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Evaluating Selected Disposal Options for POPs Waste in Developing Countries and Transition Economies

A Master's Thesis submitted for the degree of
"Master of Science"

supervised by
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Affidavit

I, **ANDREA WINTERSTETTER**, hereby declare

1. that I am the sole author of the present Master's Thesis, "EVALUATING SELECTED DISPOSAL OPTIONS FOR POPS WASTE IN DEVELOPING COUNTRIES AND TRANSITION ECONOMIES", 108 pages, bound, and that I have not used any source or tool other than those referenced or any other illicit aid or tool, and
2. that I have not prior to this date submitted this Master's Thesis as an examination paper in any form in Austria or abroad.

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ABSTRACT

The main objective of this thesis is to identify the most appropriate disposal option for POPs waste in developing countries and transition economies by evaluating the options ‘incineration within the own country’, ‘export to developed countries for incineration’ and ‘non-combustion technologies’.

After a textual analysis of the Stockholm Convention, the Basel Convention and the Rotterdam Convention and their complementary documents, a general literature review was done regarding technologies and approaches for POPs disposal. The hypothesis emerging from this literature review, that the choice of disposal options widely depend upon the conditions in the country, was tested by conducting personal interviews with representatives of UNIDO, of UNEP and of the Chinese Foreign Economic Cooperation Office of the Ministry of Environment, and also scientists from the Tsinghua University in Beijing. In order to combine the purely technological issues with the aspects referring to the specific needs of developing countries and transition economies, the cases of the Philippines and of China are presented in detail, based on projects realized under guidance of UNIDO and the World Bank.

If a country considers building a new treatment plant facility, viability and sustainability have to be carefully considered. National and local governments as well as the identified owners of the POPs wastes have to demonstrate a strong motivation to address POPs waste management. Also financial and institutional capacity and a certain domestic market size is desirable. Civil Society should be involved in the decision process. The existing amounts of POPs waste, pre-existing national legislation, potential disposal facilities already available in a country will fundamentally influence the decision whether a country chooses to develop its own disposal facility or to make use of capacities existing in other countries.

For small amounts of POPs wastes export constitutes the most appropriate disposal option. However, to avoid long distance transportation, high costs and potential environmental risks, many countries should try to combine their POPs disposal requirements with others, either through exporting to existing facilities or working together towards the development of common regional facilities, choosing either combustion or non-combustion technologies or a combination of both. Non-combustion technologies are more consistent with the language of the Conventions than incineration. However, they still have some major drawbacks. Also cement kilns co-processing POPs wastes can constitute an inexpensive, environmentally sound and sustainable alternative.

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ACRONYMS AND ABBREVIATIONS

EST Environmentally Sound Technologies
ESM Environmentally Sound Management
BAT Best Available Techniques
BCD Base Catalyzed Decomposition
BEP Best Environmental Practice
COP Conference of the Parties
DDT Dichlorodiphenyltrichloroethane
DE Destruction Efficiency
DENR Department of Environment and Natural Resources
DRE Destruction and Removal Efficiency
EMB Environmental Management Bureau
EIA Environmental Impact Assessment
EU European Union
FAO Food and Agriculture Organization
FECO Foreign Economic Cooperation Office
GEF Global Environment Facility
GPCR Gas Phase Chemical Reduction
HCB Hexachlorobenzene
ICS UNIDO International Centre for Science and High Technology United Nations Industrial Development Organization
IHPA International HCH & Pesticides Association
INC Intergovernmental Negotiating Committee
I-TEQ International Toxic Equivalent
NGOs Non-Governmental Organizations
NIP National Implementation Plan
OECD Organization for Economic Cooperation and Development
PAFC Philippine Alternative Fuel Corporation
PBB Polybrominated Biphenyl
PCB Polychlorinated Biphenyl
PCDD/Fs Dioxins, Furans
PIC Prior Informed Consent
POPs Persistent Organic Pollutants
POPRC Persistent Organic Pollutants Review Committee
PPM Parts per Million
TAG The Technical Advisory Group
UNCED United Nations Conference on Environment and Development
UNEP United Nations Environment Programme
UNIDO United Nations Industrial Development Organization
US United States
WHO World Health Organization

1 Introduction

Of all the chemical substances regularly released into the environment by anthropogenic activities, persistent organic pollutants (POPs) are among the most dangerous. POPs are highly toxic and persistent, bio-accumulate in the environment and have the potential for long-range transport. Due to increased and wide-ranging awareness about their potential adverse impact on human health and the environment, POPs have been of major concern to political decision-makers at the national and international levels for more than twenty years now and today there are three major internationally binding agreements dealing partly or exclusively with the management of these chemicals: The Stockholm Convention, the Basel and the Rotterdam Convention.

Even though many countries have started banning POPs since the early 1970s, they are still partly used as pesticides, consumed in industrial production, or generated unintentionally as by-products of various industrial / combustion processes, to name only a few examples. After prohibition many POPs containing materials such as electrical equipment or obsolete pesticide stockpiles were simply stored in temporary depositories. This was especially the case in developing countries.

Industrialized countries have grounded their POPs elimination programs on the fact that they can use the large number of high temperature incineration facilities already existing. Developing countries, however, which usually do not have such incineration facilities, have been facing problems in identifying appropriate disposal options and technologies to deal with the elimination of POPs wastes in their countries. Therefore, the central overall goal of this thesis is to identify the most appropriate disposal option for developing countries and transition economies.

Under the Stockholm Convention 'disposal' is defined as *"the irreversible conversion of a POP substance or a POPs waste into its elemental components, or into different chemical species which do not exhibit the characteristics of persistent organic chemical."*[1]

In order to narrow the scope a bit down, only the disposal options 'incineration within

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[1]Stockholm Convention, Article 6.1(d)(ii).

the own country', 'export to developed countries for incineration' and 'non-combustion technologies' will be treated in detail. Other disposal methods are specially engineered landfill or permanent storage in underground mines and formations.

Non-combustion technologies in this thesis are defined as *"technologies where the major proportion (99.99%) of POPs destruction takes place under reducing conditions"*.[2]

Disposal represents only one part of the POPs management process, together with analysis, sampling, capture, containment, inventories declaration, registration, secure storage, packaging, transport, and post disposal residuals management / monitoring of POPs wastes. However, these steps will be touched only superficially.[3]

'POPs wastes' in this thesis are defined as "*wastes consisting of, containing or contaminated with a chemical listed in Annex A, B or C"*[4].

POPs wastes can have a number of physical forms, including, for instance, electrical equipment, oils, solvents, end-of-life vehicles, demolition wastes soils and sediments, rock and aggregates, sludge, plastics, fire suppression equipment, and other wastes consisting of, containing or contaminated with POPs. Also stockpiles of obsolete pesticides can be defined as POPs wastes. POPs wastes are often complex due to their mixed composition. Hence, each stockpile must be treated individually.[5]

Even though this work deals mainly with intentionally produced POPs, unintentionally produced POPs such as dioxins and furans are to be considered when assessing potential disposal technologies, especially for combustion technologies.

The first part of this work will reveal how the disposal options incineration, export and the use of non-combustion technologies are regulated under the Stockholm and the Basel Convention. Further, it will show how the Stockholm Convention cooperates with the Basel and the Rotterdam Convention concerning the general management of POPs and what provisions these three Conventions contain on the different disposal alternatives.

In the second part the three disposal options will be described in detail and compared to each other based on five indicators. Case studies will illustrate the specific

[2]UNEP 2004b: 10.
[3]UNEP 2011: 33.
[4]Stockholm Convention, Article 6.1.
[5]UNEP 2004b: 7.

experiences made with each disposal method. In the end it will be tried to answer the initial question concerning the most appropriate disposal options for POPs wastes in developing countries and transition economies. Finally, recommendations will be formulated on how to identify the influencing factors in order to select the most appropriate disposal option.

1.1 State of the art

The main objective of this thesis is to identify the most appropriate disposal option for POPs waste in developing countries and transition economies by evaluating the options 'incineration within the own country', 'export to developed countries for incineration' and 'non-combustion technologies', also with regard to the requirements arising from the three chemical Conventions.

In developing countries and often also in transition economies, suitable and adequate destruction facilities are usually inexistent, and the costs connected with providing them are likely to be higher than what the country can afford without technical assistance. Further, developing countries are generally not willing to finance the disposal of POPs wastes with development funds.

Without the intervention of the international community and the associated funding of projects aiming specifically at the disposal of POPs wastes, in most developing countries wastes would be left where they are, namely often in temporary storages, where they start leaking in the environment after a while, posing a major threat to human health and the environment.

So far, the majority of POPs wastes from developing countries have been exported to developed countries for high temperature incineration. A summary analysis to the end of GEF-4 (2006 – 2010) shows that 24 projects based on export for disposal, and 18 projects based on in-country disposal were financed by GEF. Further, 19 projects selecting/favoring combustion technology and 7 projects selecting/favoring non-combustion technology were financed, while 15 projects did not have a stated technology preference.[6]

This reveals that combustion technologies have usually been believed to be the most economical way for concentrated POPs waste treatment. Therefore they have been the most widely used disposal option, both in developed countries and - if available - in already existing facilities in developing countries and transition economies.

However, reports dealing with environmentally sound POPs waste disposal without exception stress the significance to do further research on possible alternatives to the options ‘incineration’ and ‘export to developed countries for incineration’. This is due to problems related to incineration processes failing to meet the stringent environmental conditions that have progressively been set in the last decade. Risks linked to long-distance transportation of the wastes and dependence on developed countries represent further concerns.

Existing reports primarily compare incineration and non-combustion technologies, or exclusively focus on the comparison of different types of non-combustion technologies. Most of these reports address the specific needs of developing countries when assessing potential technologies. In general, when comparing only non-combustion technologies the reports do not come to a conclusion on the most appropriate disposal method, but rather recommend doing some further research on the still immature and not very well known non-combustion technologies and looking at specific country situations.

The reports “Non-Combustion Technologies for POPs Destruction – Review and Evaluation” (ICS – UNIDO 2007) and “Survey of Currently Available Non-Incineration PCB Destruction Technologies” (UNEP 2000), providing guidance for evaluation and selection of non-combustion technologies highlight that the conditions in developing countries are a unique challenge to modern technology. However, these reports do not specify what conditions have to prevail in a developing country or a transition economy to make it eligible for the operation of non-combustion technologies.

In contrast, the report “Review of Emerging, Innovative Technologies for the Destruction and Decontamination of POPs and the Identification of Promising

[6] UNEP 2011: 35.

Technologies for Use in Developing Countries" (UNEP 2004a) uses two sets of criteria, namely whether the technology is applicable in the country and whether the country is eligible for a certain technology. Hereby, it applies criteria of robustness, safety, sustainability, ease of operation, cost-effectiveness, conformity with the Basel Convention and Stockholm Convention, composition of existing stockpiles, as well as the conditions prevailing in developing countries, with the view to identify promising technologies.

Similarly, the technology review "Non-combustion technologies for the destruction of POPs stockpiles" (UNEP 2004b) uses evaluation criteria related to risks, country-drivenness, sustainability, finance capacities and enabling environment as a basis for supporting the introduction of non-combustion technologies in a country or region.

The reports "Selection of Persistant Organic Pollutants Disposal Technology for the Global Environment Facility" (UNEP 2011) and "Destruction Technologies for Polychlorinated Biphenyls (PCBs)" (Rahuman, et al. 2000) compare combustion and non-combustion technologies, based on environmental performance, commercial viability and infrastructure considerations. They also take into account country specific safeguard measures such as national regulatory control system, environmental impacts, depending on the specific geographic site location, ownership / liability and public participation.

There are only few reports including the disposal option 'export to developed country for incineration'. The report "Destruction and Decontamination Technologies for PCBs and Other POPs Wastes - A Training Manual for Hazardous Waste Project Managers – Volume A" (UNEP 2002) touches the export option only superficially, using it as departing point for the introduction of alternative disposal methods.

The document "Updated general technical guidelines for the environmentally sound management of wastes consisting of, containing or contaminated with persistent organic pollutants (POPs)" (UNEP 2006a) dealing with incineration, non-combustion technologies as well as with export, treats export only in the context of provisions arising from the Basel and the Stockholm Convention.

The technology review "Non-combustion technologies for the destruction of POPs stockpiles" (UNEP 2004b) states, that if certain criteria supporting non-combustion technologies in a country such as sustainability, financial capacities and enabling environments are not met, stockpiles should rather be packed and shipped to facilities that meet internationally agreed standards of destruction.

However, none of these reports makes a direct comparison on an equal level between the export option and the disposal technologies involving incineration and non-combustion technologies, by applying the same evaluation criteria such as cost, operation, applicability etc as it will be done in this thesis.

Another contribution made by this work is the demonstration of specific examples showing concrete situations of different countries, who made different decisions concerning the most appropriate disposal options. Such case studies help to illustrate abstract evaluation criteria influencing the decision process, but cannot be found in the existing literature.

This work is an attempt to show, as comprehensively as possible, the way from the legal text of the chemical Conventions over the decision making process regarding the selection of appropriate disposal options to the implementation of concrete measures in a country.

1.2 Methods

For the first part, the author did a textual analysis of the three chemical Conventions, the Stockholm, the Basel and Rotterdam Convention. Also complementary documents to the Conventions such as the "Guidance Document on Preparation of Technical Guidelines for the Environmentally Sound Management of Wastes Subject to the Basel Convention" were analyzed.

The second part is mainly a literature review of UNIDO / GEF / UNEP documents and project reports as well as of general literature concerning the technologies and approaches for POPs disposal. In order to test working hypotheses that emerged from the literature review, the author conducted personal interviews regarding the disposal options and their evaluation with representatives of UNIDO in Vienna and Beijing, of UNEP and of the Chinese Foreign Economic Cooperation Office of the Ministry of Environment (MEP), and also scientists of the Tsinghua University in Beijing.

In order to depict specific experiences made in different countries under different conditions and to verify working hypotheses coming from the general literature review, the cases of the Philippines (export and non-combustion technologies) and of China (incineration) were chosen and presented in detail, based on projects realized under guidance of UNIDO (Philippines) and the World Bank (China). The Philippines was selected as a representing developing country, and China as a representing transition economy. The case studies also demonstrate the considerations involved during the decision making process, combining the purely technological issues with the aspects referring to the specific needs of developing countries and transition economies.

2 How are Incineration, Export and the Use of Non-Combustion Technology for the Disposal of POPs Wastes Regulated Under the Stockholm Convention and the Basel Convention

There are two major multilateral environmental agreements, dealing with the management and disposal of POP wastes: The Stockholm Convention on Persistent Organic Pollutants and the Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal. The first part of this thesis will show how these conventions interact and cooperate, on the one hand amongst each other, and on the other hand with the Rotterdam Convention on the Prior Informed Consent Procedure for Certain Hazardous Chemicals and Pesticides in International Trade. This interaction concerns the general management of POP wastes, and more specifically the provisions on the disposal options involving incineration, non-combustion technologies (both within the country) or export for incineration to developed countries.

2.1 POPs and the Stockholm Convention

In May 1995, the United Nations Environment Programme Governing Council started investigating POPs and set up an initial register of the following twelve POPs, the so-called “dirty dozen”, including aldrin, chlordane, DDT, dieldrin, endrin, heptachlor, hexachlorobenzene, mirex, toxaphene, polychlorinated biphenyls (PCBs), dioxins and furans (PCDDs/PCDFs).

According to the definition of the UNEP, POPs are “chemical substances that persist in the environment, bioaccumulate through the food web, and pose a risk of causing adverse effects to human health and the environment.”[7]

POPs are organic (carbon-based) compounds resistant to photolytic, biological and chemical degradation and originate primarily from anthropogenic activities and processes. They are characterized by long half-lives, low water solubility and high lipid solubility. Because of their resistance to metabolism, they easily accumulate in human and animal fat tissue and hence increase in concentration within food chains. Some of these pollutants such as polychlorinated biphenyls (PCBs), may persist in the environment for several years and can bioconcentrate by factors of up to 70,000 fold.[8]

There are two important subgroups of POPs, namely the polycyclic aromatic hydrocarbons and the halogenated hydrocarbons. Of the latter group of halogenated hydrocarbons, organochlorines are by far the most important class, including dioxins and furans, PCBs, hexachlorobenzene (HCB), mirex, toxaphene, heptachlor, chlordane and DDT. The degradation of POPs in the environment depends largely on its degree of chlorination. The greater the number of chlorine substitutions and/or functional groups, the more POPs resist to biological degradation and photolysis. POPs have very low water solubility and high lipid solubility, resulting in their propensity to pass easily through biological membranes. Consequently, the highly chlorinated POPs tend to accumulate to a greater extent in fat deposits than the less chlorinated POPs, as also metabolism and excretion are slower for them. The number and position of chlorine atoms affect also the toxicology of POPs.[9]

Exposure of human beings to POPs, either acute or chronic, can lead to a wide range of potential significant adverse impacts on human health and the environment, particularly death, disease, and birth defects. Specific effects can include allergies and hypersensitivity, damage to the central and peripheral nervous system, immunity system diseases, reproductive disorders and cancer.

[7]“Persistent Organic Pollutants”, UNEP Chemicals, http://www.chem.unep.ch/pops/ (Accessed: 10 April 2012).
[8]Ritter L; Solomon KR, Forget J, Stemeroff M, O'Leary C.:”Persistent organic pollutants - An Assessment Report on: DDT-Aldrin-Dieldrin-Endrin-Chlordane Heptachlor-HexachlorobenzeneMirex-Toxaphene Polychlorinated Biphenyls Dioxins and Furans". United Nations Environment Programme. http://www.chem.unep.ch/pops/ritter/en/ritteren.pdf (Accesssed: 20 February 2012).
[9]Ibid.

Laboratory investigations and environmental impact studies in the wild have found some POPs to be endocrine disrupters, which can harm the reproductive and immune systems of exposed individuals as well as their offspring, by modifying their hormonal system. Moreover, they can have developmental and carcinogenic effects.[10]

POPs easily volatilize from vegetation, soils and water bodies into the air. Before being re-deposited they are subject to long-range atmospheric transport, since they can last for years or decades before breaking down. Due to this resistance to breakdown reactions in air, the cycle of evaporation and deposition may be repeated several times. This (often seasonal) process is known as the 'grasshopper effect'. Therefore POPs concentrations can be measured in regions far removed from where they were used or emitted.

Due to these the long-range transport mechanisms and the resulting transboundary impacts of POPs many countries have started to ban POPs in the early 1970s. Concurrently, the production of new POPs, such as brominated and fluorinated compounds has augmented since the 1990s, chemicals that are commonly used in a wide range of consumer goods.[11]

However, it has soon been recognized that it is impossible for an individual government to protect its citizens or its environment from POPs. In response, the Stockholm Convention on Persistent Organic Pollutants was adopted in 2001 and entered into force on 17 May 2004. As of April 2012, there are 177 Parties to the Convention.

The Stockholm Convention provides its subscribing Parties with basic aims, principles and elements for developing comprehensive programs of measures and control regimes with regard to POPs. It requires Parties to regulate - with the aim of preventing - the production and use of new pesticides or industrial chemicals, which exhibit the characteristics of POPs, taking into consideration the POPs screening criteria set out in Annex D of the Convention, when assessing pesticides or industrial

[10] Anonymous (2001): "Persistent organic pollutants and the Stockholm Convention: A resource guide." A report prepared by Resource Futures International for the World Bank and CIDA, http://siteresources.worldbank.org/INTPOPS/214574-1115813449181/20486510/PersistentOrganicPollutantsAResourceGuide2001.pdf (Accessed: 14 February 2012).

[11] Weber, R., Watson, A., Forter, M., &Oliaei, F. (2011): "Review Article: Persistent organic pollutants and landfills – a review of past experiences and future challenges", Waste Management & Research, 29 (1), 107-121.

chemicals currently in use.[12]Under Article 18 a subsidiary body, the Persistent Organic Pollutants Review Committee (POPRC), was set up, being in charge of assessing whether new chemicals are POPs and whether they should be subject to the Convention.[13]In 2009 nine new chemicals as well as one persistent toxic substance were added to the Stockholm Convention. Together with the initial twelve POPs, the Convention so far contains provisions of 21 chemicals in total.[14]

The chemicals to be eliminated, from production and use, are listed in Annex A to C of the Convention, each addressing different kinds of POPs: Annex A is about intentionally produced pollutants, on the one hand, for agricultural use, such as pesticides, insecticides, rodenticides and fungicides. On the other hand this section addresses also POPs, which had been synthesized for industrial uses, such as PCBs and polybrominated diphenyl ethers (PBDE).

Annex B treats POPs that have been produced intentionally and whose use is restricted to disease vector control. This exemption applies, for example, to DDT for controlling malaria. The Convention's goal for those substances is expressed under Article 3, which requires *"measures to reduce or eliminate releases from intentional production and use"*.[15] Concurrently, the Convention requires information exchange and research on POPs alternatives. It obliges each Party using DDT to develop an action plan, including for application of alternative products.[16]

A third group of substances represents those POPs, which have been produced and released unintentionally as a result of anthropogenic activities. They are generated primarily as accidental by-products of (incomplete) combustion or due to the industrial synthesis of other chemicals. Those substances are listed in Annex C of the Stockholm Convention as 'unintentionally produced chemicals', including dioxins, furans (PCDD/Fs), polychlorinated biphenyls (PCBs) and hexachlorobenzene (HCB). Article 5 of the Convention requires continuing minimization and, where feasible, ultimate elimination of the total releases of these chemicals.[17]

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[12]Stockholm Convention, Article 3.3 / Article 3.4 / Annex D. 1.
[13]Stockholm Convention, Article 18.
[14]Newly added chemicals in 2009: Alpha hexachlorocyclohexane (alphaHCH), beta hexachlorocyclohexane (BetaHCH), chlordecone, hexabromodiphenyl ether and heptabromodiphenyl ether (C-octaBDE), hexabromobiphenyl (HBB), lindane, pentachlorobenzene (PeCB), perfluorooctane sulfonic acid (PFOS), its salts and perfluorooctanesulfonyl fluoride (PFOSF), tetrabromodiphenyl ether and pentabromodiphenyl ether (C-pentaBDE), Persistent Toxic Substance: Endosulphan
[15]Stockholm Convention, Article 3 / Annex B.
[16]Stockholm Convention, Article 9 / Article 11 / Annex B.
[17] Jones, K.C. and Voogt, P. de (1999): "Persistent Organic Pollutants (POPs): State of the Science." Environmental Pollution 100, 209-221.

According to Article 10 and 11 of the Convention, the Parties shall encourage and develop activities to research, develop and monitor POPs and their alternatives as well as other potential POPs. PCB containing equipment, for instance, shall be identified, labeled and removed from use by 2025 and efforts leading to environmentally sound waste management shall be made no later than 2028.[18]

The Conference of the Parties (COP) is the legislative body of the Convention, whose Secretariat is provided by the UNEP's Chemicals Unit. The Global Environment Facility (GEF) acts as financial instrument providing funding for the costs to match the commitments coming from Governments and Private sectors.

GEF finances the additional costs linked to the transformation of a project with national benefits into a project with global environmental benefits. Hereby, GEF funding covers the "increment" between a cheaper, more polluting option and a costlier, more environmentally sound alternative. In order to determine the incremental cost, first, the environmental problem has to be fully understood and it must be figured out, what would happen without the intervention of GEF. Then, global environmental benefits have to be identified, and brought in line with GEF priorities. After developing a results framework of the intervention, the incremental reasoning has to be done and the GEF's role has to be identified, including its potential role of co-financing.[19]

The GEF works with several implementing and executing agencies, such as World Bank, UNDP, UNIDO and the Regional Banks for Africa, Asia, Europe and Latin America. These agencies, based on their comparative advantages, assist the countries to undertake measures, programs and activities, to train and create national human resources and to build institutional capacities to perform their obligations under the Convention.[20]

In order to ensure implementation of the Convention's provisions, within two years after entry into force Parties are required to develop and submit country-specific National Implementation Plans (NIP) to demonstrate how their obligations will be implemented.[21] The Stockholm Convention's COP has set up guidelines for the GEF financial mechanism that focuses mainly on capacity building. It recommended that

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[18]Stockholm Convention, Annex A, Part II.
[19]"Incremental Costs", Global Environment Facility, http://www.thegef.org/gef/policy/incremental_costs (Accessed: 28 May 2012).
[20]Eisa, Mohamed (2008): "Technology Transfer Opportunities in East and South East Asian Countries through the UNIDO POPs Program, 14 November 2008, UNU Conference, Tokyo -Japan.
[21]Stockholm Convention, Article 7.

activities aiming at the development of NIPs and activities being in line with the main priorities identified in the Parties' respective NIPs should receive financial support. The NIPs shall cover three major points: It shall i) contain an initial inventory of POP stockpiles and information about their location, ii) offer a framework for developing national legislation on POPs and iii) provide a detailed action plan that specifics how to rank POPs, monitor the POPs inventory, and shows how to eliminate POPs in the long and the short run.[22]

2.2 Cooperation of the Stockholm Convention with the Basel Convention and the Rotterdam Convention concerning the general management of POPs

There are three important multilateral environmental agreements, whose declared common goal it is to protect the environment and human health from hazardous chemicals and wastes: The above-mentioned Stockholm Convention on Persistent Organic Pollutants, the Rotterdam Convention on the Prior Informed Consent Procedure for Certain Hazardous Chemicals and Pesticides in International Trade and the Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal.

