

System outputs generated during waste treatment activities are treated solids, water and product gas, all of which are clean, reusable or disposal products. All of the solid wastes are suitable for landfill and this amounts to about 2% of the organic waste input.

3. Waste quality properties (pH, TCLP):

All wastes generated by the GPCR process in the past have met local regulatory requirements for discharge.

2. Deposited waste at landfill (% of input waste):

The deposited waste at landfill amounts to about 2% of the organic waste input. If solid wastes are treated than 100% of the inorganic portion of the waste will also be a residual and must be deposited at landfill or recycled.

Gas-Phase Chemical Reduction (GPCR)

-Liquid effluents were permitted to discharge to open water, municipal sewers, and to irrigation systems. Typical analysis: pH 7-9, TDS<1000, Temp<35C
-Solid effluents met criteria for TCLP

**Note: This Technology Specification and Data Sheet (TSDS) does not certify any particular technology, but tries to summarise the state of the art of the concerned technology on the basis of data delivered by the companies and technology suppliers or other sources, which have been made available to the author and refers the reader to original documents for further evaluation. Without the efforts below listed technology suppliers it would not have been possible to set up this TSDS. Date: 25.03.2005*

7. Technology suppliers that have contributed to this TSDS:

Bennett Environmental, Canada
Hallett Environmental and Technology Group, Canada

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GPCR– ANNEX TO POPS TECHNOLOGY SPECIFICATION AND DATA SHEET

16. Table 1: Technology Overview – Summary Technical Details

TECHNOLOGY PROVIDER	TECHNOLOGY	SCALE+	PEST COMP. TREATED	RELATED COMP TREATED	VALIDATION PROJECT EXPERIENCE**	APPLICABILITY RANKING++	ADDITIONAL REMARKS	OTHERS
ECO LOGIC	GPCR	F	DDT AND MIXED	PCBS		DA	COMMERCIAL OPERATION OF FULL-SCALE GPCR PLANT TREATING DDT, PCBS AND OTHER ORGANOCHLORINE PESTICIDES	
ECO LOGIC	GPCR	F	HCB			DA	COMMERCIAL-SCALE ENGINEERING TRIAL TREATING INCREASING QUANTITIES OF HCB	
ECO LOGIC	GPCR	F		PCBS		DA	TREATMENT OF PCB-CONTAMINATED MATERIAL INCLUDING ELECTRICAL EQUIPMENT, OIL (ASKAREL), CONCRETE, PERSONAL PROTECTIVE EQUIPMENT, AND OTHER DUNNAGE.	
ECO LOGIC	GPCR		DDT, DDD, DDE SOIL			DA	TREATABILITY TESTING ON PESTICIDE-CONTAMINATED SOIL FROM THE NAVAL AIR STATION PATUXENT RIVER SITE, MD.	
+KEY: F - FULL-SCALE APPLICATIONS COMPLETED						++KEY: APPLICABILITY RANKING FOR PESTICIDES		
P - PILOT/DEMONSTRATION SCALE COMPLETED; NO F-APPLICATIONS						DA – DIRECT APPLICABLE		
B - BENCH/LABORATORY SCALE COMPLETED; NO P OR F-APPLICATIONS						FS 1 – FULL SCALE WITHIN REASONABLE PERIOD POSSIBLE 0-2 YEARS		
T - THEORETICAL APPLICABLE, NO B, P, F APPLICATIONS						FS 2 – FULL SCALE WITHIN CONSIDERABLE PERIOD POSSIBLE 2-5 YEARS		
* VENDOR CLAIMS PERFORMANCE OF DEMONSTRATION, BUT NO DATA PROVIDED						**VALIDATION ON THE BASIS OF INFO PROVIDED IN TABLE 2 AND 3		

16.1.
16.2.

GPCR– ANNEX TO POPS TECHNOLOGY SPECIFICATION AND DATA SHEET

16.3. Table 2: Overview Project Experience per Technology Supplier

LOCATION/PROJECT	CONTAMINANTS	AMOUNT TREATED IN TONS	RESULTS INCL. DRE, PRE-TREAT, POST TREAT EMISSIONS, ENERGY CONSUMPTION, COSTS*	CLIENT REFERENCES NAME, ADDRESS, CONTACT PERSON PHONE, EMAIL, FAX
KWINANA, WESTERN AUSTRALIA - ROUTINE OPERATIONS AND REGULATORY TESTING	DDT (IN A TOLUENE MIXTURE); OTHER ORGANOCHLORINE PESTICIDES; PCBS	APPROXIMATELY 500 TONS PESTICIDES, 1500 TONS PCBS	REGULATORY TESTING RESULTS: DESTRUCTION EFFICIENCIES OF 99.999984% AND 99.999968 % FOR DDT AND 99.999998% FOR PCBS (TAKES INTO ACCOUNT GASEOUS, LIQUID AND SOLID OUTPUTS); NO PCBS OR DDT DETECTED IN OUTPUTS.	PLEASE SEE LIST AT END OF TABLES.
KWINANA, WESTERN AUSTRALIA – PILOT- AND COMMERCIAL-SCALE TREATABILITY TESTING	PILOT TESTING – LABORATORY-SCALE STUDY TREATING PURE HCB SOLID AND MIXED HEXACHLORINATED SOLID	PILOT TESTING: TREATMENT OF 2 SAMPLE TYPES: PURE HCB AND SOLID CONTAINING 66% HCB, 17% HCB, 2% HCE, 15% UNKNOWN ENGINEERING TRIALS: TOTAL OF 8 TONS OF HCB WASTE	PILOT TESTING RESULTS: ` DESTRUCTION EFFICIENCIES FOR BOTH WASTE SAMPLES WAS 99.9999% FOR HCB; NO ANALYSED HEXACHLORINATED COMPOUNDS WERE DETECTED IN POST-TEST SCRUBBER WATER. COMMERCIAL-SCALE ENGINEERING TRIAL: DESTRUCTION AND REMOVAL EFFICIENCIES FOR HCB IN TESTS 1, 2, AND 3 RESPECTIVELY ARE 99.9999974%, 99.9999938%, AND 99.9999922%	
GENERAL MOTORS OF CANADA LIMITED, COMMERCIAL-SCALE TESTING	REGULATORY TESTING - HIGH-STRENGTH PCB OIL ROUTINE OPERATIONS -PCBS	89 TONS PCB OIL AND WATER WASTE, 576 TONS ELECTRICAL EQUIPMENT AND MISC. BULK SOLIDS, 191 TONS SOIL, CONCRETE, AND ASPHALT, 70 TONS SOIL	REGULATORY TESTING RESULTS: DESTRUCTION EFFICIENCIES OF 99.9999996%, 99.9999985%, AND 99.9999808% FOR PCBS, 99.9999836%, 99.9999972%, AND 99.9999971% FOR CHLOROBENZENES, AND 99.999 TO 99.9999% FOR POLYCHLORINATED DIBENZO-P-DIOXINS AND POLYCHLORINATED DIBENZOFURANS (TAKES INTO ACCOUNT GASEOUS, LIQUID AND SOLID OUTPUTS).	
BROWN & ROOT ENVIRONMENTAL – TESTING CONDUCTED AT ECO LOGIC'S TEST FACILITY, ROCKWOOD, ONTARIO	TREATABILITY TESTING – PESTICIDE-CONTAMINATED SOIL	CONDUCTED 2 TEST RUNS TREATING 7.5 POUNDS PER HOUR OF SOIL FOR OVER	DESTRUCTION AND REMOVAL EFFICIENCY FOR DDT IN THE SOIL WAS 99.999987% AND 99.999985% FOR RUNS 1 AND 2, RESPECTIVELY. NO DDT WAS DETECTED IN THE PROCESS OUTPUTS EXCEPT FOR RUN 2 TREATED SOIL,	

