Non-combustion Destruction Technologies for POPs

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Stockholm Convention

The Stockholm Convention states that Parties are to take measures so that POPs wastes are:

- *"Disposed of in such a way that the persistent organic pollutant content is destroyed or irreversibly transformed so that they do not exhibit the characteristics of persistent organic pollutants or otherwise disposed of in an environmentally sound manner when destruction or irreversible transformation does not represent the environmentally preferable option …"* (Article 6, L (d) (ii))

Further, measures are to be taken so that POPs wastes are:

- *"Not permitted to be subject to disposal operations that may lead to recovery, recycling, reclamation, direct reuse or alternative uses of persistent organic pollutants."* (Article 6 (d) (iii))

Stockholm Convention

Based on provisions for POPs disposal, a technology should:

- Prevent the formation of dioxins, furans and other by-product POPs.
- Prevent the release of dioxins/furans and other by-product POPs.
- Not generate any wastes with POPs characteristics.
- Not utilise any POPs disposal methods which are non-destructive, such as landfilling or recycling in any form.

Criteria for Destruction

- Destruction Efficiency (DE) ~ is calculated on the basis of the total mass of POPs fed into a process, versus the sum of the POPs in all products, by-products, and environmental releases (e.g. gaseous, solid and liquid) i.e. DE considers the total destruction of POPs in a given process

- Destruction and Removal Efficiency (DRE) ~ is calculated on the basis of total POPs fed into a process, versus the concentration of POPs in the stack gases. It ignores releases in solid and liquid waste streams.

Technology Selection

- Based on Stockholm Convention criteria
- Destruction Efficiency (based on inputs vs. all outputs)
- Ability to contain all process streams
- Ability to reprocess materials, residues, gases, liquids if required
- Availability of complete process information Track record/commercial availability
- Safety/OH&S
- Hazardous materials use
- Community acceptability and participation

Note on Destruction Efficiencies

- A number of POPs treatment technologies are capable of very high Destruction Efficiencies.
- Data from large scale clean-ups and remediation projects do not necessarily reflect the high DE's achievable for a given technology.
- This is largely due to clean up standards being set at lower levels of destruction than the technology is capable of achieving. Lower clean up levels result in residual POPs in treated soils, wastes, etc. remaining after treatment.
- Licensing requirements for any POPs destruction project should set strict limits for the Destruction Efficiency, with sufficient validation sampling and analysis protocols to ensure compliance.
- DE requirements should take into account the potential for hazardous by-products formed during the course of the treatment process and require sampling for all potential POPs and other hazardous substances in all waste streams and process residues.
- It should be a requirement of any remediation or clean-up project to destroy all POPs to the maximal extent possible and ensure that the clean-up goals are to ensure no toxic legacy remains at the site after remediation has been concluded.

Note on Containment

- Most practical systems will have some potential for release of gases due to safety or regulatory requirements. For example pressure relief valves in case of system upsets.
- Technologies designed to contain all process streams in a batch process, will have the highest potential to maximise containment and subsequent testing for potential POPs releases.
- Technologies that operate at room temperature and pressure, will have the greatest potential to maximise containment during processing.
- Any technologies that utilise high temperatures and pressure will introduce the potential for gaseous releases due to process upsets, unless specific redundant systems are employed by the technology.
- Regulators should require a maximum level of containment for all process wastes and streams, commensurate with regulations for worker health, safety and environmental protection.

Combustion Technologies

- According to the FAO, large scale incinerators are very expensive and small scale incinerators may not be suitable for destruction of highly chlorinated materials.

- Any incineration option will require a significant investment in air pollution control devices to minimise the emissions of dioxins and other toxic products of incomplete combustion from being emitted in the stack.

- Incineration generates a significant amount of solid wastes (e.g. ashes) and residues that must be dealt with in a responsible manner. Fly ash and other residues contain high levels of dioxins and other POPs and these wastes must then be further treated.

- Exporting POPs wastes for treatment in incineration facilities in Europe or North America is not necessarily an easy solution. Repackaging and transport costs can be high and many proposals for trans-national shipments of POPs wastes for incineration meet strong opposition from local communities near the incinerators.

- Recently, a proposed shipment of HCB waste from Australia to France for incineration was denied by the French Government on the grounds that "The transport of dangerous waste ... is an environmental aberration." "Such waste, "should be treated near their source of production…". The German and Danish government also rejected the shipment.