Having the longest history of these three conventions, the Basel Convention was adopted in 1989 and entered into force on 5 May 1992. The Basel Secretariat is provided by UNEP. During its first years, the Convention's primary emphasis was the development of controls on the movement of hazardous wastes across international frontiers, and the elaboration of criteria for environmentally sound management of the wastes. However, in more recent times the Convention's activities have increasingly focused on promoting environmentally sound management of hazardous wastes and on the disposal of such wastes as closely as possible to the source of generation. Concurrently, it aims at minimizing the amount and toxicity of wastes generated. There are currently 176 Parties to the Convention.

In 1997 the Executive Director of the United Nations Programme (UNEP) was asked

[22]Office of the National Coordination Group for Stockholm Convention Implementation (2007): "The People's Republic of China: National Implementation Plan for the Stockholm Convention on Persistent Organic Pollutants", China Environmental Science Press.

to set up an intergovernmental negotiating committee (INC) together with other relevant international organizations. This committee was then asked to prepare an internationally legally binding instrument for action on twelve specified POPs. Information on alternatives to POPs, available destruction technologies, inventories of PCBs, as well as on management strategies for PCDD/PCDF were gathered and communicated. And finally the negotiations under the INC resulted in the adoption of the Stockholm Convention in 2001.[23]

The Stockholm Convention, being the only agreement focusing exclusively on persistent organic pollutants, pursues the elimination or restriction of production and use of 21 chemicals that are listed in three Annexes. It seeks to continuously minimize and, where possible, to finally eliminate on the one hand the release of intentionally produced POPs, such as pesticides, insecticides or industrial chemicals as well as on the other hand to reduce and eventually stop the release of unintentionally produced POPs, such as dioxins and furans.[24]

The Rotterdam Convention was adopted in 1998 and entered into force on 24 February 2004, in the same year when also the Stockholm Convention entered into force. So far there are 144 Parties to the Convention, whose Secretariat is jointly provided by UNEP and FAO.

The Rotterdam Convention replaces the voluntary Prior Informed Consent (PIC) procedure, which had been introduced in 1989. It encompasses a mandatory PIC procedure that applies to 40 chemicals including 29 pesticides and 11 industrial chemicals, as well as information exchange mechanisms on hazardous chemicals and pesticides. These information exchange provisions concern any chemical that is banned or severely restricted by a Party.[25] The Rotterdam Convention requires Parties to notify the secretariat of final regulatory actions taken in respect of banned or severely restricted chemicals, for the information of other Parties and possible listing under the Convention.[26]

Each of the three Conventions addresses the technical and financial assistance needs of countries with economies in transition as well as developing countries.

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[23]UNEP (2002): "Destruction and Decontamination Technologies for PCBs and Other POPs Wastes - A Training Manual for Hazardous Waste Project Managers – Volume A", Secretariat of the Basel Convention, United Nations Environment Programme, http://archive.basel.int/meetings/sbc/workdoc/TM-A.pdf (Accessed: 9 April 2012).

[24]Stockholm Convention, Article 3 / Article 5.

[25]UNEP (2009): "The Hazardous Chemical and Wastes Conventions", United Nations Environment Programme, http://www.pops.int/documents/background/hcwc.pdf (Accessed: 9 April 2012).

[26]Rotterdam Convention, Article 5 / Article 6.

The Basel Convention wants Parties to co-operate with each other in order to attain environmentally sound management of POP wastes. Article 10, paragraph 2 of the Convention requires them to co-operate *"in developing the technical capacity among Parties, especially those which may need and request technical assistance in this field"*.[27]And in accordance with decision SC-1/15 of the Conference of the Parties of the Stockholm Convention, mechanisms should be guaranteed for offering technical assistance and promoting technology transfer.[28] Both conventions provide for regional centers for training and technology transfer.[29]Moreover, the Basel Convention has a Technical Cooperation Trust Fund as well as a more recently established Emergency Fund in order to financially assist developing countries, and countries with economies in transition in *"cases of emergency and compensation for damage resulting from incidents arising from transboundary movements of hazardous wastes and other wastes and their disposal".*[30]

Under the Stockholm Convention a 'financial mechanism' is set up, with the above-mentioned Global Environment Facility being the key entity.[31] Article 13 of the Convention states that *"developed country Parties shall provide new and additional financial resources to enable developing country Parties and Parties with economies in transition to meet the agreed full incremental costs of implementing measures which fulfill their obligations under the Convention […] The implementation of these commitments shall take into account the need for adequacy, predictability, the timely flow of funds and the importance of burden sharing among the contributing Parties"*[32].

Also the Rotterdam Convention provides for technical assistance between Parties for the improvement of infrastructure and the capacity building to manage chemicals. Its financial resources come from voluntary contributions from countries into the Convention's Voluntary Trust Fund. Only if enough resources are received from donors, activities can be implemented.[33]

Taken together these three conventions provide a coherent legal framework to support environmentally sound and safe management of hazardous chemicals and wastes at

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[27]Basel Convention, Article 10.2.
[28]Stockholm decision SC-1/15.
[29]Basel Convention, Article 14 / Stockholm Convention, Article 12.
[30]"Emergency Fund", Basel Convention, http://www.basel.int/Implementation/LegalMatters/EmergencyFund/tabid/2370/Default.aspx (Accessed: 28 May 2012).
[31]Stockholm Convention, Article 13 / Article 14.
[32]Stockholm Convention, Article 13.2.
[33]Rotterdam Convention, Article 16.

different stages of their life-cycle: While the Stockholm Convention is focused on production and use of chemicals, the Rotterdam Convention deals with their trade and the Basel Convention is concentrated on their disposal. Together they cover key aspects of ‘cradle-to-grave’ management of hazardous chemicals, most comprehensively for persistent organic pollutants.

The Stockholm Convention provides explicitly for funding of technical cooperation, whereas the Basel and the Rotterdam Convention have very limited possibilities to finance technical assistance. While the latter two rather focus on providing policy instruments and a legislative framework, the Stockholm Convention prioritizes to a greater extent the support of concrete activities in order to promote the implementation of the Convention.

In order to simplify and accelerate the implementation of the conventions, the COPs have over the time adopted a series of decisions aiming at enhancing cooperation and coordination among the conventions. Hence, a framework for the so-called synergies process has been established.[34]

By decision SC-1/18 in 2004 the Secretariat of the Stockholm Convention was requested to enhance synergies within the chemicals and waste cluster adopted at the first meeting of the Conference of the Parties and to improve the cooperation with the Basel Convention, with the Rotterdam Convention as well as with other relevant programs.[35]

In 2005 it was agreed to set up an ad hoc joint working group to prepare joint recommendations on enhanced cooperation and coordination among the three conventions.[36]

Later on, in 2008 / 2009, the Conferences of the Parties to all three Conventions adopted various decisions on enhanced cooperation and coordination among the three agreements, also called “synergies decisions”. These decisions comprise elements related to building or enhancing cooperative activities, services and management throughout the secretariats of the Conventions. They indicate specific areas for improved collaboration and coordination, such as strengthening implementation of the

[34]“History of the Synergies Process”, Synergies among the Basel, Rotterdam and Stockholm Conventions, http://synergies.pops.int/SynergiesProcess/History/tabid/2615/language/en-US/Default.aspx (Accessed: 11 April 2012).
[35]Stockholm decision SC-1/18, 2004.
[36]Stockholm Decision SC-2/15, Rotterdam decision RC-3/8, Basel decision VIII/8.

three conventions at the regional, national and global levels, promoting coherent policy guidance, increased cooperation on compliance, cooperation on technical and scientific issues as well as on information management and public awareness issues.[37]

In 2010 the so-called “omnibus decisions” were taken at the simultaneous extraordinary meetings of the Conferences of the Parties to the three conventions, promoting joint activities, joint managerial functions, joint services, synchronization of budget cycles, joint audits and review arrangements.[38]

One year later, in 2011, the conferences of the Parties to the Basel, Rotterdam and Stockholm conventions adopted substantively identical decisions to further cooperation and coordination, approving, among others, an interim organization of the secretariats, cross-cutting and joint activities for inclusion in the programs of work, detailed terms of reference for the review of the synergies process and holding again simultaneous extraordinary meetings of the Conferences of the Parties in 2013.[39]

In July 2011, a Task Force on Restructuring has been set up within the Secretariat of the three conventions and was requested, by 31 December 2011 to prepare a proposal for the re-organization of the Secretariats, including staffing levels, numbers and structure, to be implemented by 31 December 2012.[40]

The successful cooperation and coordination of the Stockholm, the Basel and the Rotterdam conventions concerning the management of POPs has become visible and measurable in various activities jointly executed by the secretariats of the three agreements. Specific examples for this institutional collaboration are joint training activities, such as awareness raising workshops on POPs, subregional workshops on the coordinated implementation of multilateral environmental agreements on chemicals and wastes in various regions, seminars on Cleaner Production, as well as various regional workshops on the reduction/elimination and management of pesticides in the context of the Stockholm Convention and the Basel Convention.[41]

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[37]Basel decision BC IX/10, Rotterdam decision RC-4/11, Stockholm decision SC-4/34.

[38]Decisions BC.Ex-1/1, RC.Ex-1/1 and SC.Ex-1/1 were adopted by the conferences of the parties to the Basel, Rotterdam and Stockholm conventions, respectively, at their simultaneous extraordinary meetings in Bali, Indonesia, on 24 February 2010, held in coordination with the eleventh special session of the UNEP Governing Council/Global Ministerial Environment Forum

[39]Stockholm Decision SC-5/27, Rotterdam decision RC-5/12, Basel decision BC-10/29.

[40]Secretariat of the Basel, Rotterdam and Stockholm Conventions (2011): “Findings of the subgroups set up under the secretariat Task Force on Restructuring, December 2011, available at www.basel.int.

[41]Recommendations on improving cooperation and synergies prepared by the Secretariat of the BaselConvention; This document was circulated to the eighth meeting of the Conference of the Parties to the Basel Convention (document UNEP/CHW.8/INF/30), the third meeting of the Conference of the Parties to the Rotterdam Convention (document UNEP/FAO/RC/COP.3/INF/10), and the second

2.3 Provisions under the Stockholm Convention, the Rotterdam Convention and the Basel Convention regarding the export of POPs wastes for the purpose of incineration in developed countries

When it comes to import and export of hazardous wastes (including wastes consisting of, containing or contaminated with POPs), all three Conventions provide for control and restriction provisions. The Stockholm Convention allows for the import and export of POPs only under certain circumstances such as for environmentally sound disposal.[42] It also states that POPs or their wastes may not be transported across international boundaries without respecting relevant international standards and guidelines.[43]

Due to its very nature the Basel Convention contains the most extensive provisions on hazardous waste exports. While its main focus is clearly on waste exports from developed to developing countries, the provisions are of course also applicable to transboundary movements from developing countries to developed countries.

The Convention distinguishes between 'hazardous wastes', and 'other wastes'. Hazardous wastes, including POP wastes, are defined as "toxic, poisonous, explosive, corrosive, flammable, ecotoxic, and infectious."[44]

Article 4 of the Basel Convention requires each Party to minimize waste generation and to guarantee the availability of adequate disposal facilities to the extent possible *within the State's own territory*, as far as it is compatible with environmentally sound and efficient management. This means that the disposal of hazardous wastes must take place as close as possible to their point of generation, recognizing, however, that economically and environmentally sound management of some wastes will only be

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meeting of the Conference of the Parties of the Stockholm Convention (document UNEP/POPS/COP.2/INF/19).

[42]Stockholm Convention, Article 3.2.

[43]Stockholm Convention, Article 6.1.

[44]Basel Convention, Annex III.

accomplished at specialized facilities situated at greater distances from the point of generation.[45]

Therefore the preamble of the Basel Convention highlights the importance to promote the transfer of technology for the sound management of hazardous wastes and other wastes produced locally to developing countries, which is also the aim of Article 10 requiring international cooperation of the Parties.[46]

The Basel Convention allows for transboundary movements of hazardous wastes only under very strict conditions. Waste may only be exported if the exporting country does not have the technical capacity and the necessary facilities to dispose of the wastes in questionor if existing disposal sites cannot dispose of the waste in an environmentally sound manner. So, export should only be an option if the transport and the ultimate disposal of such wastes in the importing country are environmentally sound and if it is conducted under conditions that do not endanger human health and the environment.[47]

Another exemption for export limitations can be approved if the importing country needs the wastes as a raw material for recycling or their recovery industries.[48] In general, trade with non-parties is forbidden, unless these exports happen under a comparable bilateral, multilateral or regional arrangement. Nevertheless, also under these bilateral, multilateral or regional agreements an equally sound management structure for transboundary movements of waste has to be guaranteed.[49] The original prior informed consent procedure under the Basel Convention was strengthened when Parties decided to adopt amendments in order to restrict exports of hazardous wastes from OECD to non-OECD countries.[50]

All three conventions contain provisions for the compulsory communication and transmission of hazard information.[51] The Rotterdam Convention establishes a prior informed consent procedure regarding the transboundary movement of certain hazardous chemicals and wastes. Export has to be subject to prior written notification

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[45] Anonymous (1994): “Guidance Document on Preparation of Technical Guidelines for the Environmentally Sound Management of Wastes Subject to the Basel Convention”, Secretariat of the Basel Convention, United Nations Environment Programme.

[46] Basel Convention, Article 10.

[47] Basel Convention, Article 4.2.

[48] Basel Convention, Article 4.9.

[49] Basel Convention, Article 4.5 / Article 11.

[50] Basel Convention, Article 4.1.: The Conference of the Parties adopted Decision III/1 at its third meeting to amend the Convention by adding, inter alia, a new Article 4A. The amendment is not yet in force.

[51] Basel Convention Article 4 / Article 13, Rotterdam Convention Article 5.1, Stockholm Convention Article 10.

from the exporting country and prior written consent from the importing and, if appropriate, transit countries. Parties shall prohibit the export of hazardous wastes and other wastes if the country of import prohibits the import of such wastes.[52]

Also transportation of POP wastes should occur in an environmentally sound manner in order to avoid accidental spills and to track their transport and ultimate destination appropriately. Before transport, contingency plans should be prepared in order to minimize environmental impacts associated with spills, fires and other emergencies that could occur during transport.[53]

The Basel Convention requires that information concerning any proposed transboundary movement is provided using the accepted notification form and that the approved consignment is accompanied by a movement document from the point where the transboundary movement starts to the end point of disposal.

Furthermore, hazardous wastes and other wastes subject to transboundary movements should be packaged, labelled and transported in accordance with international rules and standards. Companies transporting wastes within their own countries should be certified as carriers of hazardous materials and wastes, and their staffs should be qualified and also certified.[54]

Since primarily the Basel Convention and the Stockholm Convention provide for the main guidance on disposal options for POPs wastes, especially regarding technology choices, they are the most relevant for the purpose of this thesis and therefore, will be analyzed in more detail in the following chapter.

[52]Rotterdam Convention, Article 12.

[53]UNEP (2006)a: "Updated general technical guidelines for the environmentally sound management of wastes consisting of, containing or contaminated with persistent organic pollutants (POPs)", Secretariat of the Basel Convention, United Nations Environment Programme, http://chm.pops.int/Implementation/PCBs/DocumentsPublications/tabid/665/Default.aspx (Accessed: 10 April 2012): 27.

[54]Basel Convention, Article 4.

2.4 Technology options concerning the disposal of POPs wastes under the Stockholm Convention and the Basel Convention

Both the Basel Convention and the Stockholm Convention contain various articles providing for and promoting *environmentally sound management* for the disposal of POP wastes. Several complementary documents offer concrete technical guidelines.

'Environmentally sound management' is an extensive policy concept without a clear general definition, and also the Stockholm Convention does not offer an explicit and exact definition of this term. Article 6 of the Stockholm Convention, however, obliges Parties to develop strategies to manage POP wastes *"in a manner protective of human health and the environment"*.[55] The preamble of the Stockholm Convention even calls for the development and the use of environmentally sound alternative processes and chemicals.

In a similar way, the Basel Convention, in accordance with its Article 2, paragraph 8, defines environmentally sound management of hazardous wastes or other wastes as *"taking all practicable steps to ensure that hazardous wastes or other wastes are managed in a manner which will protect human health and the environment against adverse effects which may result from such wastes"*.[56]

In order to achieve environmentally sound management of wastes, the 1994 "Guidance Document on Preparation of Technical Guidelines for the Environmentally Sound Management of Wastes Subject to the Basel Convention" defines some legal, institutional and technical criteria to be met, such as a regulatory and enforcement infrastructure ensuring compliance with the existing laws and regulations. Environmentally sound management involves strictly controlling storage, transport, treatment, reuse, recycling, recovery and final disposal of wastes.

Sites or facilities have to be authorized, licenced and must have an adequate standard of technology and pollution control to handle and dispose of hazardous wastes. Especially, the existing level of technology and pollution control in the exporting country shall be taken into consideration. Operators of sites or facilities, where hazardous wastes are dealt with, have to assure recording programs for all input and

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[55] Stockholm Convention, Article 6.1.
[56] Basel Convention, Article 2.8.

output streams and materials. They also have to strictly monitor their activities and the resulting environmental impacts. People involved in the management of hazardous wastes must be qualified and adequately trained on their jobs. Immediate action is to be taken when the management of hazardous wastes has caused unacceptable releases, following appropriate and verified emergency plans. Adequate financial means for emergency situations and closure have to be guaranteed.[57]

The Basel Convention's preamble calls for continuous "*development and the implementation of environmentally sound low-waste technologies, […] and management systems with a view to reducing to a minimum the generation of hazardous wastes and other wastes.*"[58]

According to a definition agreed on at the UN Conference on Environment and Development (UNCED) 'Environmentally Sound Technologies' (EST) are technologies which "*protect the environment, are less polluting, use all resources in a more sustainable manner, recycle more of their wastes and products, and handle residual wastes in a more acceptable manner than the technologies for which they are substitutes.*"[59]ESTs are therefore technologies that have the potential for significantly improved environmental performance relative to other technologies.

Aside from process and product technologies generating low or no waste, for the prevention of pollution, UNCED's definition of environmentally sound technologies covers also 'end of the pipe' technologies for treatment of pollution after it has been generated.[60] Based on these characteristics, ESTs are techniques and technologies capable to reduce environmental damage by generating fewer potentially damaging substances, recovering such substances from emissions prior to discharge or utilizing and recycling production residues. The definition of ESTs captures additionally the full life cycle flow of the material, energy and water in the production and consumption process and considers technology development and transfer within the socio-economic, cultural and environmental context.[61]

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[57]Anonymous 1994.
[58]Basel Convention, Preamble.
[59]UNCED (1992): "Agenda 21, Section IV, Means of Implementation, Chapter 34, Transfer of Environmentally Sound Technology, Cooperation & Capacity Building", http://www.un.org/esa/dsd/agenda21/res_agenda21_34.shtml, (Accessed: 12 February 2012).
[60]Ibid.
[61] UNEP (2003): "Environmentally Sound Technologies for Sustainable Development"- Revised Draft, International Environmental Technology Centre Division of Technology, Industry and Economics United Nations Environment Programme, http://www.unep.or.jp/ietc/techtran/focus/sustdev_est_background.pdf (Accessed: 7 April 2012).

Article 6, paragraph 2 (c) of the Stockholm Convention requires that characteristics of environmentally sound methods for disposal of POP wastes shall be determined by the Conference of the Parties in cooperation with the appropriate bodies of the Basel Convention. Also, levels of destruction and irreversible transformation shall be defined. Similarly, *"as appropriate, the concentration levels of the chemicals listed in Annexes A, B and C in order to define the low persistent organic pollutant content referred to in paragraph 1 (d) (ii)"*[62] should be established.

In the "Updated general technical guidelines for the environmentally sound management of wastes consisting of, containing or contaminated with persistent organic pollutants (POPs)" [63] (in the following called: "the general technical guidelines") it is recognized that the disposal of wastes with a high POP content, including waste stockpiles, should have utmost priority.

Taking into consideration limit values within national legislation, available treatment capacities and analytical methods as well as the potential lack of knowledge and data, this guidance document provides the following provisional definitions for low POP content:[64] The limit value for PCBs is 50 mg/kg[65], for aldrin, chlordane, DDT, dieldrin, endrin, heptachlor, HCB, mirex and toxaphene it is likewise 50 mg/kg for each[66] and for PCDDs and PCDFs 15 μg TEQ/kg.[67]

For wastes consisting of, containing or contaminated with POPs above the low POP content, according to Article 6, 1(d) (ii), Parties are to take measures so that POPs wastes are: *"Disposed of in such a way that the POPs content is destroyed or irreversibly transformed so that they do not exhibit the characteristics of POPs or otherwise disposed of in an environmentally sound manner when destruction of irreversible transformation does not represent the environmentally preferable option."*[68]

Under Article 5 of the Stockholm Convention Parties have to make sure that POPs

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[62]Stockholm Convention, Article 6.2.

[63]Pursuant to decisions IV/17, V/26, VI/23, VII/13 and VIII/16 of the Conference of the Parties to the Basel Convention, I/4, II/10, III/8, IV/11 and V/12 of the Open-ended Working Group of the Basel Convention, resolution 5 of the Conference of Plenipotentiaries to the Stockholm Convention, decisions INC-6/5 and INC-7/6 of the Intergovernmental Negotiating Committee for an International Legally Binding Instrument for Implementing Action on Certain Persistent Organic Pollutants and decisions SC-1/21and SC-2/6 of the Conference of the Parties to the Stockholm Convention.

[64]UNEP 2006a:15.

[65]Determined according to national or international methods and standards.

[66]Determined according to national or international methods and standards.

[67] Concentrations are expressed in (TEQ) toxic equivalents, as referred to in annex C, part IV, paragraph 2, of the Stockholm Convention, but only for PCDDs and PCDFs.

[68]Stockholm Convention, Article 6. 1(d) (ii).

wastes are *"Not permitted to be subject to disposal operations that may lead to recovery, recycling, reclamation, direct reuse or alternative uses of POPs".*[69]

Regarding the choice of disposal methods for POPs wastes, neither the Basel Convention nor the Stockholm Convention specifies a particular technology to be used. However, they prescribe the level of destruction to be achieved and require the irreversible transformation of POPs.

The Stockholm Convention requires the use of the Best Available Techniques (BAT) for technologies for destruction or irreversible transformation, where formation of unintentionally produced POPs can occur.[70]Additionally, the parties should promote the use of Best Environmental Practices (BEP) for identified source categories, meaning that they should apply the most suitable combination of environmental control measures and policies. The term ‘best’ is defined as being *the "most effective in achieving a high general level of protection of the environment as a whole".*[71]

Destruction of POPs wastes must be accomplished in a manner that does not further degrade the environment by generating or releasing POPs. Annex C, Part V, B. (b)) requires Parties to take measures to make sure that residuals, wastewater, wastes and sewage sludge are treated, for example, by thermal treatment or by rendering them inert or by chemical processes that detoxify them. Also, processes should be changed in order to reduce or eliminate releases, such as moving to closed systems.

Uncontrolled releases from the process must be avoided. Moreover, process designs shall be modified in order to improve combustion and prevent formation of unintentional POPs, by controlling certain factors such as incineration temperature or residence time.[72]

The possibility of total containment of all process streams, in case that testing and reprocessing become necessary, has to be ensured. Efforts have to be undertaken that while decreasing the release of persistent organic pollutants, the increasing release of other pollutants (e.g. mercury) is avoided. Possible measures could, for instance,

[69]Stockholm Convention, Article 6. 1 (d) (iii).
[70] Definition of BAT under the Stockholm Convention: "BAT means the most effective and advanced stage in the development of activities and their methods of operation which indicate the practical suitability of particular techniques for providing in principle the basis for release limitations designed to prevent and, where that is not practicable, generally to reduce releases of chemicals listed in Part I of Annex C and their impact on the environment as a whole."
[71]Stockholm Convention, Article 5, (f).
[72]Stockholm Convention, Annex C, Part V, A.

include the use of low-waste technology or the use of less hazardous substances.[73] It should be mentioned, that the application of BAT for unintentionally produced POPs will often result in automatic reduction and elimination of other pollutants, like particulate matter, certain metals (such as mercury), nitrogen oxides (NOx), sulphur dioxide (SO_2), and volatile organic compounds.[74]

The Stockholm Convention provides general guidance on BAT and BEP where Parties shall take measures in order to prevent the formation and release of the chemicals listed in Part I of Annex C. It addresses the 'consideration of alternatives' as follows: *"When considering proposals to construct new facilities or sign modify existing facilities using processes that release ... [dioxins/furans]..., priority consideration should be given to alternative processes, techniques or practices that have similar usefulness but which avoid the formation and release of such chemicals"*[75]

However, the concept of best available techniques does not prescribe any specific technique or technology, but considers the technical characteristics of the installation concerned, as well as its geographical location and the specific local environmental conditions. In order to determine best available techniques, special consideration should be given to various factors. The nature, effects and mass of the releases concerned are decisive and highly important to know, since technologies and techniques may vary depending on these criteria. Also the consumption and nature of raw materials used in the process and its energy efficiency has to be considered, as well as technological advances and changes in scientific knowledge and understanding. Moreover, it is necessary to prevent or at least reduce to a minimum the overall impact of the releases to the environment and the risks to it.

Comparable processes, facilities or methods of operation, which have been successfully tried on an industrial scale, shall be used as a benchmark for BAT.[76]

According to the general technical guidelines the following provisional definitions for levels of destruction and irreversible transformation, shall be applied: The limit value for atmospheric emissions dioxins (PCDD) and furans (PCDF) is 0.1 ng I-TEQ/Nm^3. For all other POPs in gaseous emissions as well as in aqueous releases pertinent

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[73]UNEP (2006)b: "Revised Draft Guidelines on Best Available Techniques and provisional guidance on Best Environmental Practices relevant to Article 5 and Annex C of the Stockholm Convention on persistent organic pollutants", Secretariat of the Basel Convention, United Nations Environment Programme, http://www.pops.int/documents/guidance/batbep/batbepguide_en.pdf (Accessed: 20 February 2012).

