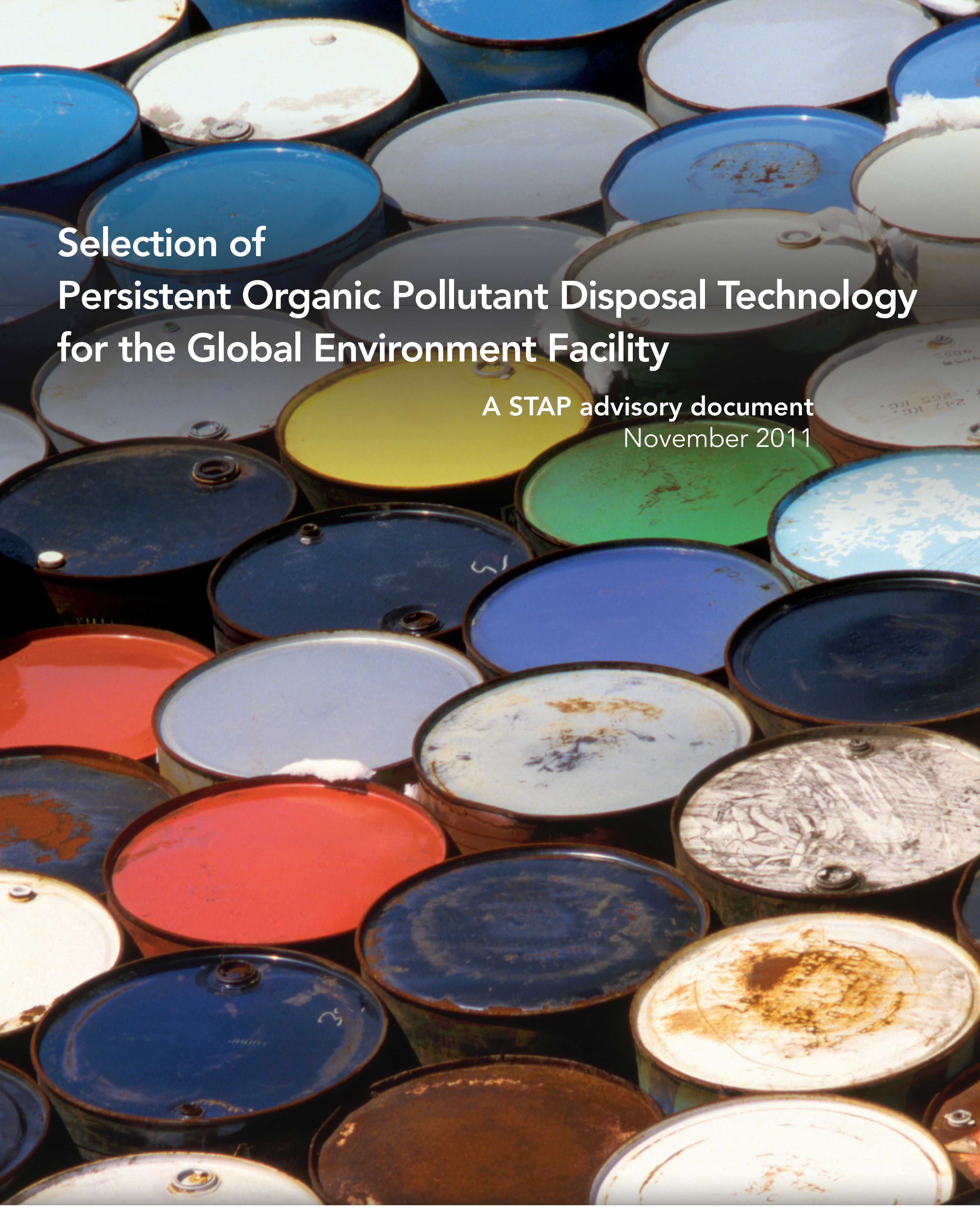

Selection of Persistent Organic Pollutant Disposal Technology for the Global Environment Facility