Combustion - Incineration

- Fails to meet criteria for destruction of POPs chemicals.
- Is essentially an open process, with large amounts of gaseous emissions.
- Attempting to deal with the air emissions, substantially increases costs and complexity of the system, that result in further hazardous waste streams.
- Is a known source of dioxins and furans and other POPs, to air, **solid** and liquid wastes.
- Is controversial and subject to considerable public opposition.
- A state of the art incinerator will require a substantial investment and a continuous hazardous waste stream for decades to ensure profitability. Further costs arise over time due to maintenance and upgrading of APC to meet stricter air quality standards.

Covanta “Combined Ash” monofill, Haverhill, Massachusetts. US.

Source: Professor Paul Connett *The Zero Waste Solution (2013)* Chelsea Green Press

EU: Highly hazardous fly ash sent to deep salt mines

Fly ash from RZR Herten Incinerator located at Heilbronn and operated by the South-West German Salt Works

Combustion- Cement kiln co-firing

- Cement kiln air pollution controls (APC) are rudimentary compared to dedicated hazardous waste incinerators potentially leading to high PIC emissions.
- The lack of rapid quench technology encourages *de novo* synthesis of dioxins and other POPs during the relatively long cool down period between 450 -200 degrees Celsius while the flue gases are in a high particulate environment.
- Dedicated incinerators operate with relatively high excess oxygen (8-12 vol %) to maintain gaseous stability compared to 1-2 vol % for kilns decreasing stability and the risk of POP and PIC formation.
- DRE is a poor measure of POPs destruction efficiency in kilns as the potential for migration to the cement product is high with significant life cycle risks to workers and the environment

Non-combustion technologies

- Many proven technologies are available for a wide range of POPs wastes.
- Meet the criteria for appropriate technologies for the destruction of POPs wastes.
- Enable the containment of all process streams to allow for further processing in cases of system upsets or less than expected destruction.
- Are not inherently a significant source of POPs pollution due to higher destruction efficiencies and ability to contain all waste streams for further processing.
- More acceptable to local communities for the destruction of POPs stockpiles and contaminated sites than incineration.

Non-combustion Technologies

- Ball Milling
- Bioremediation
- Base Catalyzed Decomposition
- Catalytic hydrogenation
- Copper Mediated Destruction
- Gas Phase Chemical Reduction
- Hydrodechlorination
- Mediated Electrochemical Oxidation
- Potassium tert-butoxide (t-BuOK) method
- Plasma technologies
- Solvated Electron Technology
- Sonic Technology
- Super-Critical Water Oxidation
- Sodium Reduction
- Vacuum Heating Decomposition
- Vitrification

Technologies chosen for detailed review after assessment

- Gas Phase Chemical Reduction
- Super-Critical Water Oxidation
- Base Catalyzed Decomposition
- Catalytic hydrogenation
- Copper Mediated Destruction
- Ball Milling
- Plasma systems
- Solvated Electron Technology
- Sodium Reduction

Overview of Technologies

	Capable of High DE	Containment of all Residues / Wastes	Commercially available	Commercial Experience with POPs*	Vendors
Ball Milling	☐	High	☐	Moderate	Several
Base Catalyzed Decomposition	☐	High	☐	Extensive	Several
Catalytic hydrogenation	☐	High	☐	Limited	Two
Copper Mediated Destruction	☐	High	☐	Very Limited	One
Gas Phase Chemical Reduction	☐	High	☐	Moderate	One
Plasma systems	☐	Low - High	☐	Moderate	Several
Solvated Electron Technology	☐	High	☐	Limited	One
Sodium Reduction	☐	High	☐	Extensive	Many
Super-Critical Water Oxidation	☐	High	☐	Moderate	Several

* Extensive = many years of commercial operation from multiple vendors. Moderate = many years of commercial operation from one or more vendors. Limited = some years of experience, from at least one vendor. Very limited = Only available from one vendor with limited commercial application.