[74] UNEP 2006b: 38.

[75]Stockholm Convention, Annex C, Part V, B. (b)).

[76]Stockholm Convention, Annex C.

national legislation and international standards, rules and guidelines shall be applicable.

In solid residues POP contents should be below the low POP contents as above-mentioned in this chapter. However, if the POP content of unintentionally produced PCDD/PCDFs is above the low POP content the solid residues should be treated adequately.[77]

The general technical guidelines suggest various methods, which are considered as environmentally sound disposal. In certain cases pre-treatment operations may be necessary for the proper and safe operation of the final disposal technologies, but only under the condition that the POPs, which are separated from the waste during these preceding operations are afterwards disposed of in such a way that POPs are destroyed or irreversibly transformed. The guidance document recommends the following pre-treatment methods: i) Adsorption and absorption processes in order to concentrate contaminants and separate them from aqueous wastes and from gas streams. ii) Dewatering for disposal technologies that cannot treat aqueous wastes. iii) Mechanical separation in order to remove larger-sized fragments from the waste stream. iv) Size reduction for technologies that can process wastes only within a defined size limit. v) Mixing of materials in order to optimize treatment efficiencies. However, mixing of wastes with POP contents above the defined low POP content with other materials in order to achieve a mixture with a lower POP content is not environmentally sound vi) Oil-water separation as some treatment technologies are not suitable for aqueous wastes and others not for oily wastes. vii) Ph-Adjustment in order to achieve highest effectiveness of certain treatment technologies, viii) Solvent washing to remove POPs from electrical equipment such as capacitors and transformers or to treat contaminated soil. ix) Low-temperature thermal desorption using heat to separate volatile and semi-volatile compounds and elements from contaminated media (often excavated soils), also used for the decontamination of electrical equipment such as transformers that contained PCB-containing fluids before.

The guidance document emphasizes, however, that also other pre-treatment options can be applied. If only part of a product or waste, such as waste equipment, contains or is contaminated with POPs, it has to be isolated and then disposed of in an appropriate

[77] UNEP 2006a: 15.

manner, meaning that POPs shall be destroyed or irreversibly transformed, if possible.[78]

Taking the general requirements of the two Conventions regarding POP wastes into account, the general technical guidelines provide for concrete technology options, being on the one hand incineration technologies, such as cement kiln co-incineration and hazardous-waste incineration and on the other hand non-combustion-technologies[79], such as gas-phase chemical reduction, base-catalysed decomposition, plasma arc, supercritical water oxidation and subcritical water oxidation, photochemical dechlorination and catalytic dechlorination reaction, potassium tert-butoxide method, alkali metal reduction (sodium reduction), catalytic hydrodechlorination, waste-to-gas conversion. Some of these technologies may require pre-treatment.[80]In the following chapter of this work some of these non-combustion technologies will be presented in more detail and compared to technologies involving incineration.

Where neither destruction nor irreversible transformation is the environmentally preferable option, for wastes with a *higher than the low POP content* (as defined at the beginning of this chapter), countries may give the authorization that such wastes containing or contaminated with POPs are being disposed of by other methods than the disposal operations just mentioned above. These 'other disposal methods' include specially engineered landfill or permanent storage in underground mines and formations. This can be the case, for instance, for wastes from the iron and steel industry or construction and demolition wastes.

When the POP content of the wastes is low, meaning at concentrations *under the low POP content* and if they are not disposed of with the methods described above, they should be disposed of in a way consistent with relevant national legislation and international rules, standards and guidelines, considering, of course, the specific technical guidelines developed under the Basel Convention.[81]

Summarizing the above-mentioned provisions of the Stockholm Convention and the Basel Convention as well as the requirements from their complementary technical guidance documents regarding the environmentally sound disposal of POP wastes, a

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[78]UNEP, 2006a: 40 – 45.

[79]General definition of non-combustion technologies "Technologies where the major proportion (99.99%) of POPs destruction takes place under reducing conditions"

[80]Details about these technologies and further references: UNEP 2006a: 46 – 73.

[81]UNEP 2006b: 45-47.

technology should prevent the formation as well as the release of dioxins, furans and other by-product POPs. Moreover, a potential technology should not generate any wastes with POPs characteristics and it should, as far as possible, not utilize any POPs disposal processes and methods, which are non-destructive. As a general principle, levels of POPs destruction and irreversible transformation should consider all POPs in waste output streams of a technology.

Low POPs content as provided for in the technical guidelines should apply as an upper limit for residues. Unintended release limits should be fixed at developed country standards, being 0.1 ng TEQ/Nm^3, for PCDD/PCDF air emissions.

Specification of BAT/BEP for design and operating conditions are assessed on a technology-specific basis.

All in all, it can be said that the guidance provided by the Conventions is primarily results-oriented, leaving developing countries with sufficient flexibility on their disposal choice. However, the fact that the Stockholm Convention calls for the research on disposal alternatives that do not release furans and dioxins and operate in essentially closed systems, can be seen as implicit preference for non-combustion technologies. Moreover, the Basel Convention calls for local destruction capacities, leaving the export option only as a last resort in order to safeguard environmental sound management of POPs wastes.

3 Comparison of Disposal Options in Developing Countries and Transition Economies: Non-Combustion Technology, Incineration or Export for Incineration to Developed Countries?

In this part of the thesis the disposal options ‘incineration within the developing country’ and ‘export to developed countries for incineration’ will be compared to some selected non - combustion technologies representing as a whole an alternative to the incineration of POP wastes.

3.1 Criteria for the evaluation and selection of appropriate disposal options for POPs wastes

There are a number of criteria with varying prioritization for the evaluation of disposal technologies and for the assessment of alternative methods in the literature.

Annex F of the Stockholm Convention addresses relevant information concerning social and economic considerations associated with potential disposal technologies and control measures, serving as a starting point for a useful list of criteria that can be used by authorities in conducting comparative evaluations of originally proposed facilities and identifying possible and available alternatives.[82]

These core criteria together with the general requirements from the Basel and the Stockholm Convention and their complementary documents serve as an evaluation base in a more or less similar way in all reports and papers dealing with the evaluation of technology for POPs disposal. According to GEF, for instance, “*technical and environmental qualification of POPs disposal technology should be performance-based. The evaluation of safeguards provisions and commercial viability should also*

[82]UNEP 2006b: 30.

be included in the selection process."[83]

The following five key categories, representing the most widely used evaluation criteria, will serve in this thesis for the assessment of the potential of non-combustion technologies in comparison to incineration within the country and export to developed countries for incineration:

- **Performance**
- **Applicability**
- **Cost**
- **Operation & Safety**
- **Important stakeholders**

3.1.1 Performance

The great overall goal of both the Stockholm and the Basel Convention is the protection of human health and the environment. Thus, basic requirement for any disposal technology is that secondary waste stream volumes are drastically smaller than the initial input waste stream volumes and that they do not contain any toxic reaction byproducts.

A potential technology should guarantee complete and efficient destruction of POPs, whereby destruction efficiencies should amount to effective 100 %. This number is necessarily based on findings of extremely low POPs concentrations in any and all residues, taking the most sensitive analytical techniques available. Achieving absolute zero residues may be technically not feasible. Therefore, the only possible criterion to decide how low the required concentration must be, is the absence of any harm to human health and the environment. Complete analyses of all out flowing streams, residues as well as possible leaks must be carried out with a frequency sufficient to ensure compliance with this criterion during start-ups, shutdowns and routine

[83] UNEP 2011: 33.

operations, event though this might be expensive.[84]

In this context two ways of measuring the destruction of POPs have to be considered. ‘Destruction Efficiency’ (DE) reflects the total destruction of POPs in a certain process. This concept was defined in 1992 by UNEP during the implementation of the global treaty on ozone depleting substances and is now used for the assessment of POPs destruction technologies. It is calculated based on the overall mass of POPs fed into a process, i.e. POPs contained in input waste streams as well as POPs concentrations in other materials or reagents fed into the process. This input of POPs minus the mass of the remaining POP content in the gaseous, liquid and solid residues (such as flue gas, sludge, treated material, water, fly and bottom ash and any other process output stream) is set in relation tothe POP content within the waste input stream. Hereby also POPs discharge during the pretreatment process is considered. DE is a key concept in order to assess and evaluate destruction technologies and irreversible transformation, even though it can be hard to measure in a reproducible and comparable way, particularly on a regular basis. The principal weakness of the DE as an indicator is the cost and sometimes also the complexity linked to the sampling and analytical determination of POPs in different materials (sludge, water, fly ash, flue gas). Measurable DE value also depends on the analytical sensitivity of the test.

The second concept is ‘Destruction and Removal Efficiency’ (DRE). It only takes the POPs in emissions to air (stack gases) into account, while ignoring releases in solid and liquid form. Hence, DRE also ignores the amount of POPs, which are not destroyed but only transferred to another media (like sludge, ash, etc.).[85] DRE is a useful indicator for incinerators, however it is less suitable as indicator for non-combustion technologies operating in closed loop.

Both DE and DRE, usually reported as a percentage, are a function of the original POP content in the input stream and do not consider formation of unintentionally produced POPs during the destruction or irreversible transformation process.[86]

Considering all inputs and environmental releases, an effective destruction efficiency of 100% shall be achieved in the ideal case.[87]

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[84]UNEP 2004a: 56.

[85]Costner, P. (2004): “PCB Management and Disposal under the Stockholm”. *Convention Consultation Meeting, Geneva 9-10 June 2004.* http://www.chem.unep.ch/pops/pcb_activities/PCB_proceeding/Presentations/Pat%20Costner%20(Greenpeace).pdf**,** (Accessed: 10 April 2012).

[86]UNEP 2006a:13.

In order to better attain the above-mentioned goal, the process must be closed with no possibility of unplanned release of any chemicals. Priority should be given to technologies that imply containment of all residues and out flowing streams for screening and, if necessary, reprocessing. This is to ensure that no chemicals of concern or other harmful compounds, such as newly formed POPs or other hazardous substances, are released to the environment. Therefore, the system must be equipped with the capacity to monitor and test all process residues and output streams and to redirect the streams for reprocessing if needed.

The environmentally sound operation of disposal technologies requires the application of both best available techniques (BAT) and best environmental practices (BEP), which are in some aspects overlapping concepts, to keep the formation and release of unintentional POPs and other substances of concern to a minimum.

The destruction of POP should be complete, meaning that organic chlorines are entirely eliminated (mineralization). In the case of non-complete dechlorination, the residual chlorinated organics can still be toxic or new chlorinated toxicants can be formed out of it (e.g. de novo synthesis of dioxins and furans).[88] Best available techniques achieve PCDD/PCDF performance levels in air emissions below 0.1 ng I-TEQ/Nm³ (at 11% O_2). Similarly, for releases of waste-water from effluent treatment plants and scrubber effluents after flue gas treatment, BAT can reach PCDD/PCDF concentration levels below 0.1 ng I-TEQ/l.[89]

Technologies involving uncontrolled releases (e.g. relief valve from high-pressure vessels) or environmental dispersal of POPs, even at barely detectable concentrations (e.g. incineration processes with high gaseous mass flow released to atmosphere), should be carefully inspected and possibly avoided.[90]

3.1.2 Cost

An evaluation of commercial viability and sustainability should be applied in the selection of POPs disposal technology in any decision to build new or use existing facilities. Predictable and competitive costs are particularly for developing countries

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[87]UNEP 2011:6.
[88]Costner 2004.
[89]UNEP 2006b:1
[90]Costner 2004.

and transition economies of utmost importance. Unit costs are usually indicated by kg of POPs disposed of or by kg of waste disposed of.
When building new facilities a thorough cost-benefit analysis is required and economies of scale should be considered. For a non-combustion technology and also for a new incinerator to be viable it will require certain minimum stockpile quantities. Some technologies will require a higher minimum stockpiles size than others to reach breakeven volumes. If it is decided to build a treatment plant for the exclusive treatment of POPs wastes, a continuous input of waste streams also for the remote future should be safeguarded. This issue is related to financial sustainability, meaning that it has to be assured that costs after the GEF funded period remain or become competitive, since owners of POP wastes are of course interested in the cheapest disposal option.[91]

It is strongly recommended to have a close look at the specific country situation, since certain costs are rather specific and may vary significantly from one location to another. Therefore, costs can often only be considered in detail when contractors make their offer to the client. In many cases, the tender documents contain specific country information supplied by the client to the contractors. Moreover, before a offer will be made, contractors will send their representatives to the country in order to assess the following facts.
Costs for installation and commissioning as well as for site preparation will be checked. Monitoring, reporting and compliance costs depend strongly on the amount of monitoring, reporting and compliance testing required by the national regulations of a country. Running costs with and without waste (testing and dry runs on functionality before waste treatment) have to be known.
Also the costs for energy supply, for Telekom installation, qualified staff, raw material needed etc. have to be considered.
Landfill costs and transport costs of residues depend on the local situation, too. Decommissioning costs, meaning site remediation and project completion costs at the end of the project lifetime include any necessary site clean up, dismantling and removal of equipment and restoration of site as required.
When choosing export as disposal option, also packing and shipping costs have to be

[91]UNEP 2011.

taken into account.[92]

When it comes to the treatment of POPs wastes a cost-driving factor is the concentration as well as the impurities of the POPs wastes to be treated. For liquid PCBs using a non-combustion-technology, for instance, treating waste oil is more expensive than treating transformer oil, by a factor of 2 or more, depending on the viscosity and on the impurities in the oil. Waste oil often contains solvents, water, solids, paint, etc., which needs extensive pre-treatment. Similarly, types and forms of the waste determine costs for incineration. Economies of scale play an important role and make prices usually decrease, depending on the amount of wastes to be disposed of.[93]

3.1.3 Applicability

A key challenge for a new disposal technology is the wide-ranging waste composition of obsolete stockpiles. Each stockpile is unique and in most of the cases complex because of the mixing of wastes. The waste matrix includes obsolete, banned, unwanted pesticides, pure PCB oils or other POPs, contaminated soils, contaminated equipment (e.g. capacitors) and containers, possible inappropriate disposal of stocks (uncontrolled burial). Each of the waste components may require different disposal technologies, depending on its nature as well as on the amount of waste that has to be disposed of.

In order to select an appropriate technology it is indispensable to know the stockpile situation in the region, the country and the site, since the waste matrix as well as the existing volume of wastes determines the technologies that can be used. Site cleanup can only be successfully managed with a prior soil and water assessment.

In case that there are several various compounds to be disposed of, it is highly desirable to use a technology, which is sufficiently flexible to deal with a variety of wastes with varying constituents. It is also essential that it can be applied to concentrated POPs (stockpiles) and that minimal additional pre-treatment of waste is required. Pre-treatment operations may be necessary for certain waste types for the

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[92]Vijgen, John and McDowall, Dr.Ir. Ron (2009)b: “Alkali Metal Reduction - POPs Technology Specification and Data Sheet”, International HCH & Pesticides Association (IHPA),http://www.ihpa.info/docs/library/reports/Pops/June2009/DEF_ALKALIMETAL_150109_SBCLogoCLEANVERSION.pdf (Accessed: 6 May 2012).

[93]Vijgen, John and McDowall, Dr.Ir. Ron (2009)b.

proper and safe operation of the final disposal technologies, but only under the condition that the POPs, which are separated from the waste during these preceding operations are afterwards disposed of in such a way that POPs are destroyed or irreversibly transformed. For some also post-treatment has to be considered.

Another important consideration is that stockpiles are not being produced on a continuous basis, since POPs have been phased out. They are therefore a one-time problem, and represent a bubble market. Hence, spending time and money on the development of alternative non-combustion approaches is only worthwhile if these new plants are able to treat not only banned and phased out POPs, but also new POPs or other hazardous non-POP wastes, providing for the time after stockpiles will have gone.[94]

3.1.4 Operation & Safety

Before deciding on the site of the new destruction facility it is crucial to gather extensive information on existing infrastructure, such as access to power and water supply, roads, labor, weather tight buildings, communication systems and transportation services. Also local regulations, licenses and the local residents should be taken into consideration. It is recommended to follow a far-reaching risk-based approach, including environmental impact assessment, and to conduct and stakeholder analysis. For certain technologies it is extremely important to be operated under secure infrastructure, by well-trained staff, and, in the case of non-combustion technologies, often with laboratory support due to their reagent requirements, in order to reduce any potential risks and guarantee the highest possible level of safety.[95]

The process must be able to deal with disturbances, such as power supply failure, without danger to personnel or equipment. Handling and loading of POP wastes into the destruction facility and into the process must always be safe, direct and controlled.

Equipment and controls must be simple and robust, and will ideally make use of local resources. Maintenance and the supply of spare parts have to be assured. The operating procedure must be very basic, extremely simple and easy to understand. Loading and

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[94] UNEP (2004)b: “Non-combustion technologies for the destruction of POPs stockpiles”, Scientific and Technical Advisory Panel (STAP) of the GEF UNEP, http://www.unep.org/stap/LinkClick.aspx?fileticket=XhzPXDluFhc%3D&tabid=3045&language=en-US (Accessed: 16 April 2012): 7 f.

[95] UNEP 2004b: 13.

discharging, start up and shut down must be virtually self-explanatory. As mentioned above, the destruction facility must ideally be able to deal with POPs waste in a variety of forms, which means in solid, gaseous or liquid form, as contaminated soil, concrete, equipment and containers. Moreover, the process must be able to treat the full range of obsolete POPs stockpiles with minimum change in operating procedure and reactants.

It is of utmost importance that technologies being operated in developing countries and transition economies are inherently safe under local conditions. This includes the toxicity of chemical reagents together with other issues of the technology that might be dangerous.[96]

3.1.5 Important stakeholders

When it comes to the decision on appropriate disposal options for POPs wastes, assuring the support of all concerned stakeholders can be decisive for the success of the project. The most important ones are local and national governments, the owners of the POP wastes and the general public, meaning local residents and NGOs.

The creation of a country-specific checklist is strongly recommended, as it is important that a new technology fits comparatively well within a country's sustainable development plans, taking into account effective integration of cultural, social, economic, environmental, health and safety factors.

Hereby factors like the demonstrated country-drivenness together with the local partner capability, including the relevant technical and operational experience and financial capacity, influence the smooth introduction and operation of a technology.

Moreover, acceptance by NGOs and local residents can play a crucial role. An important argument for the set up of new disposal facilities in the own country can be the potential creation of new jobs. Also the support of POPs wastes owners' are crucial, as can be seen in the case study of the Philippines in the last chapter.

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[96]Rahuman, M., L. Pistone, F. Trifiro and S. Miertus (2000): "Destruction Technologies for Polychlorinated Biphenyls (PCBs)". International Centre for Science and High Technology United Nations Industrial Development Organization, ICS-UNIDO publications, Trieste, Italy. http://www.clu-in.org/download/remed/destruct_tech.pdf (Accessed: 30 April 2012).

3.2 Combustion technologies

The "Oxford Dictionary of Science" defines 'combustion' as follows: "*A chemical reaction in which a substance reacts rapidly with oxygen with the production of heat and light. Such reactions are often free-radical chain reactions, which can usually be summarized as the oxidation of carbon to form its oxides and the oxidation of hydrogen to form water.*"[97]

Combustion technologies include hazardous waste incinerators, cement and rotary kilns, furnaces, boilers etc. and are usually believed to be the most economically suitable way for concentrated POPs waste treatment and are therefore the most widely used disposal option. The big majority of them are mature and commercialized technologies. Various vendors offer combustion technologies in a number of countries, which makes the market quite competitive. As incineration technologies have been on the market for decades, developed countries routinely burn their POPs wastes in incinerators.

However, an important point to take into consideration is potential low public acceptance (local residents, NGOs), which could be a major obstacle to the construction and operation of hazardous waste incinerators in developing countries, but also in developed countries.[98]

In the following chapter high temperature incineration and the cement kiln technology will be described in detail.

3.2.1 Hazardous waste incineration

High temperature incineration technology is the principal process used for the destruction of POPs waste in developed countries. Hazardous waste incinerators are available on the market in a number of designs, including rotary kiln incinerators, and

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[97]Oxford University (2005): "A Dictionary of Science", Oxford University Press, Market House Books Ltd, 5thed, http://www.blmasinac.com/files/A%20Dictionary%20of%20Science.pdf (Accessed: 6 May 2012): 181.

[98]Ludwig, Udo and Schmid, Barbara (2007): "Germany's Booming Incineration Industry -Burning the World's Waste", Spiegel Online International, 21.02.2007, Nr. 8 / 2007, http://www.spiegel.de/international/spiegel/0,1518,467239,00.html (Accessed: 4 April 2012) / UNIDO 2007: 16.

static ovens (for liquids only). High-efficiency boilers and lightweight aggregate kilns are used for the co-incineration of hazardous wastes as well.[99]

However, one has to take into account that hazardous waste incineration plants are *not* specifically built for the disposal of POPs. Their existence is founded on national or regional waste management plans, dealing primarily with the question of hazardous waste management and only marginally with POPs wastes. Therefore the data given here cannot simply be compared to data for technologies that are exclusively designed to treat POPs wastes.[100]

Process: In order to treat organic contaminants, controlled flame combustion is used in hazardous waste incineration, which predominantly takes place in rotary kilns. Characteristically, a combustion process involves heating to a temperature greater than 850°C. If the chlorine content is greater than 1 %, temperatures rise above 1,100°C, with a residence time longer than two seconds, representing conditions that guarantee proper mixing.[101]

Hazardous waste incinerators have a main chamber (primary chamber) for burning waste (e.g. obsolete pesticide stockpiles) and a secondary chamber, where the residence time can be extended in order to achieve maximum destruction of the material and its thermal oxidation into gases and unburnable solids.

Subsequent to the secondary chamber is the gas treatment system, often including a quench system (to reduce dioxin formation), packed tower absorbers, filters, precipitators, scrubbers and other reactive absorbers.

The chemical reaction during an incineration process is the controlled high temperature oxidation of mainly organic compounds to generate carbon dioxide and water. Inorganic materials such as salts, acids and metallic compounds can also be produced from this process. Incineration of hazardous wastes is extremely complex and demands kinetics of chemical reactions to be controlled under non steady state conditions.[102]

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[99] Vijgen, John and McDowall, Dr.Ir. Ron (2009)d: “Hazardous Waste Incineration”, Pesticides Treatment Technology Fact Sheet”,International HCH & Pesticides Association (IHPA), http://www.ihpa.info/docs/library/reports/Pops/June2009/DEFSBCLogo_Inciner_180608_.pdf (Accessed: 6 May 2012).

[100] Vijgen, John and McDowall, Dr.Ir. Ron (2009)d.

[101] UNEP 2006a: 36.

[102] UNEP 2002: 50.

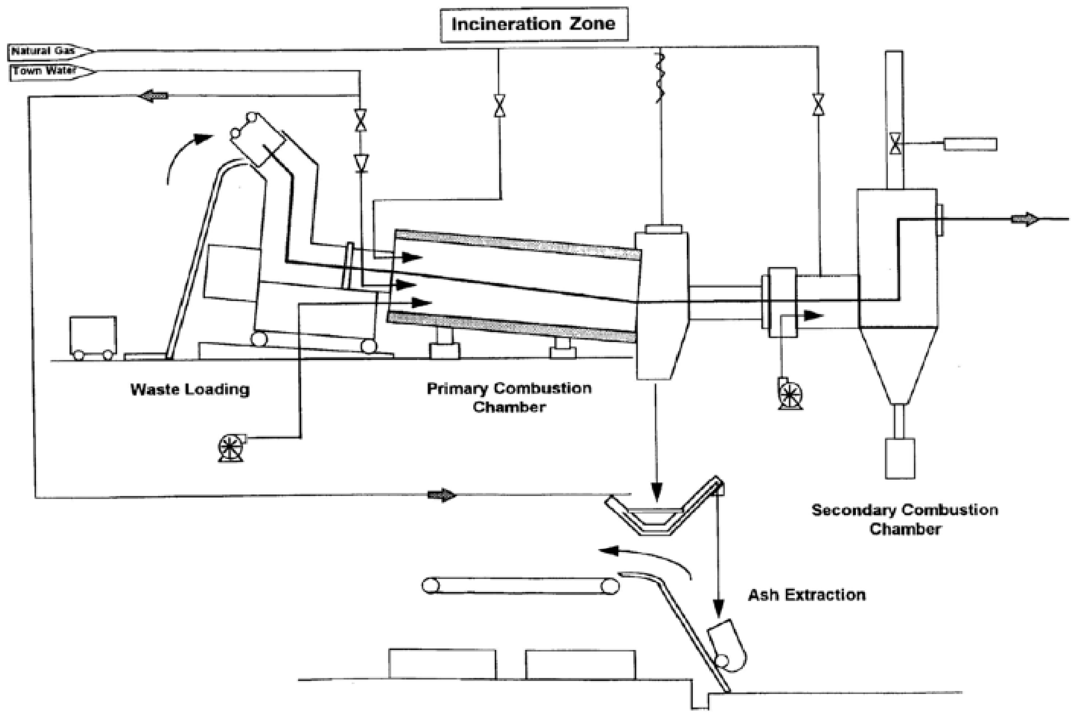

Figure 1: Schematic of a rotary kiln incineration system[103]

Applicability: Hazardous-waste incinerators can destroy wastes consisting of, containing or contaminated with any POP types. Moreover, they can be designed to receive wastes in any concentration or any physical form (liquids, gases, solids, slurries and sludge).

Depending on the design, pre-treatment requirements may comprise dewatering, blending and size reduction of wastes.