GPCR– ANNEX TO POPS TECHNOLOGY SPECIFICATION AND DATA SHEET

		2.5 HOURS. SOIL CONTAINED 690 AND 440 PPM DDT FOR RUNS 1 AND 2, RESPECTIVELY.	WHICH CONTAINED 0.004 PPM DDT.	
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GPCR– ANNEX TO POPS TECHNOLOGY SPECIFICATION AND DATA SHEET

16.4. Table 3: Overview detailed project information per project – Project name (from Table 2):

LOCATION PROJECT	PRE-TREAT MG/KG	POST-TREAT MG/KG	DRES	EMISSIONS 1. AIR (HCL, DIOXINS & FURANS ETC) 2. WATER, 3. WASTE (SLAGS)	ENERGY CONSUMPTION	COSTS(CAPITAL, OPERATING COSTS)	OTHERS, REMARKS
KWINANA, REGULATORY TESTING	JULY 1995: 30.3% DDT FEBRUARY 1996: 5.6% DDT	STACK GAS: < 1.7 µG/M ³ (1995); < 0.80 µG/M ³ (1996)	99.999984 % (1995) 99.999968 % (1996) NOTE: INCLUDES ALL OUTPUTS, NOT JUST STACK GAS	WASTE-SPECIFIC COMPOUNDS NON-DETECT IN AIR, SOLID AND LIQUID OUTPUTS; NO SLAG CREATED; DETAILED DATA NO LONGER AVAILABLE		PROTOTYPE PLANT - COST DATA NOT VALID; CURRENT ESTIMATES ARE APPROXIMATELY US\$2500 - \$3000 PER TONNE FOR BULK SOLID AND LIQUID WASTE FEEDS; APPROXIMATELY US\$200 AND UP (DEPENDING ON QUANTITY) FOR SOIL AND SEDIMENT FEEDS SEE ABOVE	
KWINANA, – PILOT- AND COMMERCIAL-SCALE TREATABILITY TESTING	WASTE INPUT: 514KG–TEST 1 1584KG–TEST 2, 4610KG–TEST 3	TREATED SOLIDS: 2KG-TEST 1 23KG-TEST 2 94KG-TEST 3	HCB: 99.9999974% 99.9999938% 99.9999922% CHLOROBENZENE: 99.9999897% 99.9999863% 99.9999869%				
GENERAL MOTORS OF CANADA LIMITED, REGULATORY TESTING	50% PCBS 30% CHLOROBENZENES		PCBS: 99.9999996%, 99.9999985%, 99.9999997% FOR TESTS 1, 2, AND 3, RESPECTIVELY. CHLOROBENZENES 99.9999842% 99.9999985% 99.9999977% FOR TESTS 1, 2, AND 3, RESPECTIVELY.			DEMONSTRATION PLANT ONLY, AND SO COST DATA NOT APPLICABLE TO COMMERCIAL OPERATIONS. SEE INFORMATION ON KWINANA SITE ABOVE.	
BROWN & ROOT ENVIRONMENTAL – TESTING	UNTREATED SOIL: 690 AND 440 PPM DDT FOR RUNS 1	TREATED SOIL: <0.006 AND 0.004 PPM DDT FOR RUNS 1 AND 2,	DRE DDT: 99.999987% AND 99.999985% FOR RUNS 1			DEMONSTRATION PLANT ONLY, AND SO COST DATA NOT APPLICABLE TO	

GPCR– ANNEX TO POPS TECHNOLOGY SPECIFICATION AND DATA SHEET

CONDUCTED AT ECO LOGIC'S TEST FACILITY, ROCKWOOD, ONTARIO	AND 2, RESPECTIVELY.	RESPECTIVELY.	AND 2, RESPECTIVELY.			COMMERCIAL OPERATIONS. SEE INFORMATION ON KWINANA SITE ABOVE.
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TABLE 4: CLIENT REFERENCES FOR GPCR PLANT IN AUSTRALIA