Partial List of Vendors

Technology	Vendor	HQ Location	Web
Ball Milling	Environmental Decontamination Ltd (EDL)	Auckland, New Zealand	www.edl-asia.com
Ball Milling	Radical Planet Research Institute Co. Ltd.	Nagoya City, Aichi, Japan	www.radicalplanet.co.jp/en/
Base Catalyzed Decomposition	BCD Technologies Pty Ltd (subsidiary of ToxFree Solutions Ltd)	Narangba, QLD. Australia	www.bcdtechnologies.com.au
Base Catalyzed Decomposition*	BCD Group Inc. (Patent holder, licences BCD to vendors)	Ohio, USA	www.bcdinternational.com
Catalytic Hydrogenation	Hydrodec Group PLC	London, England	www.hydrodec.com/
GPCR	Natural Energy Systems Inc.	Ontario, Canada	www.naturalenergyinc.com
Solvated Electron Technology	Commodore Environmental Services (subsidiary of Oasis Systems LLC)	Broomfield, Colorado, USA	www.oasissystems.com
Sodium Reduction	Kinectrics Inc.	Ontario, Canada	www.kinectrics.com
Sodium Reduction	Powertech Labs Inc.	Surrey, British Columbia Canada	www.powertechlabs.com
Sodium Reduction	Transformer Maintenance Services (TMS) (formerly ESI Group Australia)	Hume, ACT, Australia	www.tmsa.com.au
Sodium Reduction*	Dr. Bilger Umweltconsulting GmbH	Hanau, Germany	www.bilgergmbh.de

* Note: Many more vendors for BCD process over the last 20 years, some for site specific projects, others in Mexico, Spain, Europe continue operations. Many other vendors currently offer Sodium Reduction process in Europe, Asia, North America and Europe.

Indicative costs of treatment

Technology	Vendor	PCB Oils	Soils	Capacitors	Transformers
Ball Milling [1]	EDL	$300/ton	$250/ton	$300/ton	$300/ton
Base Catalyzed Decomposition [2]	Multiple	$0.7-2.2/kg depending on waste	$300/m³		
Catalytic hydrogenation [1]	Hydrodec Group PLC	5-50ppm PCB:$0.40/L 50-500ppm PCB: $0.80/L >500ppm PCB: $4.00/L			
Gas Phase Chemical Reduction [1]	Natural Energy Systems Inc.	$2,300/tonne - for 100% PCB waste	$500/tonne - assumes low % of PCB.	$1,300/tonne - assumes 40% PCB.	$1,300/tonne - assumes 40% PCB.
Solvated Electron Technology [1]	Oasis Systems /Commodore	$5512 - $6614/tonne	$5512 - $6614/tonne	$5512 - $6614/tonne	$5512 - $6614/tonne
Sodium Reduction [1]	Kinectrics Inc	$0.9 - $7/litre		$500-1700/tonne	$500-1700/tonne
Sodium Reduction [1]	ESI Group	$0.35 to $0.85/litre (up to 3000ppm)	$680 to $1,700/tonne	$1,700 to $4,250/tonne	$800 to $1,220/tonne

Vendor supplied costing information all costs given in US dollars. Actual costs will depend on site-specific conditions.

Sources:

1. SNC LAVALIN Inc., PCB Management and Disposal Demonstration Project. Analysis of PCB Treatment & Disposal Options for the Socialist Republic of Vietnam. Final Report to The World Bank, July 2008
2. Secretariat of the Basel Convention (ND). Destruction and Decontamination Technologies for PCBs and other POPs Wastes under the Basel Convention. A Training Manual for Hazardous Waste Project Manager. Volume C. Base catalyzed decomposition.

Gas Phase Chemical Reduction

COMMERCIAL PROJECTS

- Kwinana, Western Australia (May 1995-December 2000)
  - 2000 tonnes of PCB electrical equipment such as transformers and capacitors, liquid PCBs, HCB, pesticides (DDT), and other organic wastes for government and industry clients throughout Australia.
  - Destruction of Pesticide wastes from the chem-collect program.
  - Project completed when all commercially available waste in Australia at that time was destroyed.
- General Motors Canada, St. Catharines, Ontario
  - PCB contaminated transformers and capacitors for GM and for the city of St. Catharines.
  - PCB contaminated Great Lakes sediment.