Stationary units of incinerators can treat between 30,000 and 100,000 tons per year, whereas mobile and semi-mobile units have an annual capacity of 2-5,000 tons per year. Even though the share of POPs wastes is sometimes up to 5 %, it is often negligible, compared to the total amount of other wastes treated in the incinerator.[104]

Performance: Well-operated incinerators can destroy POPs with a destruction and removal efficiency (DRE) greater than 99.99 %. DREs at this level (and higher levels

[103]UNEP 2006b:11.
[104]Vijgen, John and McDowall, Dr.Ir. Ron (2009)d: "Hazardous Waste Incineration", Pesticides Treatment Technology Fact Sheet",International HCH & Pesticides Association (IHPA), http://www.ihpa.info/docs/library/reports/Pops/June2009/DEFSBCLogo_Inciner_180608_.pdf (Accessed: 6 May 2012).

of 99.99995 %) require strict control measures of the incinerator to achieve these efficiencies. The effectiveness depends on the type of waste feed, temperature, turbulence and the residence time being maintained.[105]

Regarding Destruction efficiencies (DE), the Ministry of the Environment of Japan has reported values greater than 99.999 % for aldrin, chlordane and DDT in 2004, while the US Environmental Protection Agency reported DEs ranging only between 83.15 and 99.88 % for the treatment of PCBs.[106] These comparatively low values result from the fact that incineration plants do no operate in closed systems. Therefore, the Stockholm Convention identifies waste incinerators as sources of relatively high formation and release of substances listed in Annex C to the environment.

Emissions contain carbon monoxide, carbon dioxide, HCB, hydrogenchloride, particulates, PCDDs (dioxins), PCDFs (furans) and PCBs and water vapor.

Incinerators applying BAT are equipped with systems and devices to prevent the formation of PCDDs and PCDFs and to remove PCDDs and PCDFs being unintentionally produced during the process. Combined types of post-treatments, embracing cyclones and multi-cyclones, static bed filters, scrubbers, electrostatic filters, selective catalytic reduction, rapid quenching systems and carbon adsorption, have resulted in very low discharges to water and also very low PCDD and PCDF emissions to air (<0.1 ng I-TEQ/ m^3).

Continuous drainage water sampling as well as regular flue gas monitoring according to air pollution regulations is required.[107]

In the residues, PCDDs and PCDFs are mainly found in fly ash and salt, and to some extent in bottom ash and scrubber water sludge, typically about 50 ng PCDD I-TEQ per kg ash. Residues originating from flue gas cleaning exhibit 1,500 ng PCDD I-TEQ per kg. Fly and bottom ash may require disposal within a specially engineered landfill, depending on their characteristics.[108]

Operation: Hazardous waste incinerators can be purchased as mobile / semi-mobile or stationary units. Portable units having a capacity of about 2-5,000 t/year may involve cost premium and potential lower environmental performance.[109]

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[105]UNEP 2002: 50.
[106]Vijgen, John and McDowall, Dr.Ir. Ron (2009)d.
[107]UNEP 2006a: 36.
[108]UNEP 2011: 41.
[109]UNEP 2002: 50.

The amount of combustion fuel needed will depend on the composition and on the calorific value of the waste. In many cases the installation runs fully by means of the waste provided, as an example of a German hazardous waste incinerator shows:
Two rotary kilns with a total capacity of 110 000 t/year have an average power requirement of 170 KWh per ton. In one turbine the plant generates the energy for itself. 15 % of the produced energy is supplied to the public electricity grid. Heating up the plant after standstill requires 4.4 kg combustion oil per ton of waste.

Material requirements involve cooling water (1.7 m^3/t/year) and lime or another appropriate material for the neutralization of acid gases in the wet scrubber. Typically, 40 kg/t of 50% NaOH is needed. However, it highly depends on the halogen and sulphur content of the wastes. In order to clean the gas for traces of dioxins and mercury in the last step activated carbon / chalk mixture is 1.5 kg/t.[110] Health and safety hazards are mainly associated with high operating temperatures.[111]

Cost: A rough calculation of costs for a new incineration plant in a country based on German standards gives the following result, exhibiting extremely high capital costs: Assuming a throughput of 2 x 50,000 t per year treating solid, liquid, pastes, drums, a thermal capacity (with boiler) of 2 x 22 MW, a buffer capacity for waste (5 days), would require an investment of approximately US $ 50 million plus 85 employees.
More than 30,000 tons of wastes per year are generally required for a plant focused on the broad application to hazardous organic wastes to be viable (economy of scale).[112]
Treatment costs generally amount to US $ 0.1 - 2.5/kg depending on waste type and form.[113]
Monitoring, reporting and compliance costs depend on the amount of monitoring, reporting and compliance testing required by the national regulations of a country. Landfill costs and transport costs of residues depend on the local situation, too.

[110] Vijgen, John and McDowall, Dr.Ir. Ron (2009)d.
[111] UNEP 2006a: 36.
[112] Vijgen, John and McDowall, Dr.Ir. Ron (2009)d.
[113] UNEP 2011:41.

Advantages	Disadvantages
• Applicable to any POP type, in any physical form or concentration • Generally accepted technology by many nations. • Long history of experience with management of incinerators • Large capacity • Energy recovery • Volume reduction and concentration of pollutants	• High capital and operating costs. • Mobile / semi-mobile units available but at higher cost and potentially lower environmental performance • Sophisticated emission controls and monitoring required • If poorly managed -> dioxin, furan emission possible • Identified by the Stockholm Convention as a source category for dioxin and furan emissions • Greenhouse gas emissions • Economy of scale: >30,000 t/ year generally required for development with broad application to hazardous organic wastes • Comparatively low DE (Depending on management) • Additional measures required to treat liquid and solid residues • Low public acceptance • Health and safety hazards due to high operating temperatures

3.2.2 Co-processing in cement kilns

Cement kiln plants generally exist for the purpose of producing cement, but by coincidence rotary cement kiln plants have a number of inherent features making them ideal for the treatment of hazardous waste and POP waste.[114] So one has to bear in mind that cement kilns are *not* specifically built for the disposal of POPs. Therefore, as it was also the case for hazardous waste incinerators, the data given here cannot simply be compared to data for technologies that are exclusively designed to treat POPs.[115]

The USA, some European and many developing countries have made use of existing cement kilns to treat POPs wastes. Therefore there is a number of cement kiln co-incineration operations identified in the inventory of worldwide POPs waste destruction capacity. Cement kilns are commercially applied in developed countries, but still in the demonstrations phase in developing countries.

Cement kilns might represent a useful alternative to hazardous waste incineration, but generally the application to POPs wastes is limited to relatively modern rotary kiln with overall BAT / BET environmental performance, equipped with appropriate POPs waste handling / injection infrastructure as well as monitoring capacity and appropriate and sufficient gas treatment systems, as described in the chapter above.

Even though the Stockholm Convention identifies cement kilns co-processing hazardous wastes as a source category for dioxin and furan emissions, it is unlikely that they would have been mentioned if most recent performance data and technical developments of modern kilns had been considered.[116]

Only a few of the cement kilns in developing countries fulfill the technical requirements that would allow safe and efficient destruction of POPs wastes. Expert advice is necessary in order to judge whether kilns can be used and to assess whether special equipment is required to inject the POPs waste into the kiln.[117] Potential

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[114]Karstensen, K.H. (2007): "A Literature Review on Co-processing of Alternative Fuels and Raw Materials and Treatment of Hazardous Wastes in Cement Kilns". Department for Environmental Affairs and Tourism, Republic of South Africa. Report September/KHK, http://www.aitec-ambiente.org/portals/2/docs/pubblici/documenti/raccolta%20bibliografica/coprocessing%20literature%20review%202007.pdf (Accessed: 10 May 2012).
[115]Vijgen, John and McDowall, Dr.Ir. Ron (2009)d.
[116]Ibid.
[117]Rahuman, M., L. Pistone, F. Trifiro and S. Miertus 2000:15.

application of cement kilns for the destruction of POPs wastes requires case-by-case assessment involving a thorough study of the country situation and a performance demonstration.[118]

Process: Cement kilns characteristically consist of a long cylinder of about 50 – 200 meters and up to 6 meters diameter, inclined slightly from the horizontal, rotating at about 1 – 4 revolutions per minute.

Raw materials such as limestone, silica, alumina and iron oxides are loaded into the upper end ("cold end") of the rotary kiln. The slope in combination with rotation makes materials move toward the lower end ("hot end") of the kiln. The kiln is fired at the lower end of the kiln, where temperatures reach up to 1,500°C. While the materials glide through the kiln, they undergo drying and pyroprocessing reactions to form clinker.[119]

The key processes used in making cement clinker can be classified as either "wet" or "dry" depending on how the kiln feed is prepared. In the wet process the feed material is converted into slurry, containing about 40% water, and then fed directly into the kiln. In the dry process the raw material is dried by kiln exhaust gases while being milled, which is thermally much more efficient than the wet process.

The basic dry process system is composed of the kiln and a suspension preheater. The raw materials are pulverized and blended, before they are fed in at the top of the preheater tower. Hot gas from the kiln is blown through the series of cyclones, while heat is being transferred efficiently from the hot gases to the fine raw material.

Due to the very high temperature and the long residence times of the cement kiln, very high destruction efficiency can be achieved for POP waste. Moreover, the highly alkaline conditions in a cement kiln are perfect to break down chlorinated organic waste. Chlorinated liquids, chlorine and sulphur are neutralized and converted into chlorides and sulphates.[120]

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[118]UNEP 2011:41.

[119]UNEP 2006a: 33.

[120]Winter, Nick "Manufacturing – The cement kiln", Understanding Cement, http://www.understanding-cement.com/kiln.html (Accessed: 8 May 2012).

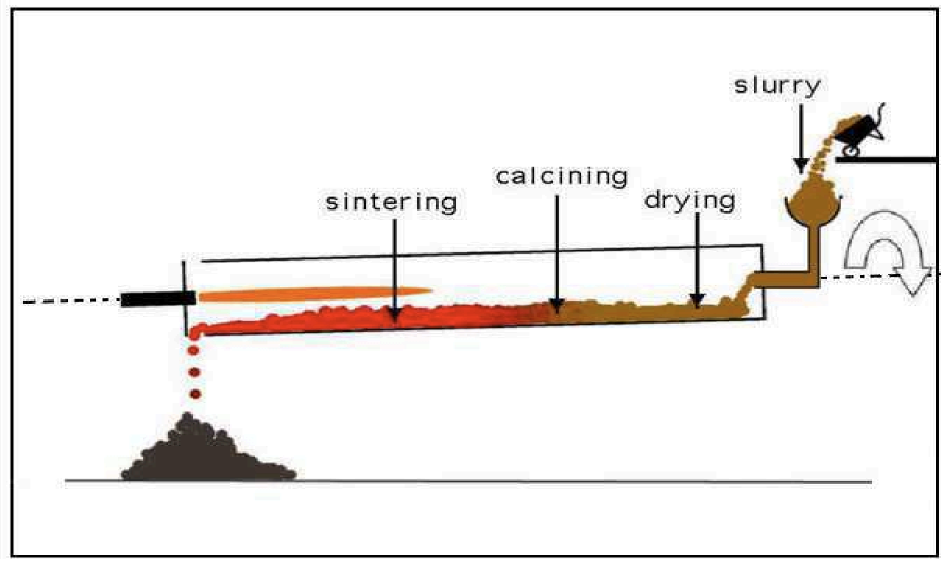

Figure 2: Principle of a basic wet-process kiln.[121]

Applicability: Cement kilns have been demonstrated with PCBs, but are also applicable to other POPs such as obsolete pesticide stockpiles. Cement kilns are capable of treating both liquid and solid wastes. Chlorides negatively impact the quality of the cement and therefore have to be limited. All the raw materials used in cement manufacture contain chlorine, so the chlorine concentrations in the POPs waste can be critical. However, if they are blended down sufficiently, cement kilns are able to treat highly chlorinated hazardous waste successfully.[122] Pre-treatment can also involve thermal desorption of solid wastes as well as the homogenization of solid and liquid wastes through drying, shredding, mixing and grinding.

As the plant is co-processing POPs waste, the traceability of the wastes needs to be guaranteed prior to reception by the facility. Deliveries of unsuitable wastes should be refused. Ideally, all materials going into the plant are analyzed in a laboratory before treatment.[123]

Performance: Both DREs and DEs of greater than 99.99998 per cent have been reported for PCBs in several countries. However, in order to achieve these efficiencies

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[121]Winter 2012.
[122]UNEP 2006a: 33.
[123]Vijgen, John and McDowall, Dr.Ir. Ron (2009)e: "Cement Kiln Co-Processing (High Temperature Treatment)", Pesticides Treatment Technology Fact Sheet",*International HCH & Pesticides Association (IHPA)*, http://www.ihpa.info/docs/library/reports/Pops/June2009/DEFSBC_LogCEMENTKILN_180608_.pdf (Accessed: 6 May 2012).

and to keep emissions to a minimum co-incineration of hazardous wastes and POPs wastes should only be performed if the cement kiln operates according to the best available techniques (BAT). BAT for control of dioxins and furans (PCDD/PCDF) in flue gases is below 0.1 ng I-TEQ/Nm³ with reference conditions of 273 K, 101.3 kPa, 11% O_2 and a dry gas basis.[124] Whether BAT standards as required under the Stockholm convention are achieved, depend on the following factors: Kiln exhaust gases have to be cooled quickly to lower than 200 °C in wet kilns, which is already an inherent feature in dry preheater and pre-calciner kilns. Alternative raw material feed as part of raw-mix (if it includes organics) should be limited. No alternative fuel should be fed during start-up and shut down. Process parameters, such as homogenous raw mix and fuel feed, regular dosage and excess oxygen have to be carefully monitored and stabilized. If necessary, additional secondary measures to reduce such emissions should be undertaken.[125]

Process gases require treatment to remove cement kiln dust and organic compounds, sulphur dioxide, nitrogen oxide and also heat in order to minimize the formation of dioxins and furans. Treatment system may include preheaters, electrostatic precipitators, fabric filters and activated carbon filters. It has been reported that dioxin and furan concentrations contained in cement kiln dusts are in the range of 0.4 and 2.6 mg/kg. Therefore, recovered cement kiln dusts should be put back into kilns to the greatest extent possible, whereas the residues may require disposal in a specially engineered landfill or an appropriate permanent storage.[126]

Operation: Cement kilns are available only in fixed configurations. Cement kilns co-incinerating waste as fuel do not allow more than 40 % of the heat requirement coming from hazardous waste. However, cement kilns with high throughput can potentially treat major amounts of waste.

Questions on energy use or water consumption are not relevant since cement kilns are already in place and would use these resources anyway to produce cement. Commonly, experts examine existing cement kilns if they meet technical requirements to treat certain hazardous wastes. The cement kiln has to be investigated further regarding raw material conditions, technology, chemistry etc, which often depends on the location of the kiln.

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[124]UNEP 2006b: 22.
[125]Karstensen 2007: 146.
[126]UNEP 2006a: 33.

Cement kilns treating hazardous wastes may require modifications to the rotary kiln. There are two suitable options for feeding the waste. The first one consists on feeding solid material together with the auxiliary fuels at the middle of the kiln through a specially designed hopper, involving a major alteration of the rotary kiln. Here the waste substitutes the fuel.

The temperature at the point of waste injection is about 1,100 °C and increases as the materials move further down the kiln. Monitoring is of utmost importance in order to guarantee the complete destruction of stable chlorinated compounds such as PCBs with the desired efficiency. Test runs and research revealed that emissions remained the same or even decreased (in the case of CO_2), when substituting parts of the fossil fuel with POPs waste.

The second option requires a pre-treatment of the solid waste (e.g. thermal desorption). After such treatment the material can act as raw material substitute, and the condensate can be incorporated in the liquid feed stream.

Treatment of wastes with cement kilns can be regarded as relatively safe if properly designed and operated. It is widely acknowledged that BAT for new cement kiln plants and major upgrades is a dry process kiln with multi-stage preheating and pre-calcination.[127]

Cost: Treatment costs for co-processing POPs wastes in cement kilns depend on waste types and on the facility. It is more expensive than incineration, but compared to other options still relatively cheap. Treatment costs typically range between US $ 1.0 - 5.0/kg.[128]

Costs for necessary technical upgrades for the co-processing of POPs wastes in order to achieve BAT / BEP standards for existing cement kilns can be comparatively cost-effective, but depend on the state of the already existing plant. Particularly for plants that already accepted co-incineration of hazardous (non-POPs) wastes, incremental investments for treatment of POPs wastes might be relatively low. Monitoring and control requirements will add to the costs significantly. If a plant owner decides to go in co-processing of hazardous waste and POPs waste, the owner will do these investments himself. Also monitoring costs must be covered by the owner and will be

[127]Karstensen 2007: 180.
[128]UNEP 2011: 41.

specified in the permit.[129] The Swiss company Holcim indicates required investment costs of US $ 200 million for the upgrade of a cement kiln with an annual capacity of 1 million tons.[130]

But even though in some cases the investment for technical upgrades and monitoring equipment might be quite high, substituting parts of fuels with wastes allows cement kilns to recover the waste energy, to conserve non-renewable fossil fuel and to emit less CO_2, which results in reduced overall costs of cement production. Particularly for countries with increasing demand of cement it is the most economic feasible option to build new cement kiln plants in line with BAT / BEP standards, as this implies competitive advantages for plant owners with regard to cement production. Therefore old polluting plants will be progressively replaced and the number of cement kilns that might potentially be capable to treat POPs wastes will increase in the near future.[131]

Advantages	**Disadvantages**
• Applicable to PCBs and POPs pesticide wastes, in solid and liquid form • Already existing in many developing countries, long history • Commercialized in developed countries • Quite safe in operation • High DRE and DE, if well operated • Primary purpose: Cement production, only secondarily POPs wastes disposal, but useful synergies • Energy recovery	• BAT standards not always assured, plant upgrades might be necessary • Cement kiln owners have to absorb costs for technical upgrades and tracing, monitoring and increase safety standards for POPs treatment. • Monitoring and controls extremely important, might be expensive • If poorly managed -> dioxin, furan emission possible • Identified by the Stockholm Convention as a source category

[129] Vijgen, John andMcDowall, Dr.Ir. Ron (2009)e.
[130] Email correspondence with Holcim, Corporate Communications, 15 May 2012.
[131] Karstensen 2007: 180.

• Waste can substitute fossil fuels or minerals • Volume reduction and concentration of pollutants	for dioxin and furan emissions • Greenhouse gas emissions • Waste composition and concentrations must be known • Only available as fixed plant • Pretreatment might be necessary

3.2.3 Case study: PCB Management in Zheyang Province, China, through incineration

Due to China's fast growing economy and its rapidly progressing industrialization, the country faces, amongst many other environmental challenges, also the question of how to successfully deal with POPs. In this context PCB wastes and unintentionally produced POPs during combustion, primarily dioxins and furans, are of major importance.

China ratified the Rotterdam Convention as well as the Basel Convention. As a party to the Stockholm Convention, it is obliged to identify, manage, and dispose of PCBs in an environmentally sound manner and to eliminate its PCBs stockpiles by 2028.The government's commitment to the Stockholm Convention is an integral part of the 12th Five-Year Plan (2011-2015). A program dealing with the first 12 POPs will be implemented in close coordination of 9 ministries. Moreover, the plan aims for POPs pollution control in the main industries in China and 10 % reduction of dioxin releases in the country.[132]

According to estimates China emitted about 10 kg –I-TEQ of dioxin in 2004. This is by far the highest quantity of dioxin released in comparison to other parties having submitted their NIP to the Convention Secretariat.[133]

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[132]FECO / MEP / UNIDO / GEF (2010): "Mission Report on Non-incineration POPs Waste Disposal Program - Sub-project of Environmentally Sound Management and Disposal Project of Pesticides POPs Waste and Other POPs Waste in China"Foreign Economic Cooperation Office, Ministry of Environmental Protection/United Nations Industrial Development Organization/ Global Environment Facility: 9.

[133]UNIDO (2008): "Independent evaluation China - Building the capacity of the People's Republic of China to implement the Stockholm Convention on POPs and develop a national implementation plan", Project Number: GF/CPR/04/002: 45.

BAT / BET guidelines require dioxin concentrations below 0.1 ng I-TEQ/Nm³ which is the most widely adopted emission control limit in Europe, while the Chinese national standard is only 0.5 ng I-TEQ/Nm³.

In China, PCB wastes are primarily PCB contaminated soils. The national threshold is 50 ppm as a maximum level for soil, above which cleanup is necessary. The Stockholm Convention distinguishes three levels of concentration at which PCBs are a concern, the first level up to 50 ppm, the second between 50 and 500 ppm and the third above 500 ppm (highly contaminated).[134]

The Chinese Standard on Pollution Control of PCB Wastes (GB13015-91) in line with the Basel Convention defines wastes, substances and articles containing PCBs at concentration level higher than 50 mg/kg as 'hazardous wastes'.[135] In China hazardous wastes have to be incinerated. However, contaminated soil is *not* covered by this definition and can therefore be potentially treated with alternative technologies, not involving incineration.[136] The "National standards for pollution control from hazardous waste incineration (GB18484)" provide technical guidelines for PCB incineration facilities.[137]

The commonly used treatments for hazardous wastes in China are cement kilns and high temperature incineration. However, China's size and the different stages of development within the country, allows the government to test various options. Therefore, at the renowned Tsinghua University, for instance, intense research on alternatives such as non-combustion technologies is done. Further, China is one of the countries participating in the UNIDO project "Global Program to demonstrate the viability and removal of barriers that impede adoption and successful implementation of available, non-combustion technologies for destroying persistent organic pollutants".[138] Public acceptance of incineration plants in China is rather low, as the

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[134]World Bank (2005): „Project Document on a proposed grant from the global environmental facility trust fund in the amout of USD 18.34 to the People's Republic of China for a PCB management and disposal demonstration project", http://www.gefonline.org/ProjectDocs/POPs/FULL%20PROJECTS%20Folder%20-%20POPs/China%20-%20PCB%20Management/CN-PCB%20Management&Disposal%20GEF%20ProjectDocument4-25-05.pdf Accessed: 20 April 2012): 39.

[135]Office of National Coordination Group for Stockholm Convention Implementation (2008): **"**POPs Action in China", No.17 Sep. – Oct. 2008, http://en.mepfeco.org.cn/Resources/Periodicals/PAIC/201009/P020100908564778437595.pdf, (Accessed: 10 May 2012).

[136]Interview, Dr. Zheng Peng, FECO, 7 February 2012, Beijing.

[137]Office of National Coordination Group for Stockholm Convention Implementation 2008.

[138]Interview, Dr. Yang Yang, Tsinghua University, 20 February 2012, Beijing.

example of Chongqing hazardous waste incinerator shows, where in 2009 angry villagers stopped its operation.[139]

According to the "National Plan on Hazardous Waste and Medical Waste Management" issued in December 2003 by the State Council, POPs wastes may be sent only to two possible hazardous waste disposal centers, to either Shenyang or Hangzhou (Zhejiang), with the Shenyang Center covering the north, and the Hangzhou Center the southern provinces. Hangzhou does not have the capacity to finally dispose of POPs, and can only handle PCB wastes from identification over recovery and packaging to shipment for final disposal.[140]

In 2005 the World Bank has started a project, which is still on-going, to demonstrate environmentally sound and cost-effective procedures for the safe disposal of PCB-wastes in China, with the PCB management in Zheyang province as one major part.

Estimations of PCB wastes in the Zhejiang province tried to cover all PCB capacitors and transformers buried in provisional PCB storage sites. Another project had identified 43 confirmed PCB contaminated sites, with another 18 suspected. The overall estimated number of sites in Zhejiang amounts to 61 sites.

The total estimated sum of 20,000 tons of less contaminated wastes (mostly soil), 2,000 tons of highly contaminated wastes, 22,500 PCBs capacitors and about 78 of older in-use large PCB transformers are probably underestimates of actual quantities. This estimates do neither comprise transformers installed after 1980 and still in usage that may be contaminated with PCBs, nor out of service PCB transformers, stockpiled in the depositories of their owners.[141]

Since China's "National Program for Construction of Hazardous and Medical Waste Disposal Facilities" issued by the State Council in 2003 clearly planned and began the construction of hazardous waste disposal facilities in Shenyang for domestic hazardous waste and PCBs, it would not have been economical to build a new facility for the World Bank's project.

Due to these facilities having the potential to dispose of PCBs in an environmentally sound manner, exporting the PCB wastes to developed countries would have been

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[139]Qian, Wang (2009): "Villagers halt waste incinerator", China Daily, 31.12.2009, http://www.chinadaily.com.cn/cndy/2009-12/31/content_9249341.htm (Accessed: 10 March 2012).
[140]World Bank 2005: 41.
[141]World Bank 2005: 39.

hard to justify under the Basel regime, since transporting considerable amounts of PCB wastes also involves unacceptable risks. Additionally, the export option would have been comparatively expensive, i.e. US $1,000 to US $ 1,500 per ton for incineration plus at least US $ 2,000 for transportation. Another reason for choosing the option to incinerate the wastes within China instead of exporting them was the consideration for China to gain important knowledge and experience in the environmentally sound management and disposal of PCBs, which may be transferred also to other hazardous wastes and POPs.[142]

It was planned to store highly contaminated PCB wastes with PCB concentration levels of over 500 ppm temporarily in Zhejiang before transporting them to the Shenyang incinerator for final destruction. Contaminated soils and other PCB wastes at levels between 50 ppm and 500ppm were supposed to be treated by a thermal desorption unit in Zhejiang.

The Shenyang Hazardous Waste Disposal Technical Center has a new state of the art rotary kiln incinerator with a capacity of 15 tons per day for the disposal of highly contaminated PCB wastes (>500 ppm). According to the BAT / BEP guideline of the Stockholm Convention rotary kiln incineration is considered as one of the best available technologies.

