Name of Process:	**Status:**
Base Catalyzed Decomposition (BCD) formerly called Base Catalyzed Dechlorination [16]	The BCD process has been used extensively in the U.S. on Superfund sites and in the clean up in 1997 of some 10,000 tons of PCB-contaminated soil on a U.S. Navy Public Works Center in Guam. Currently, the process is being used at present to treat some 40,000 tons of PCB-contaminated soil in Warren County, North Carolina. For over two years S.D. Myers de Mexico has operated the BCD process commercially near Mexico City. The Mexican plant has a 2600-gallon capacity and is a larger operation than those in Australia. The system operates also in Australia. Two proponents of the BCD technology are Enterra Pty Ltd (Formerly ADI Limited), BCD Technologies (Brisbane). A third one, Technosafe (Melbourne), was licensed by the BCD Group (patent holder) for treatment of PCB liquids and soils in Australia, but is now out of business. BCD Technologies was only licensed for the treatment of liquids in Australia. ADI held a BCD licence for Europe but was required to enter into a sublicense agreement if they wished to apply the technology in Australia. 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 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.
Vendor(s): BCD International, Inc, Ohio, USA (no vendor but sells the licences) http://www.bcdinternational.com BCD Technologies Pty Ltd (Brisbane) http://www.srlplasma.com/ Thermal and Chemical Soil Remediation Ltd, (TCSR), Czech Republic IHOBE S.A. (no vendor, but has experience) http://www.ihobe.es Enterra Pty Ltd (Formerly ADI Limited) **Note:** Some of the former users of the BCD process such as SoilTech and ETG Environmental Inc. are no longer in the hazardous waste treatment business.	
Applicable Pesticides and related POPs wastes: PCB's, pesticides and dioxins	

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 and work now as BCD International, Inc. 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 [16]. 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 pretreatment 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 [1], [2].

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.

Process diagram:

BCD Group Inc. US EPA Cincinnati, PCB Results for the PCB Study, Treating 200,000 ppm Aroclor 1242
Test Run BCD Reaction

	Measured concentrations in ppm (mg/ml)		
PCB congener Group	**Time = 0**	**Time = 30 Minutes**	**Time = 60 Minutes**
Mono-PCBs	2314	ND (0.10)	ND (0.10)
Di-PCBs	48229	ND (0.10)	ND (0.10)
Tri-PCB	115341	ND (0.20)	ND (0.20)
Tetra-PCBs	30268	ND (0.25)	ND (0.25)
Penta-PCBs	3833	ND (0.25)	ND (0.25)
Hepta-PCBs	ND (0.25)	ND (0.25)	ND (0.25)
Hexa-PCBs	ND (0.30)	ND (0.30)	ND (0.130)

Note: ND = non detect at MDQ contained in the brackets.

S.D. Myers de Mexico, a BCD licensee employs the catalyst discovered in 1997 in the 2600 gallon BCD plant now in operation in Mexico and the new catalyst effectively destroy 100% PCBs within 1-2 hours. Pesticides in concentrations of 100% can be destroyed by BCD at rates identical to PCBs in a proven safe, low cost and environmentally acceptable manner [16].

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BCD is or has been used at two commercial sites within Australia and for the treatment of PCB's, and has not been regarded adversely by the community [1]. In 1992, BCD Technologies opened the first BCD treatment plant in the world. There are a large number of BCD-variations and adaptations, which cannot be explained in detail within the limits of this fact sheet.

Another BCD system has been operating from 2000 to 2002, Basque Country, Spain by IHOBE S.A., the environmental management company of the Basque Government. Here, contrary to the Australian systems, 3500 tons of HCH waste has not been destroyed completely, but an intermediate chlorinated product TCB has been produced, which was used in the manufacture of dyes, colourings and agricultural chemicals [4].

The BCD process effects the destruction of chlorinated dioxins and furans. Certain wastes containing compounds such as chlorinated phenols and the phenoxyl herbicides quickly form dioxins and furans when heated in an alkaline environment. The BCD treatment medium contains a strong base. The BCD treatment protocol requires that the treatment medium is heated to 300° C before feeding pollutants into the treatment vessel. At BCD treatment temperatures, those compounds that can be converted to dioxins and furans are destroyed before synthesis occurs.