Gas Phase Chemical Reduction

Kwinana, Western Australia

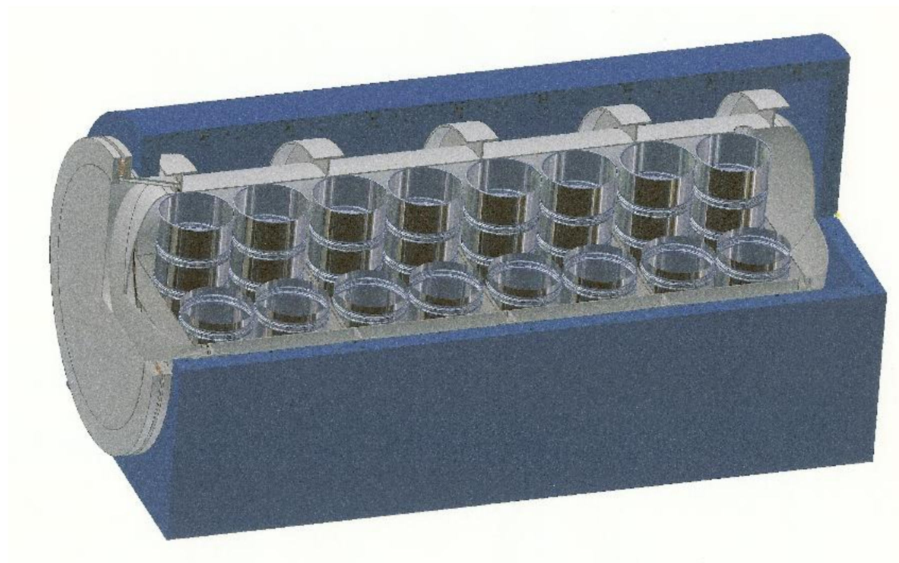
2000 tonnes of PCBs destroyed

Source: Natural Energy Systems Inc.

Gas Phase Chemical Reduction

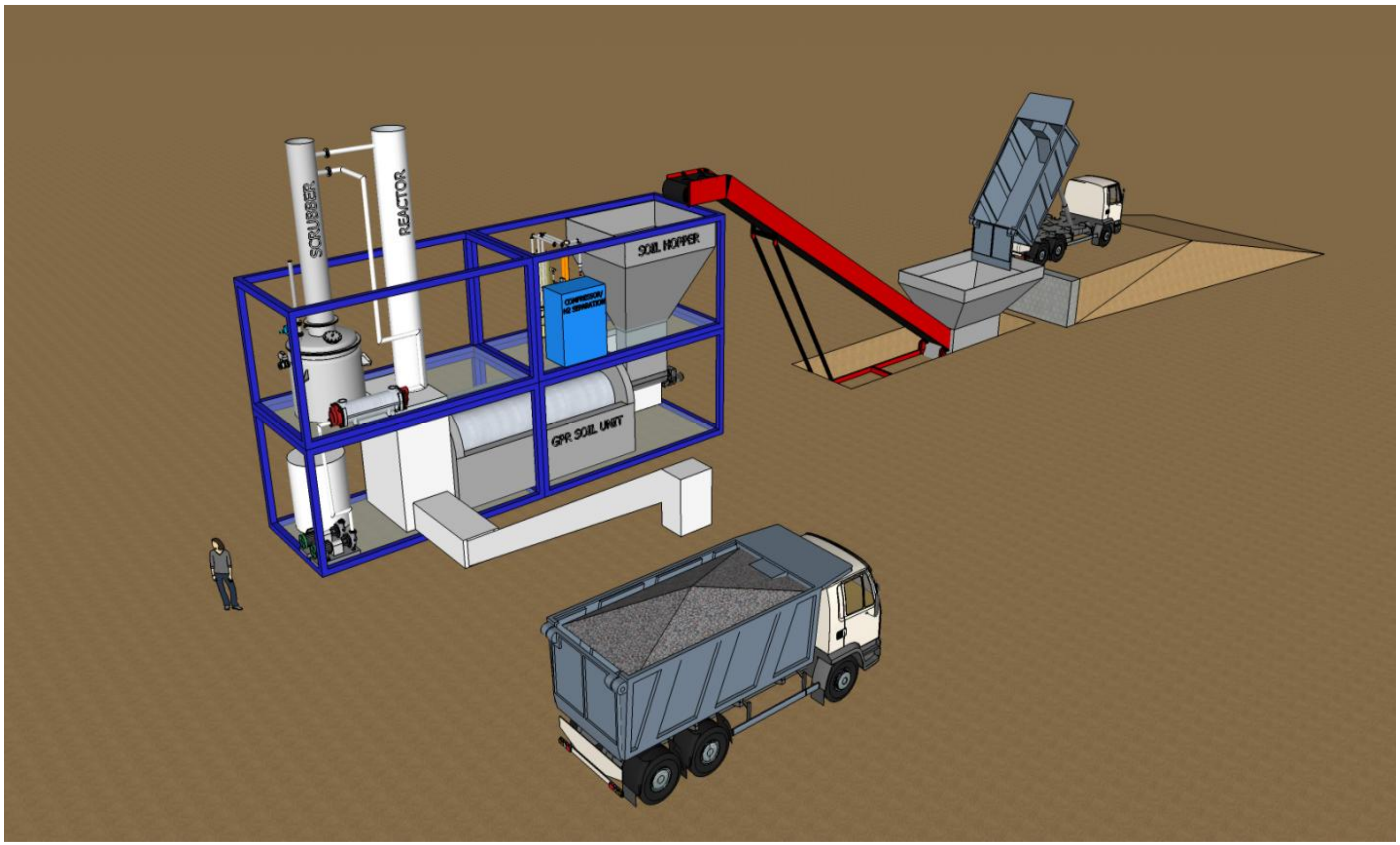
Drums and contaminated PPE can be loaded without expensive pre-treatment and homogenisation.