The plant near Shenyang has been designed to fulfill all applicable Chinese regulations and standards. However, the Stockholm Convention requires features not included in the plant's original design, specifically with regard to keeping emissions of dioxins and furans at a minimum. These features involve either a pre-treatment system for PCBs wastes or alternatively a flue gas cleaning system in order to meet the PCDD/PCDF standard values for BAT, which are below 0.1ng I-TEQ/Nm^3.

Finally, it was decided to add a pretreatment unit for the incinerator in order to be able to isolate the high concentration PCB stream (essentially PCB oil) from the low concentration PCB stream (mainly shredded material contaminated by PCB).

Moreover, four additional key technical units, which had been identified as crucial for compliance with BAT / BEP, were installed: a central control unit, an online monitoring unit, a dioxin emission monitoring unit, and a waste pretreatment and crusher unit.

While PCB contaminated oils were supposed to be recovered and regenerated, PCB-

[142]World Bank 2005: 26.

contaminated transformers were to be decontaminated through a rented small-scale mobile dehalogenation plant (non-combustion technology). It was planned to ship the recovered PCB contaminated oil first to the PCB storage plant in Zhejiang and later to the incineration facility in Shenyang.[143]

A restructuring paper dating from December 2011 reveals that this project has suffered substantial implementation delays, amongst other things due to the poor performance results of the Thermal Desorption Unit treating low level PCB soil and also, due to delays in the upgrading, test-burn and licensing of Shenyang's national incinerator facility.

Nevertheless, according to the World Bank's restructuring paper, preliminary results of the Shenyang incinerator for the disposal of the first load of highly contaminated PCB wastes (about 100 tons) demonstrated full compliance with the environmental performance standards agreed on beforehand. This means that the incinerator attained a DE and DRE of 99.9999% and dioxin concentrations in the exhaust gas were below 0.1 I-TEQ ng/Nm^3.[144] This has also been confirmed by a representative of the Chinese Foreign Economic Cooperation Office (FECO).[145]

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[143] World Bank 2005: 41.

[144] World Bank (2011): "Restructuring Paper on a proposed project restructuring of PCB Management and disposal Demonstration GEF Project to the People's Republic of China" (Grant TF056008)(Board Date: December 15, 2005), http://www-wds.worldbank.org/external/default/WDSContentServer/WDSP/IB/2012/01/01/000356161_20120101223355/Rendered/INDEX/661910PJPR0v100turingPaperDec132011.txt (Accessed: 12 May 2012).

[145] Interview, Dr. Zheng Peng, FECO, 7 February 2012, Beijing.

3.3 Export to developed countries for incineration

If combustion facilities either do not exist or, if they exist, but do not meet the required BAT / BEP standards, it is usually not an option for a developing country to consider building its own high temperature incinerator as a fixed plant. The investment cost for this is exorbitant (as shown in the previous section). Moreover, one would have to assure that a certain amount of municipal wastes and POPs wastes are produced (or are available) in a country to make the plant viable and sustainable. Under certain circumstances a mobile incineration unit might be worth being considered, but is not the ideal solution due to lower environmental performance.[146]

Unless the developing country has high amounts of POPs wastes to dispose of, shows high interest in alternative sustainable solutions and is willing and capable to co-finance innovative technologies, such as non-combustion technologies, the best solution is to pack and ship them overseas for high temperature incineration in developed country facilities**.** This is currently the most widely used approach for disposing of stockpiles of obsolete POPs in developing countries and most of the projects concerning POPs management in developing countries, funded by the financial mechanism of the Stockholm convention GEF, choose this option.[147]

Recalling the first part of this thesis dealing with the chemical Conventions' provisions on export (B.3.), **t**he Stockholm Convention allows for the export of POPs for environmentally sound disposal.[148] The Basel Convention allows for the transboundary movements of POPs wastes only, if the exporting country does not have the necessary facilities to dispose of the wastes in question or if existing disposal sites cannot dispose of the waste in an environmentally sound manner. Moreover, export should only be an option if the transport and the ultimate disposal in the importing

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[146]UNEP (2002): "Destruction and Decontamination Technologies for PCBs and Other POPs Wastes - A Training Manual for Hazardous Waste Project Managers – Volume A", Secretariat of the Basel Convention, United Nations Environment Programme, http://archive.basel.int/meetings/sbc/workdoc/TM-A.pdf (Accessed: 9 April 2012): 29.

[147]UNIDO (2011): "Draft - Independent Terminal Evaluation of the UNIDO Project: Global programme to demonstrate the viability and removal of barriers that impede the adoption and successful implementation of available Non-Combustion Technologies for destroying persistent organic pollutants (POPs)", Project Number: GF/PHI/07/001, Internal Working Document.

[148]Stockholm Convention, Article 3.2.

country are environmentally sound and if it is conducted under conditions that do not endanger human health and the environment.[149]

Performance: Waste incinerators in developed countries usually achieve satisfying results for the disposal of POPs wastes, as they are usually well-operated and monitored. Since BAT / BEP is applied, these facilities achieve highest possible DE and DRE, monitor and clean emissions sufficiently and are capable to deal with and dispose of residues (see previous section on hazardous waste incineration).

Applicability: Wastes consisting of, containing or contaminated with any POP types can be exported for incineration to developed countries. Moreover, hazardous waste incinerators usually accept wastes in any concentration or any physical form (liquids, gases, solids, slurries and sludge).[150] However, soils contaminated with POPs cannot be easily transported given their bulk, posing a problem in developing countries.[151]
Export to an incinerator in a developed country is an acceptable option for all quantities from 1 ton to 10,000 tons and more.[152]

Operation: Exports of POPs permitted under the Basel regime are subject to the mechanism of prior notification and consent, which allows parties to export hazardous wastes to another party only, if the ‘competent authority’ in the importing state has been correctly informed and has consented to the trade. The Rotterdam Convention additionally requires consent of transit countries.
The Basel Convention requires that information concerning any proposed transboundary movement is provided using the accepted notification form and that the approved shipment is accompanied by a movement document from the starting point of packaging to the end point of disposal.
Furthermore, POPs wastes subject to transboundary movements should be packaged, labelled and transported in accordance with international rules and standards.
Wastes must be properly handled with the necessary level of technology and precautions and the whole system has to be well maintained and regularly audited. Furthermore, if the waste material is well labeled with easily translatable descriptions,

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[149]Basel Convention, Article 4.2.
[150] UNEP 2011: 41.
[151]UNEP 2004b: 8-9.
[152]UNEP 2002: 51.

the importing state is fully informed about the waste constituents.

Companies transporting wastes within their own countries should be certified as carriers of hazardous materials and wastes, and their staffs should be qualified and also certified.[153]

Besides the Basel permits, also local transit permits have to be requested prior to transportation, which means lots of paper work for the owners of POP stockpiles.

If the waste is transported under controlled, technically sound conditions a safe movement can be assured for short as well as for long distances. However, certain risks such as accidents can never be excluded.[154]

Cost: Incineration is the preferred technology at this time, as it offers a safe, well-proven and practical solution for the disposal of POP wastes.[155]

The treatment costs are also comparatively competitive and therefore inexpensive, since there is significant overcapacity of well-equipped, modern incinerators in Western Europe.

It is not possible to solely consider the cost of the incineration process in isolation, when comparing with other technologies, as the costs of packaging, containerization and shipping of the waste must also be taken into account. The cost of the incineration, ranging between US $ 200 – US $ 5000 per ton, is often the lower component of the costs compared to recovery, stabilization, packaging, separation and transport inclusive insurance of the waste. Generally as rule of thumb it can be said, that for the on shore activity and the transportation of the waste, this cost will be up to five times the cost of incineration.[156]

The destruction cost (excluding transportation, packing and any other costs) obtained from a hazardous waste destruction facility situated in South Africa and operated according to international standards for destruction of POP wastes ranges between US $ 1.26 / kg and US $ 2.13 / kg.[157] Overall prices between US $ 3 - 6 / kg have been reported, including everything from packing over transportation and insurance to

[153]Basel Convention, Article 4.
[154]Interview Dr. Robert ChoongKwetYive, UNEP Chemicals, 7 May 2012, Vienna (Skype).
[155]UNEP 2002: 29.
[156]UNEP 2002: 51.
[157]UNIDO 2011:16 f.

incineration, which is very roughly in line with the previously mentioned rule of thumb.[158]

However, the ratio between transport costs and costs for incineration in a developed country strongly depends upon where the wastes are located and where they should be delivered. For China, for instance, in 2005 the costs of export for incineration to European / North American countries ranged from US $ 1,000 to US $ 1,500 per ton for incineration, plus at least US $ 2,000 for transportation, meaning that the cost for actual transport was only about the double.[159]

Prices depend for instance on, whether land transport or shipping is more practicable, as the latter might involve elevated insurance fees. Also the number of reloading activities will influence the price. In case the site is close to the coast it depends again whether there is a rather small harbor or a big international harbor nearby with many shipping companies resulting in competitive prices.[160]

Important stakeholders: However, there are some issues to be mentioned that might affect the sustainability of the export option. In developed countries new policies and laws are being introduced to forbid the importation of POP waste for incineration.

A recently introduced EU law bans the destruction of non-European contaminated soils in the EU, which has as a consequence that developing countries have to take on-site or in-country measures in order to deal with contaminated sites.

Furthermore, public acceptance of incineration is low in Europe. Despite the safety standards, there is increasing public pressure on environmental and health grounds about air emissions containing dioxins and furans from incineration. All these factors contribute to the increasing interest in building capacity to dispose of POPs safely within the developing countries, in order to decrease their dependence on developed countries. Therefore it is essential to look not only at the current waste situation but also to consider the near future. While export and incineration may be a good solution in the short term, the sustainability of this option is uncertain in the longer-term.[161]

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[158]Interview Dr. Robert ChoongKwetYive, UNEP Chemicals, 7 May 2012, Vienna (Skype).
[159]World Bank 2005: 26.
[160]Interview, Dr. Heinz Leuenberger, UNIDO Vienna, 11 May 2012, Vienna.
[161]UNEP 2004b: 8 f.

Advantages	Disadvantages
• Applicable to any POP type, in any physical form or concentration • Long history of experience with management of incinerators in developed countries • BAT applied and proper waste disposal • Suitable also for very small amounts of wastes • Overcapacities in incinerators in developed countries • Energy recovery • Volume reduction and concentration of pollutants	• Costs vary according to transport route (land or sea, distance) • Risks related to transport and shipping • Potential public resistance in developed countries • Policies and laws on import might change in developed countries • Dependence of developing countries => No capacity building in developing countries • Comparatively low DE (Depending on management) • Additional measures required to treat liquid and solid residues • Not suitable for very bulky wastes due to transportation difficulties • Consent of importing and transition countries needed under Rotterdam and Basel regime • Basel Convention allows for export only conditionally • Incinerators identified by the Stockholm Convention as a source category for dioxin and furan emissions

3.3.1 Case Study: PCB exports from the Philippines

The Philippines, like many other countries, has been importing various industrial chemicals for its use and production. Most of its hazardous wastes generated are exported for disposal or treatment whereas others are either treated or temporarily stored on site. Aside from other less significant amounts of POPs wastes, the most important group is by far PCB waste.

The Philippines is Party to the Basel Convention and signed the Rotterdam Convention. Moreover, it belongs to the early signatories to the Stockholm Convention. Already in 1990, the Philippines enacted the Republic Act 6969 ("Toxic Substances and Hazardous and Nuclear Wastes Control Act"), which regulates, restricts or prohibits the importation, manufacture, processing, sale, distribution, use, and disposal of chemical compounds that present potential risks to human health and the environment, showing the government's commitment to control toxic chemicals and hazardous wastes.

Under the Chemical Control Order, issued in 2004 in compliance with the Stockholm Convention, guidelines and liabilities for the improper management of PCB wastes have been established. It also specifies requirements for PCB owners regarding annual reporting, labeling, safe handle and safeguard, inventory, phase-out, storage, treatment, and disposal within 10 years after the effective date of the Order.

The Chemical Control Order includes closed applications such as transformers, capacitors, voltage regulators and other electrical equipment, partially enclosed applications, open-ended applications, PCB wastes such as contaminated solvents, waste oil, sludge and slurries and PCB packaging or containers in storage.[162]

A result of this Chemical Control Order is that PCB owners have to do their own inventory and self-report to the Environmental Management Bureau. The PCB inventory for Philippines' National Implementation Plan of the Stockholm

[162] DENR 2006: ES 5.

Convention, submitted in 2006, was almost entirely founded on these self-reporting inventory results.[163]

An important influence on the decision on potential disposal options has also the Republic Act 8749 ("Clean Air Act") issued in 1999, which bans the use of incinerators in order to avoid emissions form the burning of domestic, hospital, and hazardous wastes.[164]

The Philippines never produced PCBs. The main source of entry of PCBs into the country represents importation as part of electrical transformers. However, there is very little information on the exact amount of PCB transformers imported and on PCBs in use other than transformers and capacitors due to the absence of proper records. Founded on the initial inventory of PCBs, there are wastes and equipment containing PCBs in the electric utility sector, in hospitals, the manufacturing sector, in military camps and bases, old commercial buildings, and in transformer servicing facilities.

The most significant part of the inventoried material are transformer being 97.16 %, whereas only 2.57 % capacitors. The remaining part is oil circuit breakers.

As transformer equipment in the Philippines is still frequently repaired and retrofilled by equipment servicing facilities, these facilities were identified by the initial inventory actions as a major stockpile of PCB contaminated equipment. Due to the retrofilling activities of small-scale facilities, it is very likely that the mineral oil currently used in retrofilled transformers has been contaminated with PCBs.[165]

Initial inventory shows that the Philippines has a total amount of 6,879 tons of PCB-containing equipment and wastes including approximately 2,400 tons of PCBs oil, which require environmentally-sound management and disposal.[166]

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[163]UNIDO 2011: 29.

[164]DENR 2006: 2-16.

[165]DENR 2006: ES 6.

[166]UNIDO (2007): "Project for the Republic of the Philippines - Project Document", Global Programme to demonstrate the viability and removal of barriers that impede adoption and successful implementation of available, non-combustion technologies for destroying persistent organic pollutants (POPs), Project number: GF/PHI/07/XXX:21.

Industry category	PCB oil (kg)	Equipment Dry weight (kg)	Total Weight (kg)
Electrical utilities and cooperatives	1,620,310	2,788,040	4,408,350
Commercial buildings	34,723	83,454	118,177
Industrial establishments and manufacturing plants	525,399	1,098,726	1,624,125
Military camps and bases	3,516	8,204	11,720
Servicing facilities	191,397	445,121	636,518
Hospitals	25,215	55,191	80,406
TOTAL	**2,400,560**	**4,478,736**	**6,879,296**

Table 1: Summary of PCBs inventory in the Philippines[167]

Currently, co-processing of hazardous wastes in cement kilns as a disposal option is gaining recognition in the Philippines and studies have been conducted in order to investigate on their compliance to dioxin and furan emissions when injecting pesticide wastes. However, it is most likely that BAT / BEP standards as required under the Stockholm Convention can not be reached for PCB treatment

Given this present situation, the Philippines does not have the necessary technical infrastructure and sufficient technological capacity for the destruction of POPs stockpiles. Therefore, under the Basel regime the export of wastes to developed countries for incineration can be fully justified.[168]

Exporting PCB wastes for incineration is quite expensive on the Philippine market, costing about US $ 5 to US $ 10 per kg, in average US $ 7.5 per kg. This means that in fact only big companies can afford proper identification, collection and export of PCB wastes.[169] The destruction cost *without* considering costs for transportation, packaging and any other costs, gained from a hazardous waste incinerator in South Africa, which

[167]Ibid.
[168]DENR 2006: 2-45.
[169]UNIDO 2007:11.

runs a rotary kiln according to international standards for destruction of PCB and other hazardous wastes, depend on the PCB concentration in liquids and are as follows:

PCB contaminated oils:	
0 – 50ppm	US $ 1.26 / kg
50 – 500pm	US $ 1.33 / kg
500 – 10,000ppm	US $ 1.63 / kg
Above 10,000ppm	US $ 2.13 / kg
PCB contaminated materials:	US $1.87 / kg[170]

Big companies, e.g. a beer brewery and an electrical utility company, as obliged by national laws, disposed of their obsolete PCB stockpiles by exporting their wastes to Europe. However, the same electric utility company that exported some of its PCB contaminated equipment also buried and immobilized PCB contaminated soil on their site, which is now subject to monitoring by the Environmental Management Bureau in order to make sure that PCB will not leach into the environment. Due to the exorbitant cost of export, the majority of PCB contaminated equipment further remained in the electric companies' stockpiles.[171]

Meralco and NPC, two major electrical companies in the country, own substantial quantities of PCBs. In 2011 Meralco stated that the last time they exported PCBs was in 1999, a total amount of 88 tons at the rate of US $ 3 per kg. NPC exported significant amounts of PCBs for final disposal to France in 2004 / 2005 paying US $ 6 per kg.

Because of the relatively high prices for export both companies agreed to have their PCBs treated by a new non-combustion facility, a demonstration project funded by GEF (see chapter 4), under the condition that prices are competitive.

They pointed out that the possibility of local destruction would significantly facilitate their task for the sound disposal of their PCB stockpiles. In that case they do not need to go through lengthy and time-consuming procedures anymore, when exporting their

[170]UNIDO 2011: 16 f.
[171]DENR 2006: 2-45.

PCBs to foreign countries, especially for obtaining Basel permits for the trans-boundary movement of PCB wastes.[172]

3.4 Non-combustion technologies – A selective overview

Burning of hazardous waste has the potential for relatively high unintentional formation and release of persistent organic pollutants to the environment. Waste incinerators appear therefore as Part II source categories in Annex C of the Stockholm Convention. According to the Stockholm Convention, efforts should be made to identify available alternative processes, techniques or practices that have similar usefulness but which avoid the formation and release of chemicals listed in Annex C, such as dioxins.[173]

Over the last 15 years, several various non-combustion technologies have been developed and demonstrated to successfully treat POP wastes in developed countries.[174] In the following chapter some selected non - combustion technologies representing alternative to the incineration of POPs wastes will be described in detail. The definition of 'non - combustion technologies' is quite broad and includes all technologies based on so-called reductive processes. These are typically low temperature processes involving the reduction of organochlorine compounds with hydrogen, hydrogen transfer agents, or other reductants. However, since these technologies are highly different amongst each other, the technologies will be presented separately one by one. Sodium reduction (Alkali reduction) and Gas-phase chemical reduction (GPCR) will be described as representatives of the already commercialized mature technologies with operating plants, which are licensed to destroy high strength POPs stockpiles.

These include:

- Gas Phase Chemical Reduction (GPCR)
- Base Catalyzed Decomposition (BCD)

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[172]UNIDO 2011:18.

[173]Stockholm Convention, Annex C, Part V, B. (b)).

[174]ICS – UNIDO (2007): "Non-Combustion Technologies for POPs Destruction – Review and Evaluation", *International Centre for Science and High Technology - United Nations Industrial Development Organization*, Trieste, Italy. Available on request under www.ics.trieste.it:16.

- Sodium Reduction (Alkali reduction)
- Super-Critical Water Oxidation (SCWO)
- Plasma Arc (PLASCON)
- Pyrolysis / gasifiers

Ball Milling has not been commercialized yet and therefore is not yet operated on a large scale. However, along with the GeoMeltTM Process, with Mediated Electrochemical Oxidation (CerOx), the Mediated Electrochemical Oxidation (AEA Silver II Process) and the Catalytic Hydrogenation, Ball Milling is considered "promising, emerging and innovative" by the "Review of emerging, innovative technologies for the destruction and decontamination of POPs and the identification of promising technologies for use in developing countries", a study that reviewed in total 50 technologies.[175]

An important point to be raised is that most of the information available on technology performance come from the vendors themselves and have in many cases not been verified by independent institutions, which is especially true for less mature technologies.[176]

When it comes to dealing with POPs wastes and stockpiles in developing countries and economies in transition it is important to look at some issues in a more differentiated way. First of all, there is the stockpile or the contaminated equipment itself, and on the other hand, there is the contaminated soil, polluted either because of the stockpile or because of some other POPs source. It is commonly accepted that non-combustion technology for stockpile destruction might not necessarily be the same as the one required for soil decontamination.

Furthermore, there is the question of whether the stockpile shall be treated 'in situ' at each site, involving mobile destruction units, or whether the stockpile should be isolated, packed and transported to a central plant ('ex situ' destruction), meaning a fixed non-combustion technology unit. If the option ex situ treatment is selected, it has to be assured that removal, packaging, shipping and finally destruction are organized

[175] UNEP 2004a: 65.
[176] UNEP 2004b: 13.

and properly managed. However, risks to the environment and human health at each of these stages may not be underestimated.

Looking at past literature and reports on technology for POPs destruction there has been a clear preference for technologies being simple enough to be transported to all sites in developing countries and to treat each stockpile at the site. However, this approach may not be appropriate, given the complexity of the waste at the sites and the resulting technical and logistical challenges in combination with social and political circumstances. However, nowadays most of the existing non-combustion technologies are available as stationary as well as mobile units.[177]

3.4.1 Gas-phase chemical reduction (GPCR)

Process: The GPCR process involves the thermochemical reduction of organic compounds by hydrogen and some steam, which acts on the one hand as a heat transfer agent and on the other hand as another source of hydrogen. This reduction, occurring at minimum temperatures of 850°Cand at low pressures, yields primarily methane and hydrogen chloride.

The GPCR technology can be divided into three elementary operations units: the front-end waste feed system, where contaminants are prepared via vaporization for destruction in the reactor, the reactor, where the contaminants, now in gas phase, are reduced by hydrogen and steam, and the gas scrubbing and compression system, where the output is recovered (Figure 3). The front-end units, which can be seen as integrated pre-treatment of wastes, strongly depend on the waste types and are used to volatilize wastes, since they must be in a gaseous form in order to be reduced in the GPCR reactor.

While liquid wastes such as high-strength oily wastes as well as watery wastes can be preheated and injected directly into the reactor, contaminants on solids must first be vaporized from the solid.

Bulk solids such as drummed chemicals and electrical capacitors, for instance, are loaded into a Thermal Reduction Batch Processor (TRBP), which is then heated to about 650°C in a hydrogen-rich (oxygen deficient) atmosphere. The chemicals from the solid material are desorbed (leaving a hazard-free solid), and are then passed

[177] UNEP 2004a: 54.

directly to the GPCR reactor for destruction.

For soil and sediment treatment, contaminants are first desorbed from the solids with the help of a thermal desorption unit. The gas with the contaminants is then condensed, the water removed, and the remaining liquid full of concentrated contaminants fed to the preheater and GPCR reactor.

Commercial-scale GPCR plants have been operated in Canada and Australia (for more than 5 years), in the USA and in Japan.[178]

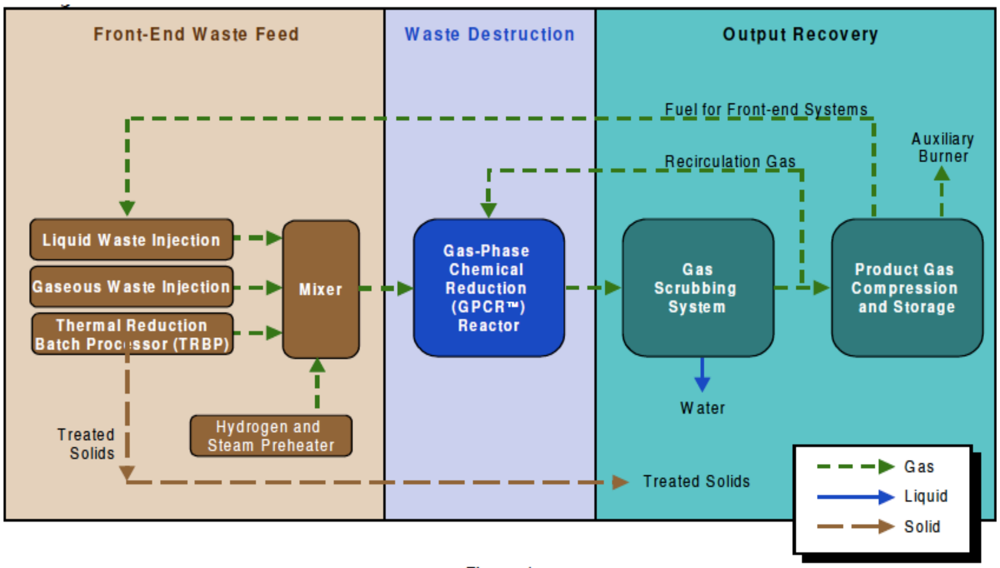

Figure 3: Process Diagram Block Flow Schematic[179]

Applicability: All POPs, including PCB transformers, capacitors, oils and high strength POPs wastes, can be treated. The GPCR technology has treated HCBs, PCBs and DDT, other chlorinated pesticides and POPs related wastes such as dioxins and furans. However, it may not be economic for low level wastes. For solids thermal desorption separation prior to treatment is required.

Performance: Destruction efficiencies (DE) of 99.9999 per cent have been reported for DDT, HCB, PCBs, PCDDs and PCDFs. Similar values are reported for Destruction and Removal Efficiencies (DRE). Contaminants are completely destroyed in the

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[178]Vijgen, John and McDowall, Dr.Ir. Ron (2009)a: "Gas-Phase Chemical Reduction (GPCR)", POPs Technology Specification and Data Sheet, International HCH & Pesticides Association (IHPA), http://www.ihpa.info/docs/library/reports/Pops/June2009/SBC_LogoGCPRDEF_190109_.pdf (Accessed: 6 May 2012).