A STAP advisory document
November 2011

Scientific and Technical Advisory Panel

An independent group of scientists which advises the Global Environment Facility

GLOBAL ENVIRONMENT FACILITY 20 YEARS INVESTING IN OUR PLANET

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Prepared on the behalf of the Scientific and Technical Advisory Panel (STAP) of the Global Environment Facility (GEF) by

Richard J. Cooke (Man-West Environmental Group Ltd.) and William F. Carroll

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About STAP
The Scientific and Technical Advisory Panel comprises six expert advisers supported by a Secretariat, which are together responsible for connecting the Global Environment Facility to the most up to date, authoritative, and globally representative science.

http://www.unep.org/stap

Foreword

Parties to the Stockholm Convention (the Convention) under Article 6 are obligated to provide for the environmentally sound disposal of POPs stockpiles and wastes. Such disposal is fundamental to achieving the Convention's objective of protecting human health and the environment. The GEF is the Convention's principal financial mechanism in developing countries and CEITs, and has a strong interest in the process of selecting and implementing POPs disposal technologies, in light of the increasing demand for funding of POPs disposal as countries implement NIPs. The GEF-5 Chemicals Focal Area Strategy considers the quantity of PCBs and obsolete pesticides including POPs pesticides disposed of as primary performance indicators and sets targets for each.

This advisory document builds on the original 2004 STAP study on the selection of POPs disposal technologies for GEF-financed projects, and utilizes experience gained during GEF-4. It is not intended to duplicate or supersede technology evaluations provided by the Basel Convention, Stockholm Convention, or other groups, but rather seeks to lay out guidance on the attributes that technologies should demonstrate when GEF funding is involved. The critical elements in POPs technology selection outlined herein can be used to help streamline the design, development, review, implementation and execution of GEF funded POPs disposal projects. This will provide a consistent overall framework for the application of GEF funding in this area, enhance appropriateness of technology to local project conditions, and also support clearer lessons learned as the portfolio of projects matures, enabling further refinement in the approach to project design and maximization of impact and sustainability.

It is specifically directed to recipient countries, implementing agencies and the GEF Secretariat; but may also serve as guidance to technology developers and proponents. Developments related to technology availability are updated, and issues associated with their application in the context of GEF financing in developing countries and CEITs are discussed. More importantly, it also places disposal of POPs stockpiles and waste within the broader context of the POPs management process and sound chemicals management. It has been circulated for review to subject matter experts, the GEF Secretariat, and GEF agencies.

The STAP concludes that destruction cannot be addressed in isolation, but instead, the application of POPs disposal technology should be viewed as one part of an overall POPs management process or system. This system includes steps taken in advance of the actual disposal or destruction to identify, capture, secure, and prepare POPs stockpiles and wastes for disposal, as well as post-destruction steps to manage emissions, by-products and residuals.

The management process depends upon high-quality information regarding POPs stockpiles and waste, and the effectiveness of the institutional and regulatory framework under which POPs management is undertaken. There are several appropriate and capable commercial or near-commercial POPs destruction technologies available; however they are limited largely by their current cost-effectiveness, commercial maturity, and/or application experience in developing countries and CEITs, where project risks and cost uncertainty are generally higher. GEF financing may consider i) direct funding of disposal costs based on an all inclusive competitive price offered by a service provider with qualified disposal capability; ii) contribution to new disposal facility development costs; or iii) supporting technology transfer through acquisition and demonstration. But as the cost of environmentally sound disposal of POPs waste in these countries will greatly exceed available GEF resources, maximization of the mass of POPs destroyed, and the global environmental benefit achieved from GEF funding, will involve trade-offs in the technology selection process among unit disposal costs, destruction efficiencies, financial risk, application location, and implementation time required.

Thomas E. Lovejoy
Chair, Scientific and Technical Advisory Panel

Hindrik Bouwman
Panel Member for Chemicals

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Acronyms

APC	Air Pollution Control
BAT	Best Available Techniques
BCD	Base Catalysed Decomposition
BEP	Best Environmental Practice
BREF	Best Available Techniques Reference Document