Some of the former users of the BCD process in the US, such as SoilTech and ETG Environmental Inc. are no longer in the hazardous waste treatment business. Since details regarding this work are not readily available (only some summary reports are available [13] and [14]), it is important to note that the clean-up with the BCD process achieved and exceeded the U.S. Office of Toxic Substance and Superfund treatment regulation standards [16].

The Alkaline polyethylene glycol (APEG) method operates at 100-180 °C to effect the dechlorination of chlorinated compounds. The total glycol moiety is employed to remove halogens by nucleophilic displacement reaction. The BCD process initially employed glycols as source of hydrogen and successfully destroyed toxic compounds. (Note: high boiling point oils are now used as hydrogen donors). Accordingly when the reaction chemistry is carried out at low temperature it is not BCD chemistry and should be referred to only as the BCD process first development when treatment conditions are at 300 °C [16].

The BCD process was successfully demonstrated at the Wide Beach Superfund site Brant in New York in 1991, where approximately 42,000 tons of stockpiled soil contaminated with PCBs, mainly Arochlor 1254, at concentrations ranging from 10 to 5,000 mg/kg, were treated. The USACE specified that the concentration of PCBs in soil treated at Wide Beach should not exceed 2 mg/kg. The Wide Beach project is notable for using full-scale treatment application using SoilTech's ATP system in conjunction with APEG dechlorination to treat soil at a Superfund Site contaminated with PCBs [5].

The combined BCD process was demonstrated under the SITE Program at the Koppers Company Superfund site in Morrisville, North Carolina, from August through September 1993. The process removed PCP from clay soils to levels below those specified in the Record of Decision. The process also removed dioxins and furans from contaminated soil to 2,3,7,8-tetrachlorodibenzo-p-dioxinequivalent concentrations less than the concentration specified in the Record of Decision [6].

At the end of the 90's ETG was also currently operating the batch vacuum system at a New York State Department of Environmental Conservation Inactive (State Superfund) Site cleanup site in Binghamton, New York. Approximately 1,500 cubic yards of soil contaminated with herbicides, pesticides, dioxins, and furans (F027 waste) are being treated. ETG 's batch vacuum Therm-o-Detox® system with solid phase BCD was selected after a competitive bidding process. This site represents the first non-incineration commercial on-site dioxin/furan treatment project in the continental U.S. Air permits were not required due to the low system air flow [13].

The Michigan Department of Natural Resources has also approved BCD for a project involving treatment of about 200 cubic yards of F027 soils at the Inactive Wood Preserving Facility, Kalamazoo. The soil was contaminated with PCP and dioxins/furans. Michigan DNR approved the work plan and issued an air permit to conduct the treatment [14]. Under contract of the State of North Carolina, Department of Environmental and Natural Resources, ETG had successfully performed a pilot scale test demonstration to perform detoxification of PCB and dioxin/furan contaminated soils utilizing the BCD Process.

ADI Services, a BCD licensee in Australia, now being overtaken by Enterra Pty Ltd, has been operating since the beginning of the 90's and quotes to have experiences at various sites. Its Environment Group has completed the successful remediation of a number of sites in Victoria and New South Wales. These sites include ADI's St Marys site in Sydney, ADI's Footscray and Marybyrnong sites in Victoria, as well as numerous smaller sites for external clients [7]. A famous project is the Homebush Bay site, which has been the site of some of Australia's most polluting industries since the earliest days of Sydney's industrial development. The Enterra BCD process was licensed by the NSW EPA, to treat the schedule chemical waste (SCW) and dioxin impacted soils and wastes, at the Sydney Olympic site.

The Homebush Bay site is a part of the Olympic site containing about 450 tons of soil contaminated with chlorobenzenes (CB), chlorophenols (CP) and dioxins. In addition about 10 tons of pure CB's and CP's required disposal. Enterra used the Indirect Thermal Desorber (ITD) to remove the contaminants from the soil, generating about 13 tonnes of highly concentrated condensate sludge (see also under residuals). In addition a small amount of miscellaneous waste containing SCW and variable amounts of soil and other solid matter, including 2 tons of spent activated carbon, was pre-processed using a ball mill and subsequently treated directly in the BCD reactor [8].