[179]Vijgen, John and McDowall, Dr.Ir. Ron 2009a.

process.

Moreover, there have been no uncontrolled releases during operation of the technology due to process control systems in place that provide thorough monitoring of all stages of the system. Hence, all process and waste residuals are contained and can be tested and reprocessed as necessary.

Residues from the GPCR process are treated solids, water and product gas, all of which are clean, reusable or disposal products, since the process features a high degree of internal waste recycle and has no waste generating side streams.

As the GPCR process occurs in a reducing atmosphere, the potential formation of PCDD and PCDF formation is considered limited.

Gases leaving the reactor are scrubbed to remove water, heat, acid and carbon dioxide. Scrubber residue and particulate have to be disposed of off-site.[180]

Operation & Safety: GPCR is available in different scale fixed and transportable configurations. The process is rather complex and labor intensive, highly qualified and trained personnel is necessary.

Since the Thermal Reduction Batch Processor requires minimal handling, worker exposure to the contaminants is very small. Material does not have to be removed from drums and does not require sorting or segregation by waste types.

It has been reported that electricity requirements range from 96 kWh per ton of soil treated to around 900 kWh per ton of pure organic contaminants treated.

Methane produced during the process can provide much of the fuel needs and is also used to form enough hydrogen to run the process thereafter, as there is a need for hydrogen supplies, at least during start-up. Other material requirements involve caustic for the acid scrubber.

The use of hydrogen gas under pressure requires appropriate controls and safeguards to ensure that explosive air-hydrogen mixtures are not formed. However, past experience has proven that the GPCR process can be operated safely.[181]

The peak power demand is at1000 kW. 2.5 MWh are required per ton of waste input to plant. Natural gas volumes per ton of waste input to plant amount to 600 Nm^3. Water

[180]UNEP 2006a: 35.

[181]Luscombe, D. (2001): "Non-incineration PCB Destruction Technologies", Greenpeace International Service Unit, www.istas.net/portada/cops8.pdf (Accessed: 4 May 2012).

requirement for steam is 1500 kg and for cooling water 500 m³ per ton of waste input to plant.

Reagents volumes required per ton of waste input to plant amount to 75 Nm³ Nitrogen, 20 kg Carbon Dioxide, 1.4 t Caustic and 1,000 Nm³ Hydrogen.[182]

Cost: The technology is reported to be especially cost-effective for low concentrated waste or small-scale applications.[183]

In general, capital costs, including installation and commissioning and site preparation) for a Two-TRBP Plant (solid feed) are estimated to amount to US $10.8 million for a full-scale plant and to US $ 5 million for a semi-mobile unit. For a One-TRBP Plant (liquid and gaseous feed) the price is US $10.3 million for a full-scale plant and for a semi-mobile unit US $ 4.75 million.

Utility and labor costs for solid or liquid pesticide treatment are estimated at US $1,317 (utilities) and US $593 (labor) for semi-mobile unit (840 t /y) and for a full-scale plant (3360 t /y) US $1,317 (utilities) and US $ 222 (labor) per ton of waste feed. These costs are comparatively high.[184][185]

If the system was running without waste input, then the main cost would be that of natural gas and staff for monitoring the system, since hydrogen and caustic would not be needed

Monitoring, reporting and compliance costs depend on the amount of monitoring, reporting and compliance testing required by the national regulations of a country. Landfill costs and transport costs of residues depend on the local situation, too. Decommissioning costs are estimated to be about US $ 750,000.[186]

Based on operating cost, prices range from US $ 0.4 to 2.0/ kg for waste treatment.[187]

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[182]Vijgen, John and McDowall, Dr.Ir. Ron 2009a.
[183]ICS – UNIDO 2007:45.
[184]Estimates based on 2004 US utility prices.
[185]Vijgen, John and McDowall, Dr.Ir. Ron 2009a.
[186]Vijgen, John and McDowall, Dr.Ir. Ron 2009a.
[187]UNEP 2011: 37.

Advantages	Disadvantages
• High destruction efficiencies and low environmental impact • Long history of commercial operation • Comparatively low amounts of solid residuals produced • Product gases can be recycled • All types of wastes can be handled • Different scale fixed and mobile units are available • Reductive environment prevents dioxin and furan formation	• Safety issue due to hydrogen use (transportation and handling) • Treatment and disposal of liquor from caustic scrubber necessary • Highly energy consuming as the waste needs to be evaporated at high temperatures • Complex and labor-intensive process, highly qualified and trained stuff needed. • Not cost-effective for low concentrated waste or small scale applications[188] • Require secure infrastructure, trained technical staff, laboratory support, utilities and re-agent supply.[189]

[188] ICS - UNIDO 2007: 45.
[189] UNEP 2011: 37.

3.4.2 Sodium Reduction (Alkali reduction)

The application of Sodium Reduction (SR) or alkali reduction technologies for PCB treatment started almost 20 years ago and has now a well-founded experience of PCB treatment worldwide. SR technology includes a number of different options for the treatment of POPs in many countries, namely France, Germany, South Africa, Australia, USA, Saudi Arabia, Japan, New Zealand, etc. All these technologies employ the same principle of reduction with sodium metal in the liquid phase, have similar technology design and therefore show similar performance.[190]

Process: Alkali metal reduction involves the treatment of wastes with dispersed alkali metal. Alkali metals react with chlorine in halogenated POP wastes to yield salts and non-halogenated waste. There are several variants of this process.[191]

In most SR processes, organic liquids (ideally with low vapor pressure), containing the contaminant is mixed with a fine sodium dispersion in hydrocarbon oil (use of potassium and sodium-potassium alloys are also known but less common).

The technology runs at atmospheric pressure and moderate temperatures (normally between 80 and 180°C, depending also on the substance treated). Nitrogen blanketing may be utilized for safety. Other process streams, apart from the mentioned basic reaction products also comprise sodium hydroxide, water, as well as solidified polymers.

After the process is complete the oil fraction is removed from salts and polymerized product. Mostly the reaction operates in a standard batch stirred reaction vessel, unless in situ treatment (e.g. for PCB-contaminated transformers) is applied. SR processes can be mobile or can be easily made such. For the in-situ treatment the sodium dispersion is put directly in the transformer containing oil.[192]

[190] ICS - UNIDO 2007: 82.
[191] UNEP 2006a: 29.
[192] ICS - UNIDO 2007: 82.

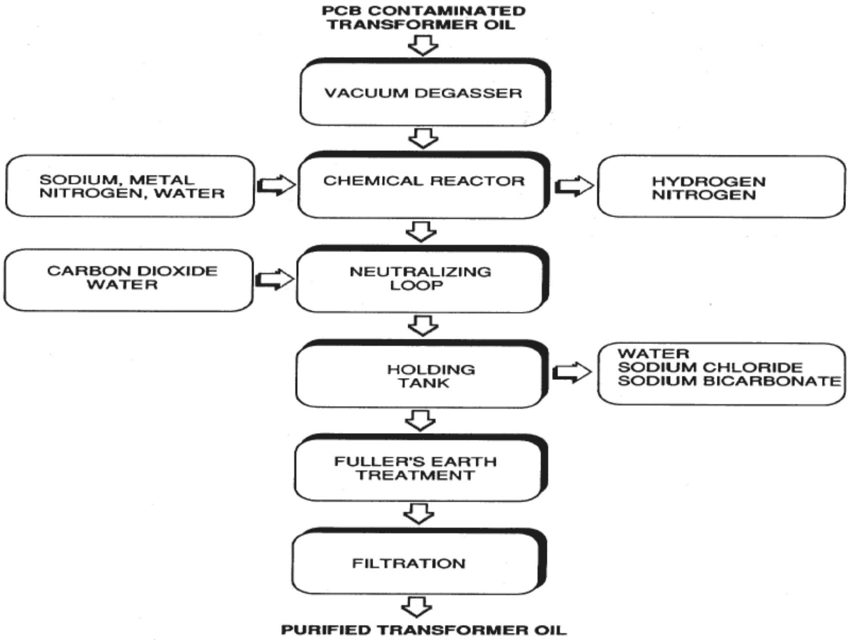

Figure 4: Process diagram: Process Flow Schedule in Canada (fixed plant)[193]

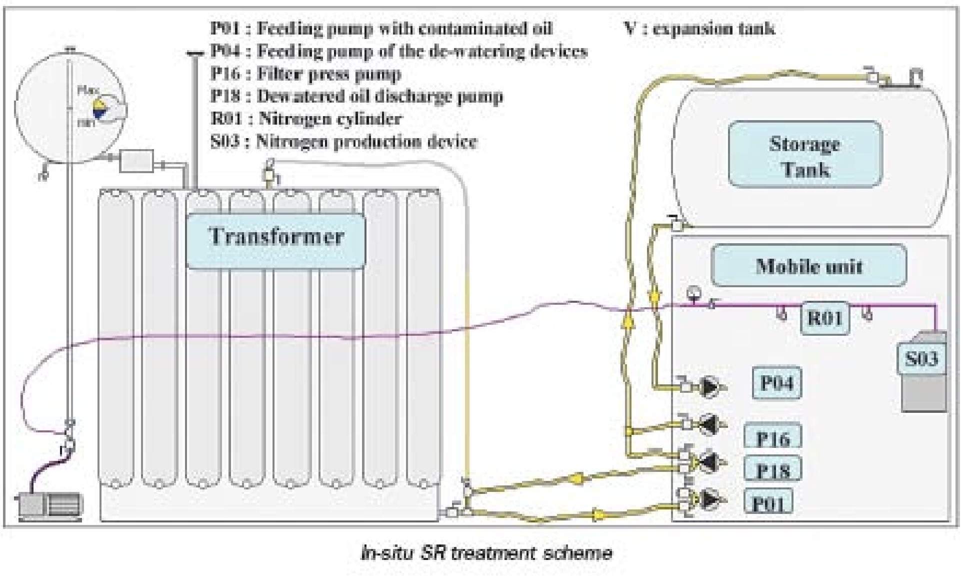

Figure 5: In-situ SR treatment scheme[194]

Applicability: Sodium reduction has been demonstrated with PCB-contaminated oils containing concentrations up to 10,000 ppm, transformers, for PCB contaminated

[193]Vijgen, John and McDowall, Dr.Ir. Ron (2009)b.
[194]ICS - UNIDO 2007: 83

soils, capacitors and ballasts. Only small quantities have been treated for contaminants other than PCBs, such as dioxins and furans, hexachlorobenzene, dieldrin.[195]

Prior to ex-situ treatment of PCBs solvent extraction of PCBs has to be carried out in order to extract contaminants from matrices and electrical equipment. Treatment of whole capacitors and transformers is possible after size reduction through shearing. Pre-treatment should also include dewatering in order to prevent explosive reactions with metallic sodium.

Performance: Destruction efficiency (DE) values of greater than 99.999 per cent and destruction removal efficiency (DRE) values of 99.9999 per cent have been testified for aldrin, chlordane and PCBs. The sodium reduction process has also proven to meet regulatory criteria in Australia, Canada, Japan, South Africa, the United States of America and the European Union for PCB transformer oil treatment, meaning that less than 2 ppm in solid and liquid residues were achieved.

However, it should be mentioned that SR technology employed for in-situ treatment of PCB-contaminated transformer oils might not destroy all the PCBs contained in the porous internals of the transformer. Therefore, re-treatment of transformers where leach back from internals occurs may be required.[196]

Air emissions include nitrogen and hydrogen gas, while emissions of organic compounds are expected to be rather small. It has been reported, however, that PCDDs and PCDFs can potentially be formed from chlorophenols under alkaline conditions at temperatures as low as 150°C. Residues produced during the operation comprise sodium chloride, sodium hydroxide, polyphenyls and water. In some process variants a solidified polymer is also formed.

After the process, the by-products can be removed from the oil through a combination of filtration and centrifugation. The decontaminated oil can be recycled, the sodium chloride can either be reused or disposed of in a landfill and the solidified polymer can also be disposed of in a landfill.

Operation & Safety: The SR process is available in fixed and mobile configurations.

While immediate energy requirements are estimated to be relatively low due to the low operating temperatures accompanying the sodium reduction process, significant

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[195] Vijgen, John and McDowall, Dr.Ir. Ron 2009b.

[196] UNEP 2006a: 29.

amounts of sodium are required to operate this process.
Dispersed metallic sodium can react heavily and explosively with water, exhibiting a major threat to workers. Metallic sodium can also react with a number of other compounds to produce hydrogen, an inflammable gas that is explosive in admixture with air. Therefore, great care must be taken in process design and operation in order to make sure that water as well as certain other substances, such as alcohols, are removed from the waste and does not get into contact with the sodium.[197]
Power requirements for mobile units are electrical (60 A at 575 V) and fuel oil for heating of the oil (about 750,000 BTU/ h depending on the unit). Units can also be entirely electrically powered. A fixed plant requires power of 100 A.
Electrical heating of the oil is favored in case oil heat will require fuel oil of about 750 000 BTU/h
Maximum reagent volumes carried with a unit are about 200 kg (for a 40% sodium dispersion in oil) or about 2000 L for K-Peg.[198]

Cost: In the case of the Philippines capital costs for the pilot plant (selection, purchase and installation) were about US $ 5.38 million in 2007. Costs for site preparation and environmental compliance amounted to US $ 4.8 million.[199] Monitoring, reporting and compliance costs depend strongly on the amount of monitoring, reporting and compliance testing required by the national regulations of a country. For the transport of residues, landfill costs and the costs for electricity, local prices have to be checked.
For transformer oils, disposal costs reflect the initial PCB concentration and other factors such as the economy of scale. For oil with low PCB concentration the costs typically amount to US $ 0.15/L, while US $ 0.70/kg is a price for oil with higher PCB concentrations or with more impurities. Hereby the costs of pre-treatment and disposal of the residuals are included. The processing cost for destruction of pure PCBs is in the order of US $ 4 to 5 per kg of waste.
Cost for waste oil treatment is more expensive due to impurities and amount to US $ 0.50/kg. Waste oil often contains solvents, water, solids, paint, etc. and thus requires extensive pre-treatment. And since the 2 ppm decontamination target often becomes impossible, in many cases the target for waste oil is only less than 50 ppm of PCB and

[197]UNEP 2006a: 25.
[198]Vijgen, John and McDowall, Dr. Ir. Ron 2009b.
[199]UNIDO 2007: 13.

the treated waste oil is subsequently used as a fuel supplement in an authorized cement kiln. Hereby the costs of pre-treatment and disposal of the residuals are not included.[200]

Further typical prices are:

PCB contaminated mineral oil:	US $ 0.2 /kg
PCB contaminated capacitors:	US $ 5.10 /kg
PCB contaminated fluorescent light ballast waste:	US $ 1.10 /kg
Soils	US $ 0.2 - 0.5/kg[201]

Advantages	**Disadvantages**
• Simple in operation and portable • No dioxin formation due to reductive environment and low temperature • Very low emissions • Relatively low cost • Treated PCBs can be recycled • Fully commercialized and well established, available in numerous configurations on the market, with multiple technology vendors and stable licensee arrangements capable of competitive tendering worldwide.	• Restricted to PCBs and liquid organic waste • Can treat efficiently only diluted POP solutions in order to reach high DE • Waste should be dewatered • Dispersed metallic sodium reacts violently with water and other substances to produce explosive hydrogen gas • Increased safety precautions required for sodium handling during storage, transportation, and process operation[202] • In-situ treatment of PCB-contaminated transformer oils might not destroy all the PCBs contained in the transformers' internals • Require secure infrastructure, trained

[200]Vijgen, John and McDowall, Dr.Ir. Ron 2009b.
[201]UNEP 2011: 36.
[202]ICS - UNIDO 2007: 64.

	technical staff, laboratory support, utilities and re-agent supply

3.4.3 Ball Milling

Unlike the two above-mentioned technologies, Ball Milling is not included in the current Basel Convention Technical Guidelines. However, in the literature it is widely considered as promising and may therefore be considered for future revisions of the Guidelines.[203]

This technology is represented by several similar processes, on the one hand the MCD process by Environmental Decontamination Ltd (EDL), New Zealand and on the other hand, the DMCR ('Dehalogenierung durch mechanochemische Reaktion') process by Tribochem, Germany. These two technologies have been developed independently from one another and have therefore different development statuses: MCD (Mechanochemical Dehalogenation) is a patented process, which is presently being shown on the full scale in a national remediation project in New Zealand. In Japan, the 'Radicalplanet technology' based on the mechano-chemical principle has been operated commercially since 2000 and received the official permission to be applied in 2004.[204] DMCR has been run on the pilot scale only, but despite its obviously advanced design for commercial operation, there has been no full-scale operation so far. The chemical processes and technical arrangements of these technologies are very similar.[205][206]

Process: The Ball Milling process is a mechano-chemical process, relying on the energy released at the point of collision between balls in a ball mill to activate a reduction reaction between the waste and a reagent.

First, the POPs wastes are placed in a ball mill (a closed vessel), together with the

[203]UNEP 2004a: 65.

[204]Vijgen, John and McDowall, Dr.Ir. Ron (2009)c: "Radicalplanet Technology (Mechanochemical principle) (Provisional Version) - POPs Technology Specification and Data Sheet", International HCH & Pesticides Association (IHPA), http://www.ihpa.info/docs/library/reports/Pops/June2009/DEFSBCFactSheetRadicalPlanet_070608_includedMTKJune2009.pdf (Accessed: 6 May 2012).

[205]ICS - UNIDO 2007: 22.

[206]The followingdataaremainlybased on theexperience in Japan.

rigid balls. Then, a hydrogen donor compound together with an alkali metal (CaO, Mg, sodium, or other metals or their oxides) is added.

The reaction between the solid reagent and the solid or liquid chlorinated substrate (PCBs, pesticides) occurs under mechanical agitation produced by rigorous shaking in the ballmill, breaking down the organochlorine compounds. Reductive dehalogenation occurs without heating the harmful compounds due to a mechano-chemical process yielding, in the case of PCBs reacting with magnesium, biphenyl and magnesium chloride. The bond of each molecule is broken by mechanical energy. The molecules are decomposed into the state of activation (radical state), so that chemical reaction is accelerated. Also, the grinding of solid reagents in the ball mill speeds up the reaction by increasing the contact surface between reagents. At the point of collision between two grinding balls, a highly localized triboplasma is formed releasing energy for chemical reactions.[207]

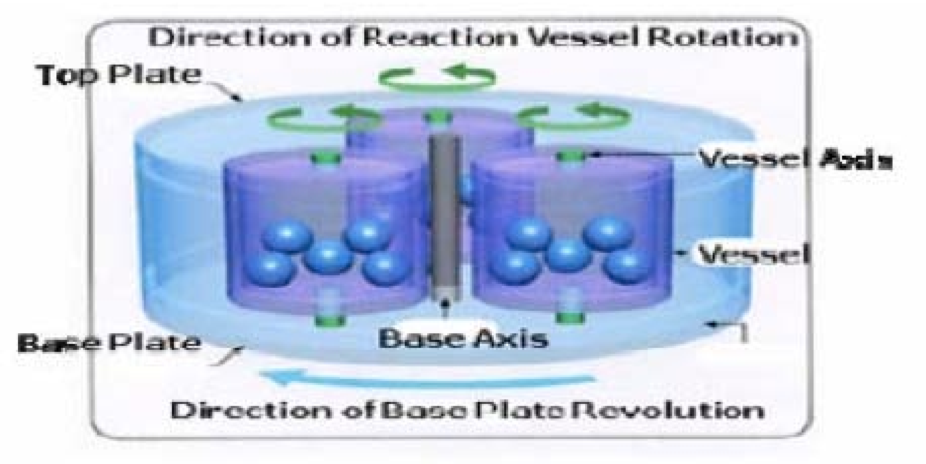
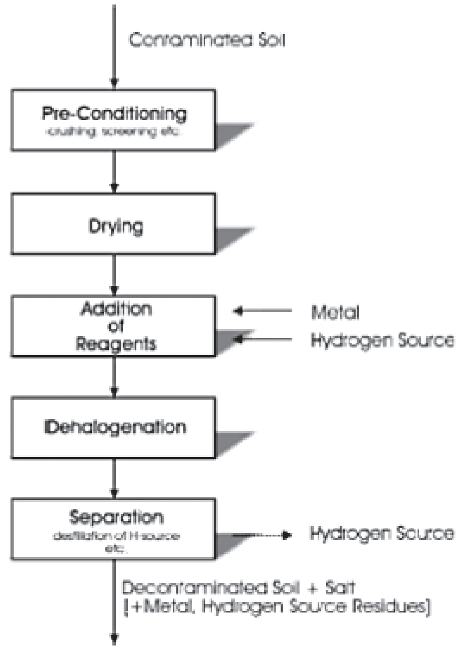


Figure 6: Schematic Profile of a Ball Mill[208]

[207]ICS - UNIDO 2007: 22.
[208]Vijgen, John and McDowall, Dr.Ir. Ron 2009c.



Flow diagram for treating contaminated soils by the DMCR process

Figure 7: Row diagram for treating contaminated soils by the DMCR process[209]

Applicability: The process has been successfully applied to PCBs, DDT, PCP, chlordane, benzene hexachloride (BHC), endrin, dioxins, to mixtures of pesticides and related POPs wastes, as well as to admixture (soil, stones, concrete,metal etc) polluted by PCB.[210]

Solid powdered contaminants or organic liquids can be treated without pretreatment. For moist waste dewatering is necessary. Solids, such as contaminated soils, sludge, rubble, etc. are usually dried and then treated directly. Shredding may be required for big pieces of solids.[211]

For contaminated electrical equipment there is the possibility to destroy the encapsulating container in the same process. Disperse wastes such as contaminated soil should be ideally concentrated by solvent extraction or a similar process prior to destruction in the ball mill.[212]

Performance: Destruction efficiency (DE) values between 99.99 and 99.999 % and destruction removal efficiency (DRE) values of 99.9999 % have been reported.[213]

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[209]ICS - UNIDO 2007: 24.
[210]Vijgen, John and McDowall, Dr.Ir. Ron 2009c.
[211]ICS - UNIDO 2007: 22.
[212] UNEP 2002: 74.
[213]UNEP 2011: 39.

There is no gas exhaust because the reaction occurs in a closed vessel by mechanical energy under non-heating conditions without producing combustion gas. The potential emissions from the pre-treating rotary drier are scrubbed prior to release into the atmosphere. Due to low temperatures and a reductive environment the risk of forming new POPs, such as dioxins, is low.[214]

There are no releases such as harmful organic compounds, due to good containment. The process can also easily be shutdown in a short period of time. As the process produces no water, there is no need for wastewater treatment. And since all material can be reused, no waste is deposited at landfills.

All POPs wastes and the reagent CaO are transformed into fine and activated powder, which is totally safe (< 1 pg-I-TEQ/g) The collected powder may be recycled and reused for new materials like high grade concrete. The organic chlorine compounds are decomposed and converted into non-chlorine organic compounds. The chlorine is changed into the inorganic components CaCl2 or Ca(ClOH)[215]

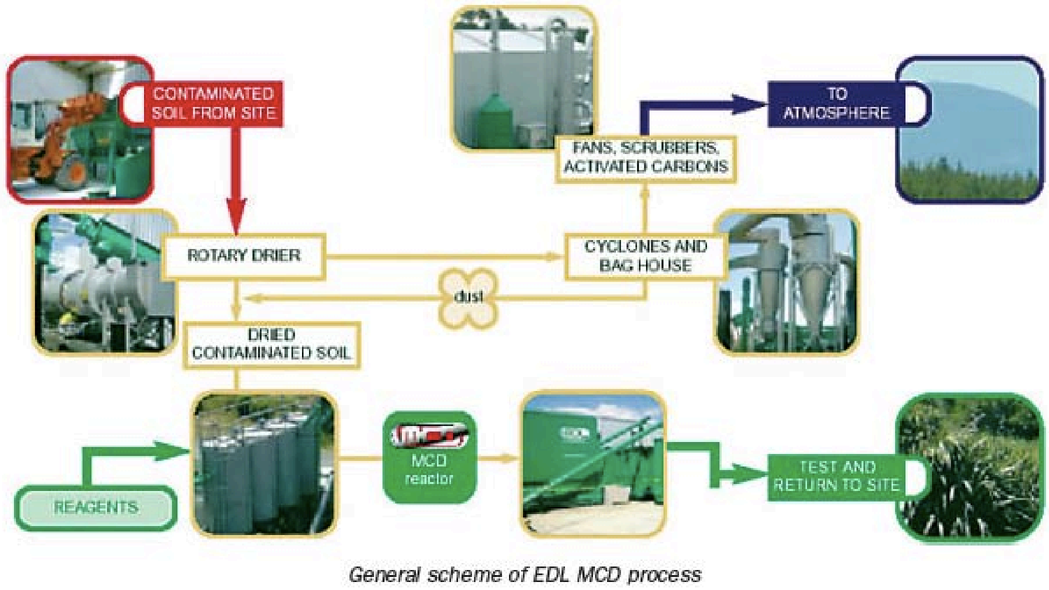

Figure 8: General scheme of EDL MCD process[216]

Operation & Safety: There is no danger of secondary pollution owing to transportation of the harmful compounds, because the Ball Milling system (available

[214]Vijgen, John and McDowall, Dr.Ir. Ron 2009c.
[215]Ibid.
[216]ICS - UNIDO 2007: 25.

in mobile and fixed units) can be moved easily and is able to treat the pollutant on site. The energy needed for the operation of the Ball Mill is due to its very nature comparatively high. (‘Radicalplanet technology’: Small version: 1,800 kwh/ton, big version: 3,600 kwh/ton.) If power sources are unavailable or power is unreliable in the concerned country, treatment plant can be operated by a diesel generator.