Organization	Contact	Description/Notes
WESTERN AUSTRALIA DEPARTMENT OF ENVIRONMENTAL PROTECTION (DEP)	LOCAL REP - PAUL BYRNES, MANAGER KWINANA BRANCH TEL 61-8-9419-5500 PERTH REP - ADAM PARKER, DIRECTOR WASTE MANAGEMENT DIVISION TEL 61-8-9222-7160	<ul style="list-style-type: none"> - GENERAL KNOWLEDGE OF OUR KWINANA OPERATION - IN 1999/2000 OVERSAW THE PROCESSING OF SEVERAL HUNDRED TONNES OF CHEMICAL COLLECTION PESTICIDE WASTE FROM WESTERN AUSTRALIA
CSPB	NATHAN DIXON - MANAGER LABORATORY TEL 61-8-9411-8221	<ul style="list-style-type: none"> - CHEMICAL MANUFACTURER - SUPPLIED PCB WASTE FOR DESTRUCTION
NUFARM	CHRIS LEE - PLANT MANAGER TEL 61-8-9411-4000	<ul style="list-style-type: none"> - AGRICULTURAL CHEMICAL MANUFACTURER - SUPPLIED OVER 100 TONNES OF 2,4-D, OTHER PHENOXY ACETIC ACIDS, AND OTHER MISCELLANEOUS PESTICIDES, INCLUDING DPE, RUBBISH, SOILS, OLD DRUMS, ETC., FOR DESTRUCTION
WESTERN POWER	ROMAN MANDYCZEWSKY - PRINCIPAL SCIENTIFIC OFFICER TEL 61-8-9326-4895	<ul style="list-style-type: none"> - WESTERN AUSTRALIA'S ELECTRICITY GENERATION AND DISTRIBUTION COMPANY - SUPPLIED MOSTLY PCBs, BUT ALSO ROUGHLY 40 TONNES OF DIELDRIN CONTAMINATED SLUDGE, OIL, RESIDUE FROM OLD TANKS OF 'POLE-MIX' (POWER POLE INSECTICIDE) - MR. MANDYCZEWSKY IS ALSO AWARE OF THE ORIGINAL DDT WORK PERFORMED FOR THE DEPT. OF AGRICULTURE -
HATLAR ENVIRONMENTAL	GEORGE HATZIMIHALIS - MANAGING DIRECTOR TEL 61-3-9629-5300	<ul style="list-style-type: none"> - HATLAR ENVIRONMENTAL MANAGED MANY OF WESTERN AUSTRALIA'S USED PESTICIDE COLLECTION AND REDRUMMING OPERATIONS - USED THE GPCR PLANT EXCLUSIVELY FOR DESTRUCTION -
BRIDLE CONSULTING	TREVOR BRIDLE - TECHNICAL DIRECTOR TEL +618 93282527	<ul style="list-style-type: none"> - MEMBER OF AUSTRALIA'S NATIONAL ADVISORY BOARD

GPCR– ANNEX TO POPS TECHNOLOGY SPECIFICATION AND DATA SHEET

TABLE 5: UTILITIES REQUIRED FOR HIGH-STRENGTH PESTICIDE WASTE TREATMENT

UTILITY	17. Units	QUANTITY REQUIRED PER TONNE OF WASTE INPUT	18. Quantity required per month 19. (Semi-mobile plant)	20. Quantity required per month 21. (Full-scale plant)
ELECTRICITY	MWH	2.5	175	700
CAUSTIC	T	1.4	98	392
HYDROGEN*	NM ³	1000	70,000	280,000
NITROGEN	NM ³	75	5,250	21,000
CO2	KG	20.1	1,407	5,628
STEAM	KG	1500	105,000	420,000
NATURAL GAS	NM ³	600	42,000	168,000
COOLING WATER	M3	500	35,000	140,000
PROCESSING RATE	KG/MIN		2	8
	TONNES/MONTH		70	280
	TONNES/YR		840	3360

16.5.

*ASSUMES HYDROGEN IS RECOVERED FROM THE PRODUCT GAS

GPCR– ANNEX TO POPS TECHNOLOGY SPECIFICATION AND DATA SHEET

TABLE 6: COMPARISON OF WORLDWIDE INCINERATOR AIR EMISSION STANDARDS WITH GPCR RESULTS

Pollutant	EU STANDARD ¹	UNITED STATES (HWC MACT PROPOSED RULE, JULY 1999, NEW SOURCES)	CANADA (FEDERAL MOBILE PCB TREATMENT STANDARDS, 1990)	ONTARIO (MUNICIPAL WASTE INCINERATORS - 2001)	MEASURED GPCR LEVELS	
					CONCENTRATION	PROJECT/WASTE STREAM
TOTAL DUST/ PARTICULATES	10 MG/M ³	34 MG MG/M ³	50 MG/M ³	17 MG/M ³	0.35 - 0.94 MG/M ³	GENERAL MOTORS OF CANADA LTD (PCB OIL - 3 TESTS)
TOTAL ORGANIC CARBON	10 MG/M ³	10 PPMV (HYDROCARBONS, REPORTED AS PROPANE)	NL	100 PPMV (EXPRESSED AS EQUIVALENT METHANE)	0.4 - 2.3 PPM (ONLY DATA TOTAL HYDROCARBONS)	GENERAL MOTORS OF CANADA LTD
HCL	10 MG/M ³	21 PPMV	75 MG/M ³	18 PPMV (27 MG/M ³)	< 0.00007 - 0.0025 MG/M ³	GENERAL MOTORS OF CANADA LTD
HF	1 MG/M ³	NL	NL	NL	NO DATA AVAILABLE	
SO ²	50 MG/M ³	NL	NL	21 PPMV (56 MG/M ³)	0 TO 1 PPM	GENERAL MOTORS OF CANADA LTD
NOX	200 MG/M ³	NL	NL	110 PPMV	63 - 79 PPM	GENERAL MOTORS OF CANADA LTD
PCDD/ PCDF ²	0.1 NG/M ³	0.20 NG/M ³	12 NG/M ³ 0.08 NG/M ³ (CCME TARGET FOR 2006)	0.14 NG/M ³	0.018 - 0.020 NG/M ³	GENERAL MOTORS OF CANADA LTD
					0.000011 - 0.00041 NG/M ³	NEW BEDFORD HARBOR (DIOXIN-CONTAMINATED SEDIMENT - 4 TESTS)
					0.0027 NG/M ³	JAPANESE REGULATORY TESTING (DIOXIN-CONTAMINATED SOLIDS)
					0.00013 - 0.00065 NG/M ³	US ARMY TESTING (PENTACHLORO -PHENOL-CONTAMINATED WOOD)
CO	50 MG/M ³	100 PPMV	NL	NL	0 TO 1.5 MG/M ³	US ARMY TESTING (TREATMENT OF CHLORINATED POLYETHYLENE)
					1 - 5 PPM	GENERAL MOTORS OF CANADA LTD
SEMIVOLATILE METALS	NL	24 µG/M ³	NL	NL		
LOW VOLATILE METALS	NL	97 µG/M ³	NL	NL		