The Enterra plant was licensed by the NSW EPA for continuous off-gas discharge, with regular periodic monitoring [7]. The NSW EPA states in June 2002 the following: "The Olympic Committee considers this treatment process a major environmental success, which has established an environmental benchmark for the remediation of heavily contaminated sites" [8].

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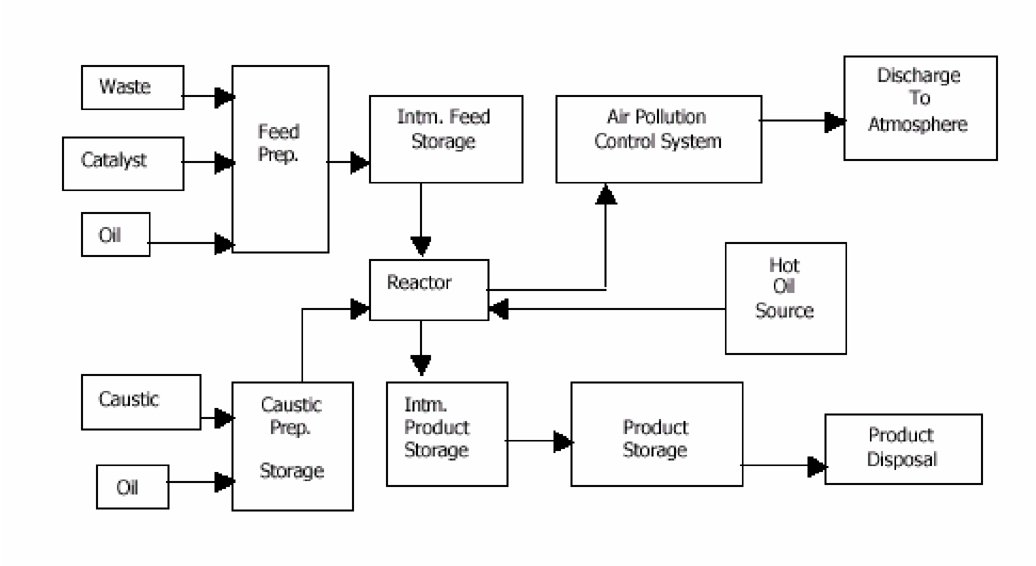
Simplified flow diagram of the Homebush Bay NSW BCD plant [8]:



Performance:

Treatment efficiency:

Wright State University, Dayton, Ohio conducted tests of a number of pesticides, dioxins, and other toxic compounds recovered from highly contaminated soil by thermodesorption were subsequently treated in their BCD liquid treatment vessel confirmed that BCD not only effects dechlorination of chlorinated compounds but decompose all organic compounds including all pesticides (see Table):

Table: Results of liquid phase BCD treatment tests on pooled condensates from the three solid phase BCD treatment tests of dioxin contaminated soil and spent carbon

Sample Description	Condensate Feed to BCD reactor	Residual Treated Condensate
Analyte – Test 1 Condensate		
2,3,7,8-TCDD (ppb)	3,520	ND (0.184)
2,4 D (ppm)	1,050	ND (0.08)
2,4,5-T (ppm)	194	ND (0.04)
Silvex (ppm)	15	ND (0.04)
Monochlorophenol (ppm)	45,000	ND (120)
Dichlorophenol (ppm)	46,000	ND (20)
Trichlorophenol (ppm)	6,670	ND (25)
Tetrachlorobenzene (ppm)	510	ND (0.2)
Analyte – Test 2 Condensate		
2,3,7,8-TCDD (ppb)	4,060	ND (0.258)
2,4 D (ppm)	1,150	ND (0.03)
2,4,5-T (ppm)	198	ND (0.04)
Silvex (ppm)	16	ND (0.03)
Monochlorophenol (ppm)	30,000	ND (250)
Dichlorophenol (ppm)	30,500	ND (80)
Trichlorophenol (ppm)	8,300	ND (80)
Tetrachlorobenzene (ppm)	680	ND (0.01)
Analyte – Test 2 Condensate		
2,3,7,8-TCDD (ppb)	3,810	ND (0.188)
2,4 D (ppm)	940	ND (0.3)
2,4,5-T (ppm)	209	ND (0.70)
Silvex (ppm)	16	ND (0.10)
Monochlorophenol (ppm)	37,400	ND (100)
Dichlorophenol (ppm)	46,700	ND (15)
Trichlorophenol (ppm)	7,400	ND (20)
Tetrachlorobenzene (ppm)	459	ND (0.2)

