Gas-Phase Chemical Reduction (GPCR)

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

Vendor:
ELI Eco Logic International Inc.
Web site: http://www.ecologic.ca

Applicable Pesticides and related POPs wastes:
Pesticides such as Hexachlorobenzene, DDT, Aldrin, Dieldrin, HCB's, DDT, PCB's, dioxins and furans and other POPs.

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

Eco Logic's partners in Japan have recently built a semi-mobile GPCR plant for the treatment of PCB wastes, which will be operational in 2003.

In combination with Foster Wheeler and Kvaerner the company is participating at present in the ACWA (Army Chemical Weapons Assessment) Program for the destruction of chemical warfare agents.

Eco Logic has partnered with Torftech Inc. for the treatment of soils and sediments at rates of up to 20 tons per hour. Eco Logic has also been selected by UNIDO for a pilot project for treatment of 1000 tons of PCB wastes in Slovakia.

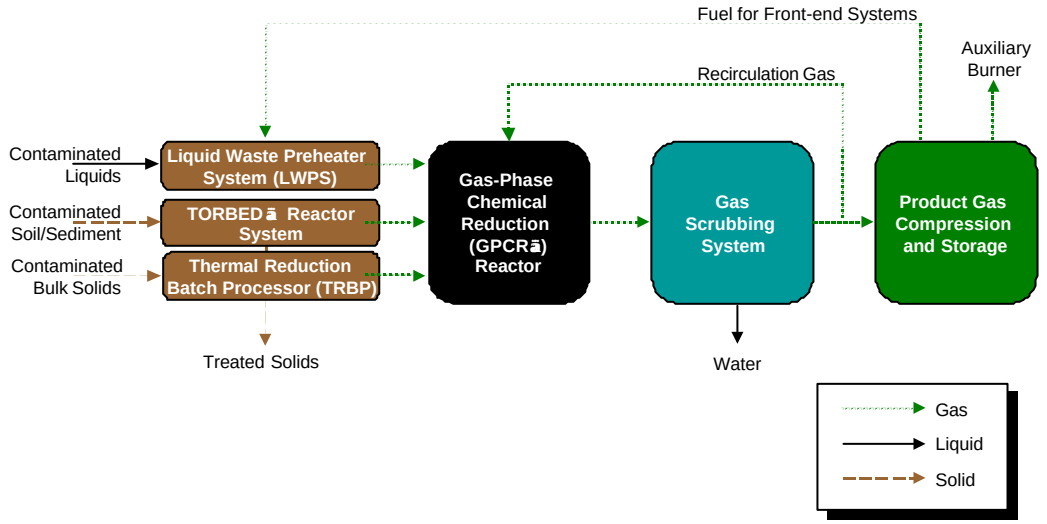
Additional approvals received:
-for PCB and dioxin waste in Japan
-for PCB's TSCA permit in USA
-for PCB's and other toxic compounds in the Province of Ontario (Canada)

Technology description:
Eco Logic's GPCR technology involves the gas-phase chemical reduction of organic compounds by hydrogen at a temperature of 850°C or higher. Chlorinated hydrocarbons, such as HCB, polychlorinated dibenzo-p-dioxins (dioxins) and other POPs, are chemically reduced to methane and hydrogen chloride (HCl). Unlike oxidation reactions, the efficiency of these reduction reactions is enhanced by the presence of water, which acts as a heat transfer agent as well as a source of hydrogen. Therefore, dewatering of input waste is unnecessary. The water shift reactions produce hydrogen, carbon monoxide and carbon dioxide from methane and water. These reactions can be used at higher efficiencies to generate hydrogen for reuse in the system by subjecting scrubbed methane-rich product gas to high temperatures in the presence of a catalyst. This is particularly useful when a hydrogen source for plant operations is not immediately available.