GPCR– ANNEX TO POPS TECHNOLOGY SPECIFICATION AND DATA SHEET

CADMIUM	0.05 MG/M ³	NL	NL	0.014 MG/M ³	0.00019 – 0.000093 MG/M ³	GENERAL MOTORS OF CANADA LTD
THALLIUM	0.05 MG/M ³	NL	NL	NL	< 0.0042 - < 0.0048 MG/M ³	
MERCURY	0.05 MG/M ³	0.045 MG/M ³	NL	0.020 MG/M ³	< 0.000048 - 0.00099 MG/M ³	
ANTIMONY	0.5 MG/M ³	NL	NL	NL	0.0012 - 0.0021 MG/M ³	
ARSENIC	0.5 MG/M ³	NL	NL	NL	< 0.00014 - < 0.00016 MG/M ³	
LEAD	0.5 MG/M ³	NL	NL	0.142 MG/M ³	0.00053 - 0.0029 MG/M ³	
CHROMIUM	0.5 MG/M ³	NL	NL	NL	0.0056 - 0.009 MG/M ³	
COBALT	0.5 MG/M ³	NL	NL	NL	< 0.00014 - < 0.00016 MG/M ³	
COPPER	0.5 MG/M ³	NL	NL	NL	0.00081 - 0.0016 MG/M ³	
MANGANESE	0.5 MG/M ³	NL	NL	NL	0.00084 - 0.0018 MG/M ³	
NICKEL	0.5 MG/M ³	NL	NL	NL	< 0.000080 - 0.0021MG/M ³	
VANADIUM	0.5 MG/M ³	NL	NL	NL	< 0.00035 - < 0.00041 MG/M ³	

(1) BASED ON DAILY AVERAGE, EXCEPT PCDD/PCDF WHICH IS BASED ON 6 TO 8 HOUR AVERAGE, AND METALS, WHICH ARE BASED ON A 30 MINUTE TO 8 HOUR AVERAGE

(2) TOXIC EQUIVALENTS CALCULATED USING THE INTERNATIONAL METHOD

NL = NOT LISTED

PLASMA ARC (PLASCON)

JOHN VILGEN, INTERNATIONAL HCH AND PESTICIDES ASSOCIATION AND DR. IR. RON MCDOWALL, AUCKLAND NEW ZEALAND FOR SECRETARIAT OF THE BASEL CONVENTION

NAME OF PROCESS:
PLASMA-ARC (PLASCON)

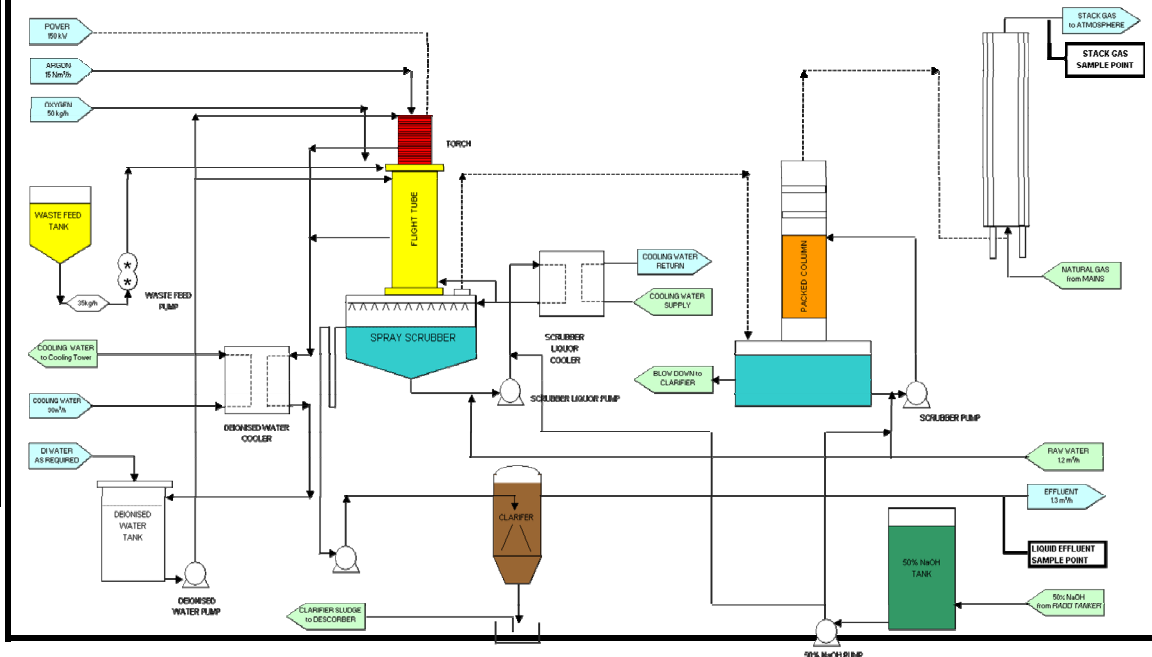
APPLICABLE PESTICIDE AND RELATED POP WASTES:
PESTICIDES SUCH AS HCB, DDT, ALDRIN, DIELDRIN, LINDANE, 2,4 D, PCBs, DIOXINS, FURANS AND OTHER COMPOUNDS SUCH AS HALONS AND CHEMICAL INDUSTRY IN-PROCESS WASTE STREAMS

STATUS:
THE "IN-FLIGHT" PLASMA ARC PLASCON TECHNOLOGY HAS BEEN OPERATING COMMERCIALY SINCE 1992. TO DATE THERE ARE 9 COMMERCIAL PLANTS OPERATING WITH LICENCES FROM THE VICTORIAN AND QUEENSLAND EPA'S IN AUSTRALIA, THE UK EPA AND THE JAPANESE MINISTRY OF THE ENVIRONMENT. 4 COMMERCIAL 150 KW PLASCON UNITS ARE OPERATING IN AUSTRALIA. 2 UNITS WERE INSTALLED AT THE NUFARM LTD AGRICULTURAL CHEMICALS IN MELBOURNE IN 1992/1993, WHICH TREAT THE LIQUID WASTE STREAM FROM 2,4 D MANUFACTURE WHICH COMPRISES 35 % CHLOROPHENOLS, 45 % CHLOROPHENOXYIES AND 20 % ADDED TOLUENE TO REDUCE THE VISCOSITY OF THE LIQUID. EACH PLANT HAS A CAPACITY OF 1 T/D OF WASTE AND TO DATE OVER 7000 TONNES OF WASTE HAS BEEN DESTROYED. ONE UNIT WAS INSTALLED IN MELBOURNE IN 1997 TO DESTROY HALONS AND FREONS. THE 4TH UNIT WAS INSTALLED AT A FACILITY IN BRISBANE TO DESTROY CONCENTRATED PCB SOLUTIONS (>10 %) AS WELL AS A RANGE POP PESTICIDES. TO DATE OVER 1000 TONNES OF CONCENTRATED PCBs AND OCPS HAVE BEEN DESTROYED. ONE UNIT IS OPERATING IN THE UK DESTROYING FIRE RETARDANTS AND ODS. IN JAPAN, A LARGE CHEMICAL COMPANY HAS INSTALLED FOUR PLASCON PLANTS TO DESTROY PCB WASTES. THE PLANTS BECAME OPERATIONAL IN MAY 2004 AND TILL APRIL 2005 900 TONNES OF WASTE HAS BEEN DESTROYED. IN JULY 2004, OVER 10 000 TONNES OF MENTIONED WASTES HAVE BEEN SUCCESSFULLY DESTROYED.