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Some PCB treatment results are shown in the following Table:

Table: BCD Group Inc. / US EPA Cincinnati, Treating 300,000 ppm Aroclor 1242
Test Run BCD Reaction

Measured concentrations in ppm (mg/ml)					
PCB congener Group	**Time = 0 (T = 305 ° C)**	**Time = 15 Minutes (T = 317 ° C)**	**Time = 30 Minutes (T = 325 ° C)**	**Time = 60 Minutes (T = 330 ° C)**	**Time = 30 Minutes (T = 335 ° C)**
Mono-PCBs	1713	ND (0.10)	ND (0.10)		ND (0.10)
Di-PCBs	51627	ND (0.10)	ND (0.10)		ND (0.10)
Tri-PCB	198616	ND (0.20)	ND (0.20)		ND (0.20)
Tetra-PCBs	42249	ND (0.25)	ND (0.25)		ND (0.25)
Penta-PCBs	45579	ND (0.25)	ND (0.25)		ND (0.25)
Hepta-PCBs	80	ND (0.20)	ND (0.25)		ND (0.25)
Hexa-PCBs	ND (0.50)	ND (0.50)	ND (0.130)		ND (0.130)

Note: ND = non detect at MDQ contained in the brackets.
Total of 300,000 ppm of PCB Aroclor 1242 was added to the reactor at Time = 0.
in Series KT02151,2,3,4,5 (02/15/97)

BCD has been or currently is being used to treat soil. This technology effects the destruction of toxic chemicals such as PCBs, chlorinated dioxins, and pesticides in soil, sediment, sludge, and liquids. Some U.S. commercial applications of BCD technology have been listed in the Annex. Currently, BCD process is being used at present to treat some 40,000 tons of PCB-contaminated soil in Warren County, North Carolina.

On stack emissions, the New Zealand Ministry of the Environment has noted as follows [9]:

"The ADI thermal adsorption process produces a variable amount of dust (usually less than 5% of the original soil feed) and condensates, both containing dioxins. While these are captured and contained within the system, they must be able to be safely decomposed for the total process to be considered effective."
In trials in 1997 in New Zealand, the solid residues were fed back into the system. This resulted in a reduction of the dioxin levels from an initial level of 1280 ppb TEQ to a value below 0.1 ppb TEQ.

Table: Base Catalyzed Dechlorination - Dioxins in Stack Gases [9].

Dioxins and Furans	**Stack Gas, ng/dscm***
Tetrachlorinated dibenzo-p-dioxins (TCDD)	0.14
Tetrachlorinated dibenzofurans (TCDF)	4.8
Pentachlorinated dibenzo-p-dioxins (PeCDD)	0.96
Pentachlorinated dibenzofurans (PeCDF)	0.72
Hexachlorinated dibenzo-p-dioxins (HxCDD)	0.17
Hexachlorinated dibenzofurans (HxCDF)	0.077
Heptachlorinated dibenzo-p-dioxins (HpCDD)	0.25
Heptachlorinated dibenzofurans (HpCDF)	0.032
Octachlorinated dibenzo-p-dioxins (OCDD)	2.34
Octachlorinated dibenzofurans (OCDF)	0.032
Total Dioxins and Furans	9.52
Total TEQs	0.707

* dscm = dry standard cubic meter

It is important to note that the data shown in the Table represent one of the first generations of commercial BCD operation. Considerable improvements in emissions control has materialised since that time as evident by the New Zealand data listed above (TEQ below 0.1 ppb). We have learned that glycols as hydrogen donors, are also highly oxygenated and when used as hydrogen donor resulted in some increased amounts dioxins in the emissions. For this reason, glycols are no longer considered for use as hydrogen donors in the BCD process [16].