Concerning the reagents volumes required, the appropriate ratio of CaO per pesticides has to be selected for each case. The Radicalplanet Technology in Japan, for instance, needs more than 1,50 kg of CaO in order to treat 1 kg BHC waste for detoxification. CaO may be complemented with SiO_2 or Al_2O_3, depending on the desired end products.

The process is simple and relatively safe in operation. It is capable to treat wastes containing various different organic contaminants, or mixtures of organic contaminants in one step, which keeps waste handling minimal and reduces the associated risk. Electrical equipment, contaminated with PCB or damaged or corroded waste containers may be fed directly into the system for destruction

The waste and the reducing agent are simply loaded in the closed ball mill. Only two workers (one skilled and one unskilled) are necessary.

Very safe agents are applied in this technology, such as CaO, SiO_2 and Al_2O_3, which are popular materials in the soil or the earth. Increased safety is ensured due to ambient conditions and absence of vigorous reactions that can go out of control.[217]

Cost: Typically capital cost range between US $ 2 - 6 million, depending on the vendor [218] For the ‘Radicalplanet technology’ building / purchasing costs range between US $ 3.6 million (105 tons/y) and US $ 4.3 million (210 tons/y).

Pretreatment equipment is about US $ 330,000 and the post treatment equipment: about US $ 390,000. Site preparation costs are estimated around 15% of the building costs. The maintenance of main equipment is very simple and thus relatively cheap, as the only expendables are the steel balls and the inside wall of vessels.

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[217] Ibid.
[218] UNEP 2011: 39.

Monitoring, reporting and compliance costs depend strongly on the amount of monitoring, reporting and compliance testing required by the national regulations of a country. Since there are no residues from the process, there are no costs for the transport of residues and no landfill costs occurring. Materials generated from the treatment are even used as various building materials. Labor costs are negligible, as only two workers are needed for the operation.

Regarding the costs for electricity, local prices have to be checked. The smaller version of the 'Radicalplanet technology' (105 tons/y) consumes 1,800 kwh/ton, while the bigger version requires (210 t/y) 3,600 kwh/ton electricity.[219] Using EDL MCD units costs will amount to US $ 200 - 500/ m³ for soil treatment.[220]

[219] Vijgen, John and McDowall, Dr.Ir. Ron 2009c.
[220] UNEP 2011: 39.

Advantages	Disadvantages
• Simple operation • Process uses well established mineral processing equipment and principles • Relatively cost-effective • Little gaseous emissions are produced. • No formation of new POPs because of low temperature and reductive environment. • No release of contaminants due to good containment. • No vigorous reactions that could go out of control. • Electrical equipment, contaminated with PCB or damaged or corroded waste containers may be fed directly into the system for destruction • Process treats wastes containing various organic contaminants, or mixtures treatable in one step => Reducing waste handling and associated risk.	• High energy requirements.[221] • Primarily used for contaminated soils • Potential pre-treatment requirements : De-watering / Particle size reduction / Solvent extraction.[222] • Extremely limited commercial experience

[221]ICS - UNIDO 2007: 26.
[222]UNEP (2002): "Destruction and Decontamination Technologies for PCBs and Other POPs Wastes - A Training Manual for Hazardous Waste Project Managers", Secretariat of the Basel Convention, United Nations Environment Programm, http://archive.basel.int/meetings/sbc/workdoc/TM-A.pdf (Accessed: 5 May 2012).

3.4.4 Case Study: Non-combustion technology in the Philippines

The Philippines is one of the countries with high interest to find effective solutions to POPs problems with strong public involvement.

The “Clean Air Act”, issued in 1999, bans the use of incinerators in the Philippines in order to avoid emissions form the burning of domestic, hospital, and hazardous wastes. Therefore, the National Implementation Plan (NIP) of the Stockholm Convention favors the application of non-combustion technologies to destroy POPs.[223] And since exporting PCB wastes to developed countries for incineration turned out to be quite expensive on the Philippine market (see case study on export chapter 3.a), the Philippines’ government decided to participate in the UNIDO project “Global Program to demonstrate the viability and removal of barriers that impede adoption and successful implementation of available, non-combustion technologies for destroying persistent organic pollutants,” which started in 2007.

The objective of this program is to prove the viability in order to promote replication of available non-combustion technologies for the destruction of POPs, specifically PCB wastes, PCBs-containing equipment and the clean - up of PCBs contaminated soils or sediments.[224]

In order to support the project the Department of Environment and Natural Resources (DENR) has not issued export permits for PCBs since 2004. The Project will support the Philippines in realizing the Chemical Control Order through safeguarding safe handling and environmentally sound storage and destruction of PCBs.[225]

Initially a project period of four years was planned. The first two years were committed to the tendering process, obtaining operating permits and conducting an environmental impact assessment. It was also intended to design, construct and test the selected non-combustion technology and to organize, among other things, a comprehensive public participation and involvement program as well as a monitoring and evaluation program.

[223]DENR2006: 2-16.
[224]UNIDO 2007: 21.
[225]UNIDO 2007: 8.

The second half of the project time includes the demonstration phase for the destruction of the first batch of 1,500 tons of PCB containing equipment and wastes out of the 6,879 tons identified during the initial inventory process, while the public participation and involvement program as well as the monitoring and evaluation program are broadly implemented.[226]

After the planned operation period, through ownership transfer of the capital equipment, the facility is supposed to be used for continued PCBs and other POPs disposal and also the destruction of non-metallic toxic substances. After the project demonstration phase, data and information obtained would facilitate the correct estimation of the destruction costs and hence its cost-effectiveness. Moreover, the potential diffusion of the technology in the region provides positively contributes to the cost-effectiveness of the project.[227]

The criteria employed during the technology selection process limit the range of possible technologies to those that operate in essentially closed systems. This means, that uncontrolled releases of POPs and other hazardous substances can be prevented and all residues from the destruction process can be contained, analyzed and, if needed, further processed before being released. A potentially employed technology should furthermore attain overall destruction efficiencies (DEs) for POPs and other substances of concern close to 100%.

The Technical Advisory Group (TAG) of the project added to these requirements to consider only commercialized technologies, which had already been successfully operated at a full scale, in a commercial or other institutional setting.

Potential vendors should be able to provide the “know-how” and assistance needed to successfully set up and operate the technology under circumstances similar to those in the Philippines.

Based on those criteria three technologies were identified for further consideration, including Gas Phase Chemical Reduction (GPCR), Base Catalyzed Decomposition (BCD) and the Sodium Reduction Process.[228]

[226]UNIDO 2007:2.
[227]UNIDO 2007:12.
[228]UNIDO 2007:27 f.

Situation in 2011: Suitable infrastructure has been set up for the implementation of project activities. At DENR / EMB level, officers have been designated to participate in the implementation and supervision of project activities.

The major stakeholders including PCB owners, the facility operator and NGOs have been involved since the preparatory phase and are members of the Project Steering Committee.[229] For the demonstration period during the first two years of operation, the facility is completely booked to treat the PCBs of four major PCB owners.[230] NGOs, such as the Global Alliance for Incinerator Alternatives (GAIA), have highlighted the significance of this project for Philippines. This means that awareness has been raised at all levels concerning the need to appropriately manage PCBs in Philippines.[231]

After the evaluation of cost and practicality the Sodium Reduction Process was selected for the treatment of wastes, provided by Kinectrics. The technology has been already installed at facility. The overall costs of the project amount to US $ 11,770,880, with US $ 4,733,000 for purchase and installation of the non-combustion technology and US $ 4,805,880 for site preparation and environmental compliance being the major parts. GEF contributed US $ 4,108,500, while the remaining amount of US $ 7,662,380 was co-financed by the main private owners of PCBs (guaranteed by the government), the operating entity, the Philippine government, UNIDO and NGOs.[232]

According to a business plan for an operational period of 7 years of the facility, the treatment costs were estimated to range between US $ 6 and US $ 7 per kg, to be paid by PCB owners to have their PCBs treated by the project facility. These costs are similar to prices PCB owners paid before for exporting their wastes to developed countries for incineration. However, as shown in chapter 4.b. of this work, in general, prices for PCB contaminated capacitors treated with the sodium reduction process do not exceed US $ 5.10 /kg.[233]

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[229]UNIDO 2011:19.
[230]UNIDO 2011:25.
[231]UNIDO 2011:6.
[232]UNIDO 2007:13.
[233]UNEP 2011:36.

Problems: The project has suffered a delay of almost 2 years. The treatment plant is not yet fully operational and also not fully compliant with the Stockholm Convention in terms of the total destruction of PCBs. The demonstration period that should have ended after completion of the project (end 2011) has not yet started. An extension of two years for the project is being requested.

The delays that the project experienced have several reasons. The Governor of the Bataan province initially did not approve the construction facility in his province, due to concerns about the disposal of toxic wastes involved in the project. The convincing efforts that finally gained his consent delayed the project by one year.

A delay of about six months arose during the development of the Environmental Impact Assessment (EIA), which was supposed to be submitted within two months after signature of contract. The main reasons for the delay were that not all information was available at the beginning because PCB owners were not involved in the design of the plant. The EIA contractor was not initially informed that apart from small and medium size transformers also very large transformers would be treated by the facility. This made modification to the EIA report necessary.

Another delay of six months occurred due to misunderstandings between PAFC, the facility operator, and IPM, the technology provider, about who was in charge of tendering out the construction of the treatment facility.[234]

An important issue is the sustainability of the project after the demonstration period. This will depend on whether a continuous input of PCB containing equipment and waste to be treated by the facility can be safeguarded. During the preliminary PCB inventory carried out for the NIP development, a total sum of 6,879 tons of PCB equipment and wastes has been identified and it is very probably that new amounts of PCBs will be found. Therefore the concern is not whether there are enough PCBs in the country for treatment in terms of existing waste quantities, but rather if the PCB owners will consent to have their stockpiles treated at the facility. This will largely depend on whether the facility can offer them competitive prices after the demonstration period.

It was found out that more than 60% of the 6,879 tons identified during NIP development is owned by small local electricity cooperatives, with limited financial means to have their PCBs treated. Therefore authorities should find a solution to

[234]UNIDO 2011:23.

finance the treatment of these PCBs by the facility. Moreover, the EMB should convince other private PCB owners such as the mining industry to bring their wastes to the facility for destruction.[235]

The overall evaluation report dating from 2011 considers the operation of such a project not entirely justified, since the costs for PCB destruction offered by the facility are similar to those for exporting them to developed countries for incineration, although the treatment technology was purchased with GEF funds.

[235]UNIDO 2011: 24 f.

4 Conclusion

POPs are highly toxic and persistent, bio-accumulate, travel long distances in the environment and are primarily caused by human activities. Due to increased and wide-ranging awareness about their potential adverse impact on human health and the environment, POPs have been of major concern to political decision-makers at the national and international levels for more than twenty years now.

4.1 Advantages and disadvantages of the three disposal alternatives

When it comes to the three disposal options described in this work, all of them have their strengths and weaknesses. Exporting POPs wastes for incineration to developed countries, which is the most widely used approach for developing countries, is suitable to any POPs type, in any physical form or concentration, except for very bulky wastes due to transportation difficulties. Export is also suitable for very small amounts of wastes and even the best option for countries whose small stockpiles would never justify to invest on their own in technologies addressing exclusively POPs wastes.

High temperature hazardous waste incinerators in developed countries are mostly well operated, fulfill BAT standards and are capable to properly dispose of wastes produced during the process. Moreover, they have been in use for many years. An advantage is that energy is often recovered in incineration facilities and that volumes and pollutants’ concentrations of the wastes are reduced.

Often, overcapacities of incinerators in developed countries make prices for the destruction process quite competitive. However, the costs for transportation, packing, insurance etc. are not to be underestimated, as they are often much higher than the actual incineration cost and highly dependent upon the transport route. Long distances and the shipping of wastes by sea increase the risks related to transport and involve high insurance fees. Possible accidents might pose a risk to human health and the environment.

The Basel Convention requires each Party to guarantee the availability of adequate disposal facilitiesto the extent possiblewithin the State’s own territory, or as close as possible to their point of generation. Waste may only be exported if the exporting country does not have the technical capacity and the necessary facilities to dispose of the wastes in questionor if existing disposal sites cannot dispose of the waste in an environmentally sound manner. The transmission of hazard information as well as the consent of the importing country is required.

A major drawback of the export option is that it might not be sustainable in the longer term as it prevents the adequate capacity building on hazardous waste management in developing countries. However, this might be necessary in case that already existing public resistance against incinerators in developed countries increases. Moreover, policies and laws on import might change in developed countries, limiting developing countries’ access to their incinerators or increasing cost to a prohibitive level, which would leave these countries without viable alternatives for POPs disposal.

Various non-combustion technologies have been developed over the last 15 years. In this relatively short period of time, out of approximately 50 existing technologies, six have managed to get licensed for the destruction of high strength POPs stockpiles and are operated on a commercial scale, predominantly in developed countries. In developing countries non-combustion technologies are still very rarely in operation and if, then mainly as pilot projects supported by international agencies such as UNIDO or World Bank with GEF funding.

It is difficult to give a blanket judgment for non-combustion technologies, since they are highly different in design, applicability, operation and performance amongst each other. Some of them have very complex and labor intensive process, whereas others are really simple to operate.

However, they all have some common characteristics. Typically they include low temperature processes involving the reduction of organochlorine compounds with hydrogen, hydrogen transfer agents, or other reductants. Unlike technologies involving incineration, non-combustion technologies avoid the production of unintentionally formed POPs such as dioxins and furans, during the destruction process, which makes them consistent with the language of the Stockholm Convention.

Moreover, they operate in essentially closed systems, which means that uncontrolled releases of POPs and other substances of concern can be avoided, resulting in higher destruction efficiencies compared to combustion technologies operating in open systems.

Gaseous, solid and / or liquid residues from the destruction process can be contained, analyzed and, if required, further processed before they are released. It also implies that the technology can avoid the “upsets” that incinerators and other open destruction process periodically experience.

In general, they can attain total DEs and DREs close to 100%. This implies that they not only successfully eliminate gaseous emissions of POPs and other toxic pollutants to the atmosphere, but also the released solid and liquid wastes. Nevertheless, it should be mentioned, that especially for less mature technologies, most of the information available on technology performance come from the vendors themselves and have in many cases not been verified by independent institutions.

Most of the existing non-combustion technologies are available in different configurations adaptable to different volumes potentially present in a country.

Also, they can be purchased either as stationary or as mobile units. However, the mobile option should only be chosen where transportation to a central plant is not practicable, given the in many cases complex composition and / or the bulk of wastes, the higher environmental risk and the resulting technical and logistical challenges in combination with potentially unstable social and political conditions. In-situ use is common for soil clean-up, since bulky contaminated soil is difficult to transport.

Non-combustion technologies can also be combined with other clean-up technologies to clean up POPs contaminated soils and sediments.

Generally, these technologies can treat POPs that are present in different matrices. Nonetheless, often they are quite specialized, meaning that one individual technology cannot treat any possible form (solid, liquid, gaseous), any waste type (transformers, soils, pure oils etc.) and any concentration of POPs in an equally satisfactory manner. For some wastes or others, one certain technology might then not be cost-effective or their destruction efficiency might be insufficient.

Most of the non-combustion technologies require some kind of pre-treatment of the wastes in order to safeguard the smooth operation of the destruction process. Often size reduction and dewatering of the waste is necessary, which implies additional infrastructure and costs.

Some of the processes require a secure infrastructure, trained technical staff, laboratory support, utilities and re-agent supply, which cannot be guaranteed in many developing countries. Moreover, some of them consume high amounts of energy and the energy supply has to be stable. Another critical point is the safety issue arising from the handling of potentially explosive chemicals, such as hydrogen.

Further, most of the non- combustion technologies are still quite expensive in terms of capital and operation costs. The costs for the development of an innovative technology are high, about US \$ 0.5 – 1 million for the concept, US \$ 5 million for the construction of a pilot plant, and US \$ 10 – 100 million for a full-scale plant. Moreover, it takes approximately 5 to 7 years for bringing a near-commercial technology to the commercial stage.[236]

Treatment costs largely depend upon the concentration and the type of wastes. Therefore, intense research should be done on the development and improvement of existing and especially on emerging and promising technologies, such as the Ball Milling process. However, public acceptance of non-combustion technologies is generally much higher than disposal technologies involving incineration. In addition, non-combustion technologies in developing countries and transition economies would result in greater self-sufficiency concerning the management of POPs wastes.

Combustion technologies include hazardous waste incinerators, cement and rotary kilns, furnaces, boilers etc. and represent also the most widely used disposal option. Especially developed countries have a long history of experience with the management of incinerators. These facilities possess large disposal capacities and energy can potentially be recovered. Waste volumes are significantly reduced and pollutants concentrated. Incineration can be applied to any POPs types, in any physical form and to wastes with any concentration level.

Due to excessively high investment costs, it is usually not an option for developing countries to consider constructing a new high temperature incinerator as a fixed plant, exclusively for the destruction of POPs wastes. Typically, in hazardous waste incinerators POPs wastes represent only up to 5 %. Therefore the potential construction of a new incinerator would have to be in line with national or regional waste management plans, dealing primarily with the question of hazardous waste management. Hereby the amounts of hazardous wastes produced in a country must justify this enormous investment, as it was the case in China.

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[236] UNEP 2004b:16.

If POPs wastes are highly dispersed and transport from remote regions to central facilities is difficult, it might be feasible to use mobile incineration units, which can be transported from site to site. Moreover, mobile treatment might involve higher cost and potentially lower environmental performance.

The Stockholm Convention identifies waste incinerators as sources of relatively high formation and release of substances listed in Annex C to the environment, as they do not operate in closed systems. Therefore, the Convention calls for the use and development of alternative processes and techniques fulfilling the same purpose.

In order to keep the release of these unintentional formed POPs to a minimum, sophisticated emission controls and monitoring is required. Another drawback of combustion-technologies is the release of greenhouse gas emission such as carbon dioxide and water vapor, inherent to the incineration process.

While destruction and removal efficiencies (DRE) in a well-managed incinerator are sufficiently high, the values of destruction efficiencies (DE) are comparatively low. This is due to the fact that DE measures not only emissions to air, but also releases in solid and liquid form.

DRE ignores the amount of POPs, which are not destroyed but only transferred to matrices such as sludge or ash, which is important to measure in open systems such as hazardous waste incinerators. Solid and liquid discharges require additional treatment measures.

Safety hazards arise due to high operating temperatures. Health concerns due to emissions have been resulting in low public acceptance of incinerators, in both developing and developed countries.

For several reasons co-processing of wastes in cement kilns needs to be treated separately and deserves particular attention. Cement kilns, generally producing cement, have a number of inherent features making them ideal for the treatment of hazardous waste and POPs waste. For the co-processing of hazardous and POPs wastes they are commercially applied in developed countries and still in the demonstrations phase in developing countries, even though they are common and available in most developing countries. Generally, their application to POPs wastes is limited to relatively modern rotary kiln with overall BAT / BET environmental performance to minimize PCDD / PCDF emissions, equipped with appropriate POPs waste handling/injection infrastructure as well as monitoring capacity and appropriate and sufficient gas treatment systems.

Even though the Stockholm Convention identifies cement kilns co-processing hazardous wastes as a source category for dioxin and furan emissions, it is unlikely that they would have been mentioned if most recent performance data had been considered. Especially nowadays, new plants in any country are built in line with BAT / BEP standards, as this is also the most economic feasible choice, representing a competitive advantage and improving the performance of cement production in developing countries. Older and less competitive cement kilns will progressively be replaced.

Technical upgrades for existing cement kilns, if they are not too old, can be comparatively cost-effective. Particularly, plants that already accepted incineration of hazardous (non-POPs) wastes and might be suited for treatment of POPs wastes since incremental investments might be relatively low. And even though in some cases the initial investment might be high, substituting fuels with waste allows the cement kilns plant to reduce its overall production costs, since wastes can either serve as raw materials and / or as alternative fuel, replacing commonly used fossil fuels. Test runs and research revealed that emissions remained the same or even decreased (in the case of CO_2), when substituting parts of the fossil fuel with POPs waste.

Cement kilns can treat PCBs and POPs pesticide wastes in solid and liquid form. They are only available as fixed plants and are quite safe in operation. The traceability of the wastes needs to be reliably guaranteed prior to reception by the facility, as waste composition and concentrations must be known. Pretreatment such as dewatering or blending might be necessary. Monitoring is extremely important in order to ensure complete destruction of stable chlorinated compounds such as PCBs with the desired efficiency.

Whether cement kilns are a viable option will depend to a large extent on the willingness of the plant owners to absorb the additional cost and effort to ensure tracing and monitoring of wastes and increase safety standards to meet requirements of POPs treatment.

Co-processing of POPs wastes in properly controlled cement kilns creates useful synergies between the waste treatment and production of cement by providing energy and recovering materials. Thus, cement kilns can constitute an inexpensive, environmentally sound and sustainable alternative.

OVERVIEW

	Performance	Applicability	Operation & Safety	Costs	Stakeholders	Conventions
Export to developed country for incineration	Volume reduction and concentration of pollutants	Any POPs type, in any physical form or concentration	Long history of experience with management of incinerators in developed countries: BAT /BEP usually applied	Cost for recovery, stabilization, packaging, separation, transport and insurance of wastes make up to five times the cost of incineration	Overcapacities in developed countries	Basel Convention allows for export only conditionally
	Greenhouse gas emissions	Suitable also for very small amounts of wastes	Energy recovery	Costs vary according to transport route (land or sea, distance)	Policies and laws on import might change in developed countries	Incinerators identified by the Stockholm Convention as a source category for dioxin and furan emissions
	Sophisticated emission controls and monitoring required	Not suitable for very bulky wastes due to transportation difficulties	Risks related to transport and shipping	Overall cost: US $ 3-6 /kg	Public resistance in developed countries	
	High DRE, comparatively low DE		Consent of importing and transition countries needed under Rotterdam and Basel regime		No capacity building in developing countries	
	Additional measures required to treat liquid and solid residues					

	Performance	Applicability	Operation & Safety	Costs	Stakeholders	Conventions
Hazardous waste incineration in the developing countries	Volume reduction and concentration of pollutants	Any POPs type, in any physical form or concentration	Long history of experience with management of incinerators	Extremely high capital costs	Generally accepted technology by many nations	Identified by the Stockholm Convention as a source category for dioxin and furan emissions
	Greenhouse gas emissions	Large capacity	Also mobile / semi-mobile units available but at higher cost and potentially lower environmental performance	Treatment costs: US $ 0.1 - 2.5/kg depending on waste type and form	Public resistance	
	If poorly managed -> dioxin, furan emission possible	Primary purpose:	Energy recovery		National and regional hazardous waste management plans have to be considered, since POPs wastes only 5%	
	Sophisticated emission controls and monitoring required	Hazardous waste management, only secondarily POPs wastes disposal	Health and safety hazards due to high operating temperatures			
	High DRE, comparatively low DE					
	Additional measures required to treat liquid and solid residues					
Cement kilns co-processing POPs wastes	Volume reduction and concentration of pollutants	Applicable to PCBs and POPs pesticide wastes, in solid and liquid form	Only available as fixed plant	Costs for technical upgrades might be high (depending on the already existing cement kiln), but waste feed can decrease cement production costs	Cement kiln owners have to absorb costs for technical upgrades and tracing, monitoring and increase safety standards for POPs treatment.	Identified by the Stockholm Convention as a source category for dioxin and furan emissions
	If poorly managed -> dioxin, furan emission possible	Primary purpose: Cement production, only secondarily POPs wastes disposal, but useful synergies	Already existing in many developing countries, long history	Treatment costs: US $1.0 - 5.0/kg		
	Greenhouse gas emissions (unaffected by POPs waste feed)		Commercialized in developed countries			

	Performance	Applicability	Operation & Safety	Costs	Stakeholders	Conventions
Cement kilns co-processing POPs wastes	High DRE and DE, if well operated	Waste can substitute fossil fuels or minerals	Quite safe in operation, but waste composition and concentrations must be known and controlled			
	BAT standards not always assured, plant upgrades might be necessary		Monitoring extremely important			
			Pretreatment might be necessary			
			Energy recovery			
Non-Combustion technology	High DRE and DE	Exclusively designed for POPs wastes disposal, might treat also hazardous non-POPs wastes	Young technologies, some of them commercialized in developed countries, but in developing countries only pilot projects	Capital costs for a pilot plant: US $ 2 – 10 million	Country-drivenness, financial capacity, enabling environment, partnership in the country to be considered	Stockholm Convention favors technologies avoiding dioxin and furan formation and release
	Operate in closed systems => Gaseous, solid and / or liquid residues can be contained	Often quite specialized application to certain waste types or concentrations	Usually available in stationary and mobile units	Capital costs for a full-scale plant US $ 10 – 100 million	Higher public acceptance	
	Typically low temperature processes involving the reduction of organochlorine compounds with hydrogen, hydrogen transfer agents, or other reductants => No dioxin and furan formation and emissions		Processes are often complex (not Ball Milling) => Often highly qualified and trained personnel, laboratory support, utilities, re-agent supply and safety measures necessary	Treatment costs: US $ 0.2 – 5 /kg depending on POPs type, concentrations and form (highly different from one technology to another)	Capacity building in developing countries	
			Often very high and stable energy demand			
			Pretreatment often necessary			

4.2 Factors influencing the decision on the most appropriate disposal option for developing countries

The initial central question of this work was to figure out the best option for the disposal of POPs wastes for developing countries and transition economies. However, the first conclusion to be drawn is, that there is no universal recipe that may be applied to any case. This is primarily due to two reasons: Firstly, the inexplicit language of the Conventions is leaving great freedom to Parties in the choice of disposal options. Secondly, conditions are highly different from one country to another, and therefore have to be investigated thoroughly on a case-by-case base.