Source: Natural Energy Systems Inc.



Gas Phase Chemical Reduction

Contaminated soil and sludge processing capability



Source: Natural Energy Systems Inc.

Base Catalyzed Decomposition

Commercial Operations examples:

- Numerous Superfund remediation projects in the USA. More than 100,000 tons contaminated soil treated for dioxins, PCBs, pesticides.
- Large scale treatment contaminated soils and waste at Spolana, Czech Republic. Involved 200 tonnes pesticides and 1200 tonnes dioxins/pesticide concentrate from remediation of 35000 tonnes of soil.
- Sydney 2000 Olympics site remediation at Homebush Bay involved treatment 400 tonnes chlorinated benzenes/dioxins
- More than 2500 tonnes PCBs treated in fixed facility in Mexico by S.D Meyers de Mexico.
- 3500 tonnes of HCH pesticide treated between 2002-2002 Spain by IHOBE S.A.
- Commercially operating in Australia for PCB treatment since 1992 at BCD Technologies Pty Ltd.

Source: Secretariat of the Basel Convention (ND). Destruction and Decontamination Technologies for PCBs and other POPs Wastes under the Basel Convention. A Training Manual for Hazardous Waste Project Manager. Volume C.

Sodium Reduction Process

Commercial Operations examples:

- Kinectrics Inc has treated more than 17,000 tonnes of PCBs since 1985.
- A Kinectrics licensee in Japan has been treating 100% PCBs since 2005.
- A new Kinectrics facility was recently completed in the Philippines for the treatment of PCBs in that country.
- Sanexen Environmental Services Inc., Canada has treated 25,000 tonnes of PCB fluids since 1985.
- Powertech Labs, Canada, has treated more than 14,000 tonnes PCBs since 1987.
- Multiple other vendors offer sodium reduction process technology in Europe, Asia and the Americas.

Source: Secretariat of the Basel Convention (ND). Destruction and Decontamination Technologies for PCBs and other POPs Wastes under the Basel Convention. A Training Manual for Hazardous Waste Project Manager. Volume C.

Pre-Treatment Technologies

Technologies which do not destroy POPs, but may be utilized to pre-treat POPs/wastes prior to destruction. For example, to remove POPs contamination from soil, drums, building materials, etc.

- Autoclaving
- Indirect Thermal Desorption
- In-situ Thermal Desorption
- Solvent Washing

Treatment Trains

The Indirect Thermal Desorption Unit (ITDU) at Spolana Neratovice, Czech Republic heats contaminated materials to 500-600 □C stripping in absence of oxygen and POPs are collected in filter and condensation system.

The Base Catalyzed Decomposition unit then destroys this concentrate.

Source: Bell, L. (2015) Identification and Management of mercury, PCB and dioxin contaminated sites in Kazakhstan: A Collective Impact approach to civil society engagement.

Conclusion

- Non-combustion technologies are:
  - Commercially available for POPs destruction.
  - Capable of meeting all the fundamental requirements of the Stockholm Convention for treatment of POPs wastes.
  - Do not further promote the releases of dioxins and other POPs to the environment.
  - Are the preferred method of treatment for POPs wastes.

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IPEN briefing paper on non-combustion treatment for POPs available at registration desk

www.ipen.org