Within the SITE Demonstration programme [10], at the Wide Beach Superfund site in 1991, the BCD/APEG process was successfully demonstrated, for the treatment of soil contaminated with PCBs, mainly Arochlor 1254, at concentrations ranging from 10 to 5,000 mg/kg:

“Gaseous emissions, which are very small compared with combustion systems [6], were treated with cyclone, baghouse, acid gas scrubber, and activated carbon adsorption. The Table shows dioxin and furan stack gas emissions measured during the SITE Demonstration. No data were presented to describe the concentrations in stack gases of other POPs potentially formed during the process or the concentrations of such substances in other process residues.”

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Key findings from the SITE demonstration at the Koppers Company Superfund site are summarized as follows:

- The MTTD achieved removal efficiencies of 99.97 percent or better for PCP and 99.56 percent or better for total dioxins and total furans.
- The treated soils were well below toxicity characteristic leaching procedure limits for SVOCs.
- Treated soil met the cleanup goal of 95 parts per million PCP in all test runs.
- Treated soil also met a cleanup goal of 7 micrograms per kilogram 2,3,7,8-tetrachlorodibenzo-p-dioxin equivalents in all test runs.
- The LTR batch tests reduced PCP concentrations by 96.89 percent or better, and total dioxin and total furan concentrations by 99.97 percent or better.

The demonstration test results indicated that the BCD process dechlorinated 76 percent of the PCBs that entered the ATP system during the test. However, this figure does not account for dechlorination from recycling residual oil through the system. In addition, an EPA SITE Demonstration was conducted during the full-scale operation in May of 1991. The SITE Demonstration results indicated that 98 percent of the PCBs that entered the ATP system were dechlorinated (6). All PCBs and other pollutants not destroyed in the ATP are collected and destroyed in liquid treatment vessel. Again glycols were used only 1-5 % concentration as hydrogen donor. The APEG reagent technology requires 100% sodium glycolate, pollutants added to medium and mixture heated with stirring to 100-180 **°** C. This chemistry is not used extensively because it only partially removes heteroatoms from toxic compounds [16].

At the Outboard Marine Corporation (OMC), Superfund Site, Waukegan, Illinois, in 1992, an early application of SoilTech's ATP system for treating soil and sediment at a Superfund Site contaminated with PCBs was executed. 12,755 tons soil and sediment contaminated with Polychlorinated Biphenyls (PCBs)-PCB concentrations in material feed to thermal desorber ranged from 2,400 to 23,000 mg/kg PCBs – were treated [11].

Following Regulatory Requirements/Cleanup Goals had to be met:
- Soil and Sediment - PCBs: 97% removal by mass - Air - PCBs: Destruction and Removal Efficiency (DRE) of 99.9999%, Dioxins/Furans: 30 ng/dscm

The following results were achieved at Outboard Marine Corporation (OMC), Superfund Site:
Soil and Sediment - Achieved PCB cleanup goal for soil and sediment; average PCB removal efficiency of 99.98%; PCB concentrations in treated soil ranged from 0.4 mg/kg to 8.9 mg/kg; most samples less than 2 mg/kg Air - Stack gas requirements met for PCBs; stack gas requirements met for dioxins/furans after system modifications [11].

At Warren Country PCB Landfill ETG utilized the BCD process in conjunction with the ETG patented batch vacuum indirect heat thermal desorption system (therm-O-Detox 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. Air emission standards (a the property line) of 8x10-4 ug/dscm for PCBs and 5x10-8 ug/dsm for dioxins were met [15].

Detailed lists on IHOBE's environmental monitoring on HCH store emissions and the emissions at the process plant are listed in [4].

Air:

IHOBE's facility has 2 stacks: one for renewing the air in the HCH preparation area and the other for the process itself.

During its first 10 months of activity, the concentrations of TCB and HCH were measured daily at each stack. A total of 400 readings were taken. Since then the measures have been made, twice a month and this system will continue until operations are completed.