TECHNOLOGY DESCRIPTION:

THE PLASCON "IN-FLIGHT" PLASMA-ARC SYSTEM WAS DEVELOPED BY THE COMMONWEALTH SCIENTIFIC INDUSTRIAL RESEARCH ORGANISATION (CSIRO) AND COMMERCIALISED BY AN AUSTRALIAN COMPANY, VIA THEIR SUBSIDIARY. IN 2001 AN AUSTRALIAN WASTE MANAGEMENT COMPANY BOUGHT THIS SUBSIDIARY. THE PROCESS DEVELOPS A HIGH TEMPERATURE (>10 000 °C) PLASMA-ARC BY IONISING ARGON GAS USING A 150 KW DC DISCHARGE BETWEEN THE CATHODE AND THE ANODE. THE WASTE, AS A LIQUID OR GAS IS INJECTED DIRECTLY INTO THE PLASMA AND RAPIDLY (<1 MS) HEATS TO ABOUT 3100 °C AND IS PYROLYSED FOR ABOUT 20 MS IN THE WATER-COOLED REACTION CHAMBER (FLIGHT TUBE). TO ENSURE NO FORMATION OF SOOT A CONTROLLED AMOUNT OF OXYGEN IS INJECTED INTO THE PLASMA TO CONVERT ANY CARBON TO CO. AT THE END OF THE FLIGHT TUBE, THE GAS AT ABOUT 1500 °C IS RAPIDLY (<2 MS) QUENCHED TO LESS THAN 100 °C IN A DIRECT SPRAY CONDENSER USING AN ALKALINE SPRAY SOLUTION. THE GAS IS FURTHER COOLED AND SCRUBBED OF ANY REMAINING ACID GASES IN A PACKED TOWER. THESE OFF-GASES, WHICH CONTAIN MAINLY CO AND AR ARE THEN FLARED TO OXIDISE THE CO TO CO₂. CONTAMINANTS IN SOLID AND BULK WASTES ARE THERMALLY DESORBED AND CONDENSED AND THEN FED AS A LIQUID TO THE PLASCON UNIT FOR DESTRUCTION.

PROCESS DIAGRAM:



PLASMA ARC (PLASCON)



PLASMA ARC (PLASCON)

PART I: CRITERIA ON THE ADAPTATION OF THE TECHNOLOGY TO THE COUNTRY

A. Performance:

1. MINIMUM PRE-TREATMENT:

THE ONLY REAL LIMITATION OF THE PROCESS IS THAT IT CAN ONLY PROCESS LIQUID OR GASEOUS STREAMS. LIQUID STREAMS SHOULD NOT CONTAIN PARTICLES GREATER THAN 0.5 MM IN SIZE. A THERMAL DESORBER IS USED TO REMOVE CONTAMINANTS FROM SOLIDS. THE CONTAMINANTS ARE CONDENSED AND TREATED BY PLASCON IN LIQUID OR GASEOUS PHASE. TYPICAL SOLIDS TREATED ARE: TRANSFORMER AND CAPACITOR PARTS, PROTECTIVE CLOTHING, CONTAMINATED DRUMS AND PACKAGING AND SOIL. LIQUID POP'S CAN BE DIRECT INJECTED. POP'S FORMULATED WITH SOLIDS ARE DESORBED FIRST AND THEN FED AS LIQUID OR VAPOUR.

2. DESTRUCTION EFFICIENCY (DE):

COMMERCIAL PLASCON PLANTS HAVE TREATED A WIDE RANGE OF SCHEDULED WASTES IN AUSTRALIA INCLUDING MOST POP PESTICIDES AND PCBs AS WELL AS PROCESS WASTE STREAMS FROM A PESTICIDE MANUFACTURER. PLANTS IN BOTH AUSTRALIA AND THE UK ARE USED TO DESTROY HALONS AND CHLORO-FLUORO HYDROCARBONS. COMMERCIAL PLANTS IN JAPAN ARE USED TO DESTROY PCBs. DESTRUCTION EFFICIENCY FOR ALL THESE CONTAMINANTS IS TYPICALLY GREATER THAN 99.9999%. A LIST OF COMPOUNDS TREATED IS SHOWN BELOW.

INDEPENDENT PERFORMANCE MONITORING DATA HAS SHOWN THAT DE'S FOR POPS AND ODSS (OZONE DEPLETING SUBSTANCES) ARE CONSISTENTLY GREATER THAN 99.9999%. THE CONCENTRATION OF RESIDUAL POPS IN THE TREATED EFFLUENT STREAM IS TYPICALLY NOT DETECTABLE, AT A DETECTION LEVEL OF 0.5 MG/L AND ATMOSPHERIC EMISSIONS ARE TYPICALLY LESS THAN 1MG/NM³. DIOXIN EMISSIONS ARE TYPICALLY LESS THAN 0.01 NG-TEQ/NM³ (SEE ALSO TABLE 1 AND TABLE 2 OF ANNEX).