Solid and bulk waste materials are processed in a Thermal Reduction Batch Processor (TRBP). This waste is placed in the TRBP, which is sealed and heated in an oxygen-free atmosphere to about 600 °C. Organic components are volatilised and swept into the GPCR reactor, where complete reduction takes place at 850-900 °C. Gas leaving the Gas leaving this reactor is scrubbed to move particulate and acid and then stored for reuse as a fuel.

Process diagram:

Block Flow Schematic:



John Vijgen, International HCH and Pesticides Association, Fellowship report: "New and emerging techniques for the destruction and treatment of pesticides wastes and contaminated soils." NATO/CCMS Pilot Study: Evaluation of Demonstrated and Emerging Technologies for the Treatment of Contaminated Land and Groundwater (Phase III)"

Performance:

Treatment efficiency:
The GPCR has treated HCBs and PCBs and DDT, other chlorinated pesticides and POPs related wastes such as dioxins and furans. The Table below provides a complete list of contaminants treated.

Compounds treated by 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	Chloropropham	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	Quintozene
Alachlor	Dicambamethyl	Fenoprop	Nicotine	Rotenone
Aldrin	Cyanthoate	Fenthion	Nornicotine	Secbumeton
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	

Commercially the system has been working more than 5 year at Kwinana in Western Australia, where it has been treating PCB's, HCB's and DDT. Here efficiencies of at least 99.9999 % [1], [2], [3], [4].

In commercial-scale performance tests in Canada, the gas-phase reduction process achieved destruction efficiencies (DE) and Destruction and Removal Efficiencies (DRE) with high-strength PCB oils and chlorobenzenes as shown below in Table 1. Dioxins that were present as contaminants in the PCB oil were destroyed with efficiencies ranging from 99.999 to 99.9999 percent [5], [6].

An evaluation for the US Department of Energy (DOE) [7] 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 authors did however note 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 [8] 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."

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 99.9999% respectively [9].

Throughput:
150 tons pre month or 1800 tons per year. Capacities can be doubled due to modular design. In the Annex is also given an overview of the estimated utility requirements for semi-mobile GCPR plant with a capacity of 70 tons pesticides per month.

Throughput of the technology will depend on the scale of GPCR plant that is deployed. The following give the rough throughput estimates for each plant size:

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 m^2 (approximately 8 to 10 trailers)
- Throughput: up to 200 tons per month bulk solids and liquids (2 TRBPs)
- Soil and Sediment Treatment Capability: 1000 to 5000 tons per month (1 TORBED) ➔ *throughput highly dependent on characteristics of waste*

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)
- Throughput: 70 tons per month bulk solid or liquid material (2 TRBPs)
- Soil and Sediment Treatment Capability: 500 to 2000 tons per month soil or sediment (1 TORBED reactor) ➔ throughput highly dependent on characteristics of waste

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) tons/year, depending on reactor configuration, chemical concentration and waste matrix

Wastes/Residuals:
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)"[10].

Reliability:
Bizzigotti et al [6] assessed the reliability of the process as, "GPCR is a straightforward operation and should be inherently stable and robust (tolerant of large changes in operating conditions without becoming unstable or unpredictable)." They also noted that, "Eco Logic reports their Kwinana plant has 84–90 percent availability (this includes allowance for four days planned shutdown every month), which is considered good for a chemical processing plant." The DOE review rated the development of the technology as "high"[5].

Limitations:

The DOE review noted a limitation in respect of heavy metal contamination [5] "GPCR is non-selective and capable of destroying agents, Schedule 2 compounds, and hazardous intermediates, which ensures organic destruction and eliminates the risk of agent reformation. However, treatment of arsenic- and mercury-containing wastes produces volatile elemental metals; although GPCR has successfully treated arsenic-containing wastes, removal of arsenic and mercury from the air effluent poses a challenge that must be considered in the design of the pollution abatement system." They also noted a concern related to the use of hydrogen, "Transportation of large quantities of hydrogen may present a risk of transportation-related accidents. However, hydrogen is a standard commercial product, and should be available locally (or generated on-site), minimizing transportation distances" [11].