"The limits set by the licensing authorities are 20 mg/Nm^3 for TCB and HCH (ref. TA Luft Technical Instructions on Air). The analyses performed show highly satisfactory levels, with an average of below 2 mg/Nm^3, well below the permitted limit."

Environmental monitoring during the operations:

Equipment has now been set up in 2 places 500 m far from the plant (Arteagabeitia and Cruces), and daily samples will be taken for one month.

The first results, corresponding to information up to March 9^{th} (2001) are ND for HCH and TCB, with a detection limit of 1 ng/m^3 for HCH & 50 ng/m^3 for TCB.

At the Homebush Bay site the contaminated soil CB and CP content was about 20,000 mg/kg (ppm) and after thermal desorption the CB and CP content was reduced to < 1 mg/kg (ppm). Dioxins were not detected in the treated soil, which was disposed to landfill. The 10 tonnes of pure CB's and CP's and 13 tons of sludge condensate from ITD were then processed in the batch BCD reactor. For all batches processed the reactor output was < 1 mg/kg (ppm) SCW and < 1 μg/kg (ppb) dioxin. As it can be seen, this data shows that the destruction efficiency for Schedule Chemical Wastes is typically around 99.9999% [8].

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Reliability:
While generally considered to be a relatively low risk technology, a BCD plant in Melbourne, Australia was rendered inoperable following a fire in 1995, as described below [1]:
"The fire damaged the treatment system and building. It is understood that the fire resulted from a combination of factors. The nitrogen blanket was in place over the reactor, however, on discharge of hot oil into a storage vessel without an adequate nitrogen blanket, the fire occurred in the storage vessel. The auto ignition point of the hot oil was lower than expected and was exceeded. " The plant has been rebuilt and is operating on a commercial basis, focusing on PCB contaminated oils, transformers and capacitors, following approval by the regional environmental agency.

(BCD plants in the US and other foreign countries have been in operation for over 8 years without incident as described above).

Limitations:
Since 1997, limitations on high concentrations PCB's are eliminated.

Transportability:
Possible use of the BCD plant on a portable basis (e.g. relocated and used on site) (Krynen, 1994b).
S.D. Myers 2,600 gallon BCD plant was initially a mobile plant. Now it is operated as a stationary facility. However, the plant can be transformed to a flexible mobile plant for on site treatment of unwanted pesticides [16].

Detailed information:
See Data in Annex

Conclusion:
The BCD process has been used extensively in the US and Australia, especially for the treatment of high contaminated soils. Also considerable experiences for waste treatment have been made, although not as many as for the soil treatment. For more than 10 years, BCD has been widely applied for pesticides and PCB's making it a ready to use technology in this field. The improved BCD process has been used in Mexico for over two years treating liquid PCBs in concentrations ranging up to 100% in a safe and cost effective manner. This mobile chemical process that has been widely used for treating PCBs, Pesticides, dioxins and other toxic and hazardous materials is well suited for use on site to destroy obsolete or unwanted pesticides without the risk of damage to public health or the environment.

Full Scale Treatment examples:
See Annex

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***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: This report is set up in close co-operation with the owners of the patents at BCD Group Inc. on 30. November, 12 and 14 December 2002*

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11. US EPA, Office of Solid Waste and Emergency Response, USEPA, Cost and Performance Report, Thermal Desorption at the Outboard Marine Corporation Superfund Site, Waukegan, Illinois, 1992
12. Further detailed information and updates on Homebush Bay can be obtained from the following websites:
    Homepage Homebay Bush Remediation: http://www.rhodesremediation.nsw.gov.au
    Homepage Olympic Committee Sydney 2002: http://www.oca.nsw.gov.au/html/chemicalwaste
13. ETG Project Summary, New York State Department of Environmental Conservation Inactive (State Superfund) Site cleanup site in Binghamton, New York
14. ETG Project Summary, Inactive Wood Preserving Facility Kalamazoo, MI
15. ETG Project Summary, Warren Country PCB Landfill Detoxification Base Catalyzed Decomposition (BCD) Therm-O-Detox® System
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