When selecting a disposal method, first of all some general requirements with respect to the environmentally sound management of POPs wastes protective to human health and the environment have to be met. The main requirements arise from provisions made under the *three chemical Conventions*, the Rotterdam Convention, the Stockholm Convention and the Basel Convention, of which particularly the latter two are closely linked to each other and provide for specific technical guidance.

While the Stockholm Convention is focused on production and use of POPs, the Rotterdam Convention deals with the trade of chemicals and the Basel Convention is concentrated on the movement and disposal of POP wastes. Together these there Conventions cover key aspects of “cradle-to-grave” management for POPs.

In order to simplify and accelerate the implementation of the conventions, the COPs have over the time adopted a series of decisions aiming at enhancing cooperation and coordination among the conventions.

Hence, a framework for the so-called synergies process has been established resulting in various benefits for the countries. Better-coordinated national frameworks, institutional capacity and enforcement mechanisms concerning chemicals and wastes improve the use of available resources and increased awareness at the national and international levels might increase resource allocation for chemicals and waste management projects.

In order to support the implementation of the Stockholm Convention in developing countries and transition economies technical assistance can be better coordinated and resources more efficiently used. Over the last years the Secretariat of the Basel Convention has supported the implementation of a number of various POPs related activities, including national inventories, regional workshops for the environmentally sound management of POPs, and the formulation of guidance manuals. With the implementing process of the Stockholm Convention, these activities have become even more dynamic.

Close cooperation among the three chemical Conventions also facilitates a more integrated approach on sound chemicals and wastes management and its realization through the national development plans in the countries. Also, greater cost-effectiveness can be safeguarded when it comes to the implementation of the conventions.

Concerning the disposal of POPs wastes primarily the Stockholm and the Basel Convention contain provisions regarding disposal options for the environmentally sound management of POPs waste. Several complementary documents provide for concrete technical specifications and guidelines, which have been established in close cooperation between the secretariats of the two Conventions.

Wastes should be managed in a way protective of human health and the environment. When selecting a disposal option generally current Basel guidelines should apply. A potential disposal technology should prevent the formation as well as the release of dioxins, furans and other unintentionally formed POPs. In addition, a potential technology should not produce any wastes with POPs characteristics and it should, as far as possible, avoid any POPs disposal processes and methods, which are non-destructive. As a general principle, levels of POPs destruction and irreversible transformation should be measured in all POPs in waste output streams of a technology. POPs destruction efficiency (DE) applicable to the initial POPs content should be >99.99%, with Destruction Removal Efficiency (DRE) >99.9999% as a supplemental requirement. Unlike DE, DRE takes only air emissions into account, while ignoring toxic solid and liquid residues such as waste ash, sludge and waste water.

As an upper limit for residues low POPs content as specified in the technical guidelines should apply. Unintended release limits, set at developed country standards, are below 0.1 ng I-TEQ/Nm³, for dioxins and furans present in air emissions and below 0.1 ng I-TEQ/l for releases of waste water from effluent treatment plants and also for scrubber effluents after flue gas treatment.

According to the Stockholm Convention alternative processes and techniques fulfilling the same purpose but which avoid the formation and release of dioxins and furans should be preferred. Specification of Best Available Techniques / Best Environmental Practices (BAT / BEP) requirements for design and operating conditions are assessed on a technology-specific basis, i.e. for facilities falling under source categories of unintentional byproduct POPs.

The next step in the decision-making process is, to have a thorough *look at the specific country situation* in order to identify suitable and cost-effective disposal approaches. Certain conditions in developing countries and transition economies might favor the use of one or the other disposal option.

The *existing amounts of POPs waste and stockpiles* will fundamentally influence the decision whether a country chooses to develop its own disposal facility or to make use of capacities existing in other countries. NIP inventories reveal that POPs stockpiles and waste differ significantly from country to country. Estimated quantities are often small and in this case the export of POPs wastes constitutes the most appropriate disposal option.

Also, *pre-existing national legislation* banning or providing for certain treatment methods for certain wastes can significantly influence the selection of a disposal option.

Moreover, *existing disposal infrastructure in a country* should be taken into account when selecting a technology. Investigations should be done on, whether potential disposal facilities being already available in a country could treat wastes in an environmentally sound manner, according to the required standards under the chemical Conventions. If not, studies have to be undertaken whether upgrading those existing facilities would be practicable and viable. This could be the case for co-processing of POPs wastes in cement kilns. Expert advice is needed in order to judge whether a certain kiln plant can be used and to assess on a case-by-case basis whether special equipment is required to inject the POP waste into the kiln. This involves also a thorough study of the country situation. Also, definite cost of applying a new technology will depend strongly on the specific situation regarding, for instance, taxes, fees, and the technical properties of the installation concerned. It is hardly possible to estimate such site-specific aspects correctly.

In the case of the Philippines combustion technologies had to be excluded as a disposal option, since incineration is banned under national law. Appropriate disposal facilities, ensuring environmentally sound disposal of POP wastes, did not exist neither or were insufficient in the case of existing cement kilns that did not achieve BAT / BEP standards for PCB treatment as required under the Stockholm Convention. Therefore, the options 'export to developed countries for incineration' (legitimate under the Basel regime) and the use of non-combustion technologies remained as alternatives.
Due to increasing prices for exporting POPs wastes, the Philippines decided to participate in a UNIDO pilot project introducing non-combustion technologies as disposal alternative. Since in this case export *costs* were comparatively high, prices for treatment of POPS wastes in the non-combustion facility plant were expected to be similar. Here it becomes quite obvious that when selecting a potential destruction technology it is of utmost importance to look at the specific country situation.

Also in the China case study existing national legislation was important, when selecting an appropriate disposal option for PCB wastes. According to national laws hazardous wastes have to be incinerated (unlike in the Philippines where incineration was forbidden). And because existing incineration facilities had the potential to dispose of PCBs in an environmentally sound manner, no new facility was built. This was also the reason, why exporting the PCB wastes to developed countries would have been hard to justify under the Basel regime, since transporting considerable amounts of PCB wastes also involves unacceptable risks. Additionally, the export option would have been comparatively expensive. An important consideration for China was also, *to gain precious experience in the environmentally sound disposal of PCBs*, which may be transferred also to other hazardous wastes and POPs. Due to China's rapidly progressing industrialization with increasing amounts of generated wastes of all types this is a highly reasonable argument, under the condition that international environmental standards at the treatment facilities can be ensured. In the case study, the existing plant was successfully upgraded. Features not included in the plant's original design were added, in order to keep emissions of dioxins and furans at a minimum and to meet BAT / BEP standards required by the Stockholm Convention. Since contaminated soil is not covered by the Chinese definition of hazardous waste and thus, does not have to be incinerated, it was possible to choose thermal desorption, a non-combustion technology, for treatment. Also for the pre-treatment of PCB contaminated oils a dehalogenation plant, which does not involve incineration, was used, showing that also combination of combustion and non-combustion technologies are possible.

If a country decides to build a new treatment plant facility, it is vital to take certain safeguard measures in order to effectively implement the new technology and to achieve the desired performance. Based on the Philippine experience it can be recognized that the *demonstrated willingness of a country's government as well as their regulatory commitment and their capacity for supervision and enforcement* (rule of law) is essential for a project's success. Thus, only politically stable developing countries with a strong government and strong institutions, a certain *financial capacity for co-financing* and a certain *market size* can effectively handle such technologies, in order to minimize the risks related to high initial investments.
An important point is *to link a national POPs inventory and an approved NIP*, which is kept regularly updated. Hereby it is crucial to identify unquestionably legal *custody and ownership of POPs wastes* and to make owners assume financial responsibility, as it was the case for the big electrical companies in the Philippines, where the government obliged them to co-finance the project. Country-specific characteristics such as the lacking capacity of small, financially weak cooperatives to pay for the disposal of their PCB contaminated transformers, have to be identified beforehand and treated with particular attention.
Reliable environmental assessments and permitting processes have to be carried out. As revealed in the Philippines the disclosure of all necessary information to the EIA contractor would have prevented a major delay of the project. Close and timely *communication and consultations with all involved stakeholders*, in this case with technology providers, the operator and the PCB owners, would have been of extreme importance, in order to communicate technical details amongst them and to the EIA contractor. Also the early involvement of local governments is crucial, as their

approval might be decisive for the implementation of the new technology, as it was the case with the governor of the Bataan province.

In this context, *public participation* is equally vital. The Philippines learnt their lessons from the Australian experience. In Australia Civil Society who had actively opposed incineration and/or landfilling of hazardous wastes, participated in the decision making process on the use of non-combustion technologies as well as in reviewing these technologies. Once the new technology is in operation, *environmental performance and safety demonstrations* are required. Before that, provisions for operational monitoring of performance and tracking of POPs from acquisition to final destruction have to be made.

Another extremely important issue is the question of *sustainability* of the new technology, meaning that provisions have to be made for the time after the demonstration phase. This might involve ownership transfer of the capital equipment, as it was the case in the Philippine project.

Moreover, a constant input of waste streams also for the remote future has to be ensured, particularly given the fact that POPs are not produced anymore. Therefore the possibility of diversification of waste treatment might be considered. Bearing this in mind, it is recommendable not to choose a technology that is too specialized, treating exclusively a certain type of waste.

In the Philippines after the planned operation period, the facility will treat, additionally to PCBs, also other POPs wastes as well as non-metallic toxic substances. Moreover, new clients such as the mining industry shall be convinced to bring their wastes to the new facility. Such sustainability considerations are critical to be properly thought through already at the very beginning of the project, as they significantly influence the selection of the non-combustion technology. Negotiations with the owners of potential additional wastes to be treated in the plant should be started as soon as soon as possible. In a second step, types of contaminants, as well as forms and concentrations of these additional wastes should be known and considered in the technology selection process.

Generally, the main concern is not whether there is enough waste in the country for treatment in terms of existing waste quantities, but rather if the PCB owners will agree to have their stockpiles treated at the facility. This will largely depend on whether the facility can offer them competitive prices after the demonstration period.

Another sustainable and cost-effective approach might be to *establish regional facilities* and treat also the POPs wastes of neighboring countries. Even though this work a priori defined ‘export’ as ‘export for incineration to developed countries’ (as this is the most common approach), waste must not necessarily be transported to developed countries implying long-distance shipments, high costs and potential environmental risks.

POPs stockpiles and waste differ significantly from country to country. Estimated quantities are usually small compared to hazardous waste produced in even moderately industrialized countries, though. And for small amounts of POPs wastes export constitutes the most appropriate disposal option.

Thus, many countries should try to combine their POPs disposal requirements with others, either through exporting to existing facilities or working together towards the development of common regional facilities. Hereby, they can choose either combustion or non-combustion technologies or a combination of both, and select for any POPs waste types and concentration level the most appropriate and at the same time the most cost-effective disposal option. This would result in greater self-sufficiency of developing countries concerning the POPs waste management. Further, this option could mitigate the risks of potentially changing laws and policies concerning POPs wastes import in developed countries.

What makes a country eligible to become a regional center is, as mentioned above, political stability, with a strong motivation demonstrated by national and local governments as well as by the identified owners of the wastes in order to seriously address POPs waste management. Also reasonable financial and institutional capacity and a certain domestic market size are desirable characteristics. Civil Society should be involved in the decision process.

If a country decides to build a new treatment plant facility, viability and sustainability are the key issues that have to be carefully considered. In case an incineration plant is chosen, the country has to make sure that not only POPs wastes to be potentially treated are considered, but also the generated quantities of other hazardous wastes, since POPs wastes constitute only a minor share of the total waste amount to be treated there.

Plants that are exclusively designed to treat POPs, like most of the available non-combustion technologies, have to safeguard a reliable, constant input of waste streams also for the remote future, particularly owing to the fact that POPs are not produced anymore. Therefore the possibility of diversification of waste treatment should be considered already in the very early planning phase. And last but not least, operators have to offer competitive prices.

5 Bibliography

Anonymous (1994): “Guidance Document on Preparation of Technical Guidelines for the Environmentally Sound Management of Wastes Subject to the Basel Convention”, Secretariat of the Basel Convention, United Nations Environment Programme.

Anonymous (2001): “Persistent organic pollutants and the Stockholm Convention: A resource guide.” A report prepared by Resource Futures International for the World Bank and CIDA, http://siteresources.worldbank.org/INTPOPS/214574-1115813449181/20486510/PersistentOrganicPollutantsAResourceGuide2001.pdf (Accessed: 14 February 2012).

Costner, P. (2004): “PCB Management and Disposal under the Stockholm”. Convention Consultation Meeting, Geneva 9-10 June 2004, http://www.chem.unep.ch/pops/pcb_activities/PCB_proceeding/Presentations/Pat%20Costner%20(Greenpeace).pdf (Accessed: 10 April 2012)

DENR (2006): “Final – National Implementation Plan for Stockholm Convention on POPs”, Department of Environment and Natural Resources, Philippines, http://www.pops.int/documents/implementation/nips/submissions/NIP_Philippines.pdf (Accessed: 25 April 2012).

Eisa, Mohamed (2008): “Technology Transfer Opportunities in East and South East Asian Countries through the UNIDO POPs Programm”, UNU Conference, Tokyo – Japan,14 November 2008.

“Emergency Fund”, Basel Convention, http://www.basel.int/Implementation/LegalMatters/EmergencyFund/tabid/2370/Default.aspx (Accessed: 28 May 2012).

FECO / MEP / UNIDO / GEF (2010): “Mission Report on Non-incineration POPs Waste Disposal Program - Sub-project of Environmentally Sound Management and Disposal Project of Pesticides POPs Waste and Other POPs Waste in China”, Foreign Economic Cooperation Office, Ministry of Environmental Protection/United Nations Industrial Development Organization/ Global Environment Facility.

“History of the Synergies Process”, Synergies among the Basel, Rotterdam and Stockholm Conventions,

http://synergies.pops.int/SynergiesProcess/History/tabid/2615/language/en-US/Default.aspx (Accessed: 11 April 2012).
ICS – UNIDO (2007): "Non-Combustion Technologies for POPs Destruction – Review and Evaluation", International Centre for Science and High Technology - United Nations Industrial Development Organization, Trieste, Italy, Available on request under www.ics.trieste.it.

"Incremental Costs", Global Environment Facility, http://www.thegef.org/gef/policy/incremental_costs (Accessed: 28 May 2012).

Interview Dr. Robert ChoongKwetYive, UNEP Chemicals, 7 May 2012, Vienna (Skype).

Interview, Dr. Heinz Leuenberger, UNIDO Vienna, 11 May 2012, Vienna.

Interview, Dr. Yang Yang, Tsinghua University, 20 February 2012, Beijing.

Interview, Dr. Zheng Peng, FECO, 7 February 2012, Beijing.

Jones, K.C. and Voogt, P. de (1999): "Persistent Organic Pollutants (POPs): State of the Science", Environmental Pollution 100, 209-221.

Karstensen, K.H. (2007): "A Literature Review on Co-processing of Alternative Fuels and Raw Materials and Treatment of Hazardous Wastes in Cement Kilns". Department for Environmental Affairs and Tourism, Republic of South Africa. Report September/KHK, http://www.aitec-ambiente.org/portals/2/docs/pubblici/documenti/raccolta%20bibliografica/coprocessing%20literature%20review%202007.pdf (Accessed: 10 May 2012).

Ludwig, Udo and Schmid, Barbara (2007): "Germany's Booming Incineration Industry -Burning the World's Waste", Spiegel Online International, 21.02.2007, No. 8 / 2007, http://www.spiegel.de/international/spiegel/0,1518,467239,00.html (Accessed: 4 April 2012).

Luscombe, D.(2001): "Non-incineration PCB Destruction Technologies", Greenpeace International Service Unit, www.istas.net/portada/cops8.pdf (Accessed: 27 February 2012).

Office of the National Coordination Group for Stockholm Convention Implementation (2007): "The People's Republic of China: National Implementation Plan for the Stockholm Convention on Persistent Organic Pollutants", China Environmental Science Press.

Office of National Coordination Group for Stockholm Convention Implementation (2008): **“**POPs Action in China“, No.17 Sep. – Oct. 2008, http://en.mepfeco.org.cn/Resources/Periodicals/PAIC/201009/P020100908564778437595.pdf (Accessed: 10 May 2012).

Oxford University (2005): “A Dictionary of Science”, Oxford University Press, Market House Books Ltd, 5^{th}ed, http://www.blmasinac.com/files/A%20Dictionary%20of%20Science.pdf (Accessed: 6 May 2012).

Qian, Wang (2009): “Villagers halt waste incinerator”, China Daily, 31.12.2009, http://www.chinadaily.com.cn/cndy/2009-12/31/content_9249341.htm (Accessed: 10 March 2012).

“Persistent Organic Pollutants”, UNEP Chemicals, http://www.chem.unep.ch/pops/ (Accessed: 10 April 2012).

Rahuman, M., L. Pistone, F. Trifiro and S. Miertus (2000): “Destruction Technologies for Polychlorinated Biphenyls (PCBs)”. International Centre for Science and High Technology United Nations Industrial Development Organization, ICS-UNIDO publications, Trieste, Italy, http://www.clu-in.org/download/remed/destruct_tech.pdf (Accessed: 30 April 2012).

Ritter L; Solomon KR, Forget J, Stemeroff M, O'Leary C.:”Persistent organic pollutants - An Assessment Report on: DDT-Aldrin-Dieldrin-Endrin-Chlordane Heptachlor-HexachlorobenzeneMirex-Toxaphene Polychlorinated Biphenyls Dioxins and Furans". United Nations Environment Programme, http://www.chem.unep.ch/pops/ritter/en/ritteren.pdf (Accesssed: 20 February 2012).

UNCED (1992): “Agenda 21, Section IV, Means of Implementation, Chapter 34, Transfer of Environmentally Sound Technology, Cooperation & Capacity Building”, http://www.un.org/esa/dsd/agenda21/res_agenda21_34.shtml (Accessed: 12 February 2012).

UNEP (1989): “Basel Convention on the Control of Transboundary Movements of Hazardous Wastes And Their Disposal – Protocol on Liability And Compensation for Damage Resulting from Transboundary Movements of Hazardous Wastes And Their Disposal – Texts and Annexes”, http://www.basel.int/Portals/4/Basel%20Convention/docs/text/BaselConventionText-e.pdf (Accessed: 15 February 2012).

UNEP / FAO (1998): “Rotterdam Convention on the Prior Informed Consent Procedure for Certain Hazardous Chemicals and Pesticides in International Trade–

Texts and Annexes (Revised 2011)” http://www.pic.int/TheConvention/Overview/TextoftheConvention/tabid/1048/language/en-US/Default.aspx (Accessed: 10 February 2012).
UNEP (2000): “Survey of Currently Available Non-Incineration PCB Destruction Technologies”, UNEP Chemicals, United Nations Environment Programme, http://www.chem.unep.ch/pops/pdf/surveypcb/PCBdesteng.pdf (Accessed: 9 May 2012).

UNEP (2001): “Stockholm Convention on Persistent Organic Pollutants”, http://chm.pops.int/Portals/0/Repository/convention_text/UNEP-POPS-COPCONVTEXT-FULL.English.PDF (Accessed: 20 February 2012).

UNEP (2002): “Destruction and Decontamination Technologies for PCBs and Other POPs Wastes - A Training Manual for Hazardous Waste Project Managers – Volume A”, Secretariat of the Basel Convention, United Nations Environment Programme, http://archive.basel.int/meetings/sbc/workdoc/TM-A.pdf (Accessed: 9 April 2012).

UNEP (2003): “Environmentally Sound Technologies for Sustainable Development-Revised Draft”, International Environmental Technology Centre Division of Technology, Industry and Economics, United Nations Environment Programme, http://www.unep.or.jp/ietc/techtran/focus/sustdev_est_background.pdf (Accessed: 7 April 2012).

UNEP (2004)a: “Review of Emerging, Innovative Technologies for the Destruction and Decontamination of POPs and the Identification of Promising Technologies for Use in Developing Countries”, Scientific and Technical Advisory Panel (STAP) to the GEF UNEP, http://archive.basel.int/techmatters/review_pop_feb04.pdf (Accessed: 15 April 2012).

UNEP (2004)b: “Non-combustion technologies for the destruction of POPs stockpiles”, Scientific and Technical Advisory Panel (STAP) of the GEF UNEP, http://www.unep.org/stap/LinkClick.aspx?fileticket=XhzPXDluFhc%3D&tabid=3045&language=en-US (Accessed: 16 April 2012).

UNEP (2006)a: “Updated general technical guidelines for the environmentally sound management of wastes consisting of, containing or contaminated with persistent organic pollutants (POPs)”, Secretariat of the Basel Convention, United Nations Environment Programme, archive.basel.int/pub/techguid/tg-POPs.doc (Accessed: 12 April 2012).

UNEP (2006)b: “Revised Draft Guidelines on Best Available Techniques and provisional guidance on Best Environmental Practices relevant to Article 5 and Annex C of the Stockholm Convention on persistent organic pollutants”, Secretariat of the Basel Convention, United Nations Environment Programme, http://www.pops.int/documents/guidance/batbep/batbepguide_en.pdf (Accessed: 20 February 2012).

UNEP (2009): “The Hazardous Chemical and Wastes Conventions”, United Nations Environment Programme, http://www.pops.int/documents/background/hcwc.pdf (Accessed: 9 April 2012).

UNEP (2011): “Selection of Persistant Organic Pollutants Disposal Technology for the Global Environment Facility”. Scientific and Technical Advisory Panel (STAP) of the GEF UNEP, http://www.thegef.org/gef/sites/thegef.org/files/publication/POPs_Disposal_Final_low.pdf (Accessed: 13 February 2012).

UNIDO (2007): “Project for the Republic of the Philippines - Project Document“, Global Programme to demonstrate the viability and removal of barriers that impede adoption and successful implementation of available, non-combustion technologies for destroying persistent organic pollutants (POPs), Project number: GF/PHI/07/XXX.

UNIDO (2008): “Independent evaluation China - Building the capacity of the People’s Republic of China to implement the Stockholm Convention on POPs and develop a national implementation plan”, Project Number: GF/CPR/04/002.

UNIDO (2011): “Draft - Independent Terminal Evaluation of the UNIDO Project: Global programme to demonstrate the viability and removal of barriers that impede the adoption and successful implementation of available Non-Combustion Technologies for destroying persistent organic pollutants (POPs)”, Project Number: GF/PHI/07/001, Internal Working Document.

Vijgen, John and McDowall, Dr.Ir. Ron (2009)a: “Gas-Phase Chemical Reduction (GPCR) - POPs Technology Specification and Data Sheet”, International HCH & Pesticides Association (IHPA), http://www.ihpa.info/docs/library/reports/Pops/June2009/SBC_LogoGCPRDEF_190109_.pdf (Accessed: 6 May 2012).

Vijgen, John and McDowall, Dr.Ir. Ron (2009)b: “Alkali Metal Reduction - POPs Technology Specification and Data Sheet”, International HCH & Pesticides Association (IHPA), http://www.ihpa.info/docs/library/reports/Pops/June2009/DEF_ALKALIMETAL_150109_SBCLogoCLEANVERSION.pdf (Accessed: 6 May 2012).

Vijgen, John and McDowall, Dr.Ir. Ron (2009)c: “Radicalplanet Technology (Mechanochemical principle) (Provisional Version) - POPs Technology

Specification and Data Sheet", International HCH & Pesticides Association (IHPA), http://www.ihpa.info/docs/library/reports/Pops/June2009/DEFSBCFactSheetRadicalPlanet_070608_includedMTKJune2009.pdf (Accessed: 6 May 2012).

Vijgen, John and McDowall, Dr.Ir. Ron (2009)d: "Hazardous Waste Incineration - Pesticides Treatment Technology Fact Sheet", International HCH & Pesticides Association (IHPA), http://www.ihpa.info/docs/library/reports/Pops/June2009/DEFSBCLogo_Inciner_180608_.pdf (Accessed: 6 May 2012).

Vijgen, John and McDowall, Dr.Ir. Ron (2009)e: "Cement Kiln Co-Processing (High Temperature Treatment) - Pesticides Treatment Technology Fact Sheet", International HCH & Pesticides Association (IHPA), http://www.ihpa.info/docs/library/reports/Pops/June2009/DEFSBC_LogCEMENTKILN_180608_.pdf (Accessed: 6 May 2012).

Weber, R., Watson, A., Forter, M., &Oliaei, F. (2011): "Review Article: Persistent organic pollutants and landfills – a review of past experiences and future challenges", Waste Management & Research, 29 (1), 107-121.

Winter, Nick: "Manufacturing – The cement kiln", Understanding Cement, http://www.understanding-cement.com/kiln.html (Accessed: 8 May 2012).

World Bank (2005): „Project Document on a proposed grant from the global environmental facility trust fund in the amount of USD 18.34 to the People's Republic of China for a PCB management and disposal demonstration project",http://www.gefonline.org/ProjectDocs/POPs/FULL%20PROJECTS%20Folder%20-%20POPs/China%20-%20PCB%20Management/CN-PCB%20Management&Disposal%20GEF%20ProjectDocument4-25-05.pdf Accessed: 20 April 2012).

World Bank (2011): "Restructuring Paper on a proposed project restructuring of PCB Management and disposal Demonstration GEF Project to the People's Republic of China" (Grant TF056008)(Board Date: December 15, 2005), http://www-wds.worldbank.org/external/default/WDSContentServer/WDSP/IB/2012/01/01/000356161_20120101223355/Rendered/INDEX/661910PJPR0v100turingPaperDec132011.txt (Accessed: 12 May 2012).