JAPANESE CONTROL LEVELS TO THE TREATED EFFLUENT STREAMS (GAS AND LIQUID) ARE VERY RIGOROUS. OUR FACILITIES HAVE ADSORPTION VESSELS OF ACTIVATED CARBON TREATMENT FOR BOTH GAS AND LIQUID EFFLUENT STREAMS. PCBs REMOVAL RATE FROM THE CONCENTRATE SOLUTION TO THE EFFLUENT STREAMS IS TYPICALLY GREATER THAN 99.999999%. (EIGHT 9S).***

3. TOXIC BY-PRODUCTS:

SODIUM CHLORIDE AND CO₂

4. UNCONTROLLED RELEASES:

NONE

5. CAPACITY TO TREAT ALL POPS:

COMPOUNDS TREATED:

Industrial chemicals and manufacturing by-products/wastes

PCBS, DIOXINS AND FURANS, WASTE CHLOROPHENOLS (DICHLOROPHENOLS AND DICHLOROPHENOXY ACETIC ACIDS) FROM HERBICIDE (2,4D) MANUFACTURE.

Commercial Pesticides

AZINOPHOS	DDE	MITOTANE
2,4 D	DDT	NONACHLOR
2,4,5 T	ENDOSULFAN	PERMETHRIN
CARBARYL	ETHION	ORYZALIN
CHLORDANE	HEPTACHLOR	TRIFLURALIN
CHLORPRYIFOS	LIMONENE	
DICHLORVOS	MALATHION	

Other Compounds treated

HALONS AND CHLORO-FLUORO HYDROCARBONS (ODS), TOLUENE, MINERAL OIL, CHLORINATED SOLVENTS, SULPHUR HEXAFLUORIDE AND MERCAPTANS.

6. Throughput:

6.1 QUANTITY [TONS/DAY, L/DAY]

EACH PLASCON UNIT CAN TREAT BETWEEN 1 AND 3 T/D OF POP WASTE, DEPENDING ON ITS STRENGTH AND

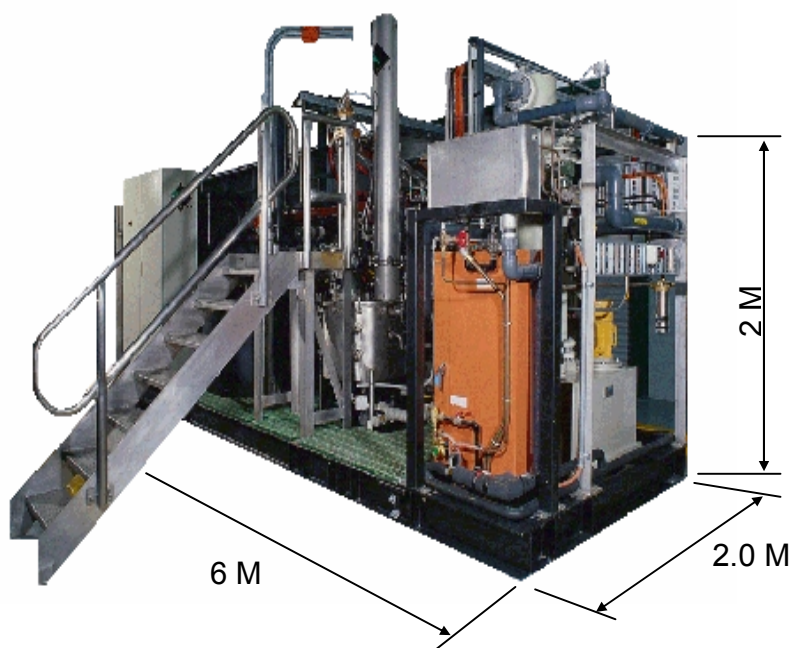
PLASMA ARC (PLASCON)

CHARACTERISTICS.

6.2 POPS THROUGHPUT : [POPS WASTE/TOTAL WASTE IN %]

POP'S THROUGHPUT IS GIVEN ON 2 EXAMPLES: FOR WASTE WITH FOR EXAMPLE 5% DDT IN 95% SOLIDS (LIME, TALCUM POWDER) PLASCON CAN TREAT ABOUT 20 T/D AFTER DESORPTION. FOR WASTE WITH 25 % DDT IN 75% TOLUENE THEN PLASCON CAN TREAT 1 T/D.

PLASCON PLANTS ARE SUPPLIED AS SKID-MOUNTED UNITS EQUIPPED WITH A 150 KW PLASMA TORCH. THE PLASMA TORCH, WATER COOLED REACTION CHAMBER (FLIGHT TUBE) QUENCH AND SCRUBBING SYSTEM, POWER SUPPLY, ASSOCIATED PUMPS AND PROCESS CONTROL SYSTEM ARE MOUNTED ON THE SKID (SEE PHOTO). THE FLARE IS PROVIDED AS A SEPARATE FULLY ENGINEERED AND CONTROLLED SYSTEM.



7. Wastes/Residuals:

7.1 SECONDARY WASTE STREAM VOLUMES:

PLASCON FACILITIES HAVE TWO WASTE STREAMS, NAMELY A GASEOUS EMISSION AND AN AQUEOUS BLOW DOWN FROM THE SCRUBBER SYSTEM. THE AQUEOUS BLOW DOWN IS A SLIGHTLY ALKALINE (PH OF 8) STREAM COMPRISING ESSENTIALLY SODIUM HALIDE SALTS. AS MENTIONED ABOVE POP CONCENTRATIONS ARE TYPICALLY NON DETECTABLE (<0.5MG/L). TYPICAL BLOW DOWN VOLUMES ARE 0.5 TO 1.2 KL/H. GASEOUS EMISSIONS HAVE FLOW IN THE ORDER OF 0.5 NM³/H AND CONSIST PRIMARILY OF ARGON (79 % BY WEIGHT), CO₂ (18.5 %), CO (2 %) AND WATER (0.5%).

FOR THE INSTALLATIONS IN JAPAN, IT WAS REPORTED THAT AFTER THE FLARE, TOTAL (PCDFS + PCDDS + COPLANAR PCBS)

PLASMA ARC (PLASCON)

EMISSIONS IN THE GAS EFFLUENT ARE TYPICALLY LESS THAN 0.01 NG-TEQ/NM³ (JAPANESE CONTROL LEVEL IS LESS THAN 0.1 NG-TEQ/NM³) AND CO CONCENTRATION IN THE GAS IS LESS THAN 10 PPM. (JAPANESE CONTROL LEVEL OF CO IS LESS THAN 200 PPM) TOTAL(PCDFS + PCDDS + COPLANER PCBs) EMISSIONS IN THE LIQUID EFFLUENT ARE TYPICALLY LESS THAN 0.01 PG-TEQ/L. (JAPANESE CONTROL LEVEL IS LESS THAN 10 PG-TEQ/L)***

7.2 OFF GAS TREATMENT:

NONE AFTER FLARE. SEE TABLE 1, 2 AND 3 OF ANNEX.

7.3 COMPLETE ELIMINATION:

YES. SEE TABLE 3 OF ANNEX.

DETAILED INFORMATION AND TREATMENT EXAMPLES:

IN THE SEPARATE ANNEX THE FOLLOWING INFORMATION IS GIVEN:

TABLE 1: TECHNOLOGY OVERVIEW - SUMMARY - TECHNICAL DETAILS

TABLE 2: OVERVIEW PROJECT EXPERIENCE PER TECHNOLOGY SUPPLIER

TABLE 3: OVERVIEW DETAILED PROJECT INFORMATION PER PROJECT - PROJECT NAME (FROM TABLE 2)

TABLE 4: CLIENT REFERENCES FOR PLASCON PLANTS IN AUSTRALIA

PLASMA ARC (PLASCON)

PART II: CRITERIA ON THE ADAPTATION OF THE COUNTRY TO THE TECHNOLOGY

NOTE: THIS PART HAS TO BE FILLED IN EVERY TIME THE "SUITABILITY" OF THE TECHNOLOGY HAS TO BE EXAMINED FOR A CERTAIN COUNTRY SITUATION!!

A. RESOURCE NEEDS:

1. POWER REQUIREMENTS :

PLASCON UNITS ARE EQUIPPED WITH A STANDARD 150 KW PLASMA TORCH FOR POPS. THE PLASMA TORCH, WATER COOLED REACTION CHAMBER (FLIGHT TUBE) QUENCH AND SCRUBBING SYSTEM, POWER SUPPLY, ASSOCIATED PUMPS AND PROCESS CONTROL SYSTEM ARE MOUNTED ON THE SKID. THIS PLANT USES ABOUT 180 KW.

2. WATER REQUIREMENTS:

COOLING WATER AND DEIONISED WATER FOR COOLING THE TORCH (THIS STREAM IS RECYCLED THROUGH HEAT EXCHANGERS) BOTH COOLING AND DEIONISED WATER ARE CONTINUOUSLY REUSED BUT THE PLANT USED 1M³/H OF RAW WATER FOR EFFLUENT DISCHARGE. TOTAL WATER CONSUMPTION WITH EVAPORATION ABOUT 1.4M³/H.

3. FUEL VOLUMES:

NO FUEL IS CONSUMED

4. REAGENTS VOLUMES:

ARGON, OXYGEN AND A 30 TO 60 % CAUSTIC SOLUTION. ARGON USE IS INDEPENDENT OF THROUGHPUT 15 M³/HR CAUSTIC 1.4 TON / TON OF CONCENTRATED WASTE (CAUSTIC IS DIRECTLY PROPORTIONAL TO WASTE CONCENTRATION I.E. CHLORINE CONTENT) OXYGEN 0.8 TON/ TON OF CONCENTRATED WASTE.(OXYGEN USE VARIES WITH CHEMICAL COMPOSITION OF WASTE AND HYDROCARBON SOLVENTS MIXTURES)

5. WEATHER TIGHT BUILDINGS:

WEATHER TIGHT BUT VENTILATED.

7. SAMPLING REQUIREMENTS/FACILITIES:

SAMPLING IS REQUIRED IF THE COMPOSITION OF THE WASTE IS NOT EXACTLY KNOWN (UNLABELLED OR OPEN DRUMS) IT IS ALSO REQUIRED TO MONITOR EFFLUENT QUALITY.

9. LABORATORY REQUIREMENTS:

ON SITE REQUIREMENTS:

BELOW IS THE EQUIPMENT LISTED, AS USED AT ONE OF THE PLANTS AND ANY OPERATOR WOULD NEED SIMILAR EQUIPMENT, WITH THE EXCEPTION OF THE MASS SPECTROMETER IS OPTIONAL AND DEPENDS ON THE WASTE TREATED:

2 GASCHROMATOGRAPHS FITTED WITH ELECTRO CAPTURE DETECTORS (ECD) AND AUTO SAMPLERS FOR LIQUIDS GAS SAMPLING GASCHROMATOGRAPH FITTED WITH 4 DETECTORS INCLUDING ONE ECD FOR YOUR OWN GAS SAMPLING PLUS A GASCHROMATOGRAPH FITTED WITH A MASS SPECTROMETER DETECTOR MAINLY USED FOR IDENTIFYING PESTICIDES.

REQUIREMENTS IN COUNTRY:

APART FROM COMPULSORY IN-HOUSE TESTING, AUSTRALIAN REGULATION REQUIRES RETENTION OF ALL RECORDS FOR 5 YEARS INCLUDING TRANSPORT DOCKETS.

INDEPENDENT SAMPLES ARE COLLECTED 4 TIMES PER YEAR AT RANDOM AND INDEPENDENTLY TESTED. THE FACILITY IS AUDITED ONCE PER YEAR AT SHORT NOTICE.

11. NUMBER OF PERSONNEL REQUIRED: 2

11.1 NUMBER OF TECHNICIANS REQUIRED (SKILLED LABOUR):
1

6. HAZARDOUS WASTE PERSONNEL REQUIREMENT:

PERSONNEL REQUIRE TRAINING IN THE O H S ASPECTS FOR EACH WASTE THAT IS ACCEPTED FOR TREATMENT.

8. PEER SAMPLING:

INDEPENDENT SAMPLING AND ANALYSIS HAS BEEN CARRIED OUT BY PURCHASERS OF PLANTS DURING ACCEPTANCE TRIALS AND COMMISSIONING.

10. COMMUNICATION SYSTEMS:

THE SYSTEM IS FULLY AUTOMATED AND IS PLC CONTROLLED WITH A CITECT SCADA SYSTEM. MONITORING CAN BE DONE BY TELEPHONE OR INTERNET AND FROM WITHIN BY LAN.

MOBILE NETWORK:

FIXED NETWORK:

11.2 NUMBER OF LABOURERS REQUIRED (UNSKILLED LABOUR): 1

B. COSTS: STANDARD 150KW PLASCON PLANT APPROX. \$USD 1 MILLION. OPERATING & MAINTENANCE COSTS \$USD 1.50 PER KG FOR SCHEDULE WASTES

1. INSTALLATION AND COMMISSIONING COSTS [US DOLLARS]:
INCLUDED IN PURCHASE PRICE

2. SITE PREPARATION COSTS [US DOLLARS]:
\$100 000

PLASMA ARC (PLASCON)

3. ENERGY & TELECOM INSTALLATION COSTS:

DEPENDS ON COUNTRY

5. COMPLYING COSTS:

INCLUDED IN OPERATING COSTS

7. RUNNING COSTS WITH NO WASTE:

4. MONITORING COSTS:

INCLUDED IN OPERATING COSTS

6. REPORTING COSTS:

INCLUDED IN OPERATING COSTS

8. RUNNING COSTS WITH WASTE:

9. DECOMMISSIONING COSTS:

UNKNOWN.

11. TRANSPORT COSTS OF RESIDUES:

DEPENDING ON LOCAL SITUATION – SHOULD BE FILLED IN FOR THE CONCERNED COUNTRY

10. LANDFILL COSTS:

DEPENDING ON LOCAL SITUATION – SHOULD BE FILLED IN FOR THE CONCERNED COUNTRY

C. IMPACT:

1. DISCHARGES TO AIR:

3. DISCHARGES TO LAND:

NONE

D. RISKS: SEVERAL HASOP'S CONDUCTED ON VARIOUS PLANTS SHOWING FEW RISKS

1. RISKS OF REAGENTS APPLIED:

CAUSTIC SODA COULD BE CONSIDERED A REAGENT IT IS WIDELY USED IN HOME AND INDUSTRY AND WELL MANAGED

3. OPERATIONAL RISKS:

THE PLANT IS INHERENTLY SAFE SINCE IT IS POWERED BY ELECTRICITY AND CAN THUS BE SHUT DOWN INSTANTANEOUSLY. PLASCON UNITS ARE EQUIPPED WITH ALL APPROPRIATE SAFETY FEATURES AND NECESSARY CONTAINMENT MEASURES SO THAT THE EFFECTS OF ANY ACCIDENTS ARE MINIMISED.

2. DISCHARGES TO WATER:

1M³ /H CONTAINING 50 GRAMS SODIUM CHLORIDE 5 GRAM SODIUM CARBONATE

4. SOIL IMPACT (NOISE ETC):

LOW NOISE

2. RISKS OF TECHNOLOGY:

THE FLARE IS PROVIDED AS A SEPARATE FULLY ENGINEERED AND CONTROLLED SYSTEM. THE SYSTEM IS FULLY AUTOMATED AND IS PLC CONTROLLED WITH A CITECT SCADA SYSTEM.

E. CONSTRUCTABILITY:

1. EASE OF INSTALLATION/CONSTRUCTION OF PLANT:

SIMPLE TO OPERATE. EASY TO LEARN WITHOUT SPECIAL SKILLS

2. EASE OF SHIPPING/TRANSIT:

THE FOOTPRINT OF THE SKID IS 12 M². THE HEIGHT IS 2 M, SO ALL FITTING IN CONTAINERS.

3. Ease of operation:

START UP AND SHUT DOWN IS COMPLETELY AUTOMATIC AND OPERATORS CAN BE TRAINED IN A SHORT TIME.

4. EASE OF PROCESSING:

THE PROCESS IS VERY ROBUST AND RELIABLE, WITH UP-TIMES TYPICALLY GREATER THAN 90%. ROUTINE MAINTENANCE USUALLY INVOLVES: WEEKLY CLEAN FILTERS AND FEED NOZZLE. MONTHLY INSPECT TORCH AND SCRUBBER SYSTEM.

F. OUTPUT/GENERATION WASTE

1. GENERATED WASTE (% OF INPUT WASTE):

IN ADDITION THE INVENTORY OF UN-DESTROYED POPS IN THE SYSTEM IS VERY LOW AT ROUGHLY 0.5 GRAMS. THE 0.5 GRAM IS UN-DESTROYED ONLY IN CASE OF SUDDEN SHUTDOWN AND IS THE AMOUNT IN THE SYSTEM AT ANY GIVEN MOMENT AT A 45 KG/H FEDERATE. THIS 0.5 GRAM IS RECOVERED BEFORE A RESTART.

3. WASTE QUALITY PROPERTIES (PH, TCLP):

PH 9 FOR REST SEE UNDER DISCHARGE TO WATER (C.2)

**NOTE: THIS TECHNOLOGY SPECIFICATION AND DATA SHEET (TSDS) DOES NOT CERTIFY ANY PARTICULAR TECHNOLOGY, BUT TRIES TO SUMMARISE THE STATE OF THE ART OF THE CONCERNED TECHNOLOGY ON THE BASIS OF DATA DELIVERED BY THE TECHNOLOGY SUPPLIERS OR OTHER SOURCES, WHICH HAVE BEEN MADE AVAILABLE TO THE AUTHOR AND REFERS THE READER TO ORIGINAL DOCUMENTS FOR FURTHER EVALUATION. WITHOUT THE EFFORTS BELOW LISTED TECHNOLOGY SUPPLIERS IT WOULD NOT HAVE BEEN POSSIBLE TO SET UP THIS TSDS. DATE: 19.04.2005*

2. DEPOSITED WASTE AT LANDFILL (% OF INPUT WASTE):

NONE

8. Technology suppliers that have contributed to this TSDS:

9. **BCD Technologies Pty Ltd, Australia**

PLASMA ARC (PLASCON)

10. **Bridle Consulting, Australia**
11. **Mitsubishi Chemical Corporation, Japan*****
12. **SD Meyers de Mexico de CV**
13. **SRL Plasma Pty Ltd, Australia**

REFERENCES:

The Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal was adopted in 1989 and entered into force in 1992. Its purpose is to protect human health and the environment from the adverse effects caused by the generation, management and transboundary movements of hazardous and other wastes.

To achieve its purpose the Basel Convention aims at reducing the transboundary movements of hazardous wastes, the prevention and minimization of their generation, the environmentally sound management of such wastes, and the active promotion of the transfer and use of cleaner technologies.

Presently, there are over 150 Parties to the Basel Convention.

In December 1999, the Parties to the Basel Convention adopted the Basel Protocol on Liability and Compensation for Damage resulting from the Transboundary Movements of Hazardous Wastes and Their Disposal.

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