The system does not produce slag or ash – the only residual we have (other than the treated steel and that sort of thing) is our filter systems, and even these are not an output. When the filters are "spent", we simply place them in the TRBP, heat them to desorb and destroy the contaminants, and then reuse them. This is a common practice with our commercial operations [12].

Transportability:
See also under Throughput under Semi mobile and portable plants.
The DOE review [5] 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 [6] 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." [11]

Detailed information:
See Data in Annexes

Full Scale treatment examples:
See Annexes

Conclusion:
The GPCR process is a well-developed technology and has a proven record of practical and commercial experiences for pesticides and related POPs compounds.

Vendor contact details:

ELI Eco Logic International Inc.
K. Elizabeth (Beth) Kümmling
143 Dennis Street
Rockwood, Ontario
Canada N0B 2K0
Phone: +1 (519) 856-9591 ext. 203
Fax: +1 (519) 856-2625
Email: beth.kummling@ecologic.ca

**Note: This NATO/CCMS fellowship report 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 of the Technology supplier it would not have been possible to set up this fact sheet.*
*** Note:The text for this report is verified by the Technology supplier on 1. October 2002*

References:

1. ELI Eco Logic International Inc., Eco Logic's Gas-Phase Chemical Reduction Process, Application to the Treatment of Persistent Organic Pollutants

2 . Kummling, K. E., Gray D.J., Power J.P., Woodland S.E., Gas-phase chemical reduction of hexachlorobenzene and other chlorinated compounds: Waste treatment experience and applications, 6th Int. HCH & Pesticides Forum, 20-22 March 2001, Poznan, Poland, February **2002**

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10. USEPA. Potential Applicability Of Assembled Chemical Weapons Assessment Technologies To RCRA Waste Streams And Contaminated Media, U.S. Environmental Protection Agency, Office of Solid Waste and Emergency Response, Technology Innovation Office, Washington, DC, EPA 542-R-00-004, August **2000**

11. Greenpeace, Non-Incineration Technology Fact Sheet #4

12. Beth Kümmling, Eli Ecoligic, written comments for Pesticides Treatment Technology Fact Sheet, 1. October 2002

Gas-Phase Chemical Reduction (GPCR) – Annex to Pesticides Treatment Technology Fact Sheet

Table 1: Technology overview Alternative Waste technologies – 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

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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% HCBD, 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 2.5 hours. Soil contained 690 and 440 ppm DDT for Runs 1 and 2, respectively.	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, which contained 0.004 ppm DDT.	

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Table3: 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	
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%			See above	
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 conducted at Eco Logic's test facility, Rockwood, Ontario	Untreated Soil: 690 and 440 ppm DDT for Runs 1 and 2, respectively.	Treated Soil: <0.006 and 0.004 ppm DDT for Runs 1 and 2, respectively.	DRE DDT: 99.999987% and 99.999985% for Runs 1 and 2, respectively.			Demonstration plant only, and so cost data not applicable to 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	- 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	- Chemical manufacturer - Supplied PCB waste for destruction
Nufarm	Chris Lee - Plant Manager Tel 61-8-9411-4000	- 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	- 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	- HATLAR Environmental managed many of Western Australia's used pesticide collection and redrumming operations - Used the GPCR plant exclusively for destruction -
ESI	Trevor Bridle - Technical director Tel 61-8-9473-3302.	- Member of Australia's National Advisory Board

Estimated Utility Requirements for Semi-Mobile GPCR Plant Treating 70 Tonnes Pesticides per Month

Utility	*Units*	*Quantity*
Nitrogen	m^3/month	3,800
Carbon Dioxide	kg/month	2,260
Caustic (50%)	tonnes/month	38
Fresh Water (for scrubbing system)	L/month	48,000
Cooling Water (recirculating volume)	L/min	1,600
Power (peak demand)	kW	1,000
Natural Gas (normal usage)	tonnes/month	20
Natural Gas (maximum)	tonnes/month	122
Hydrogen	m^3/month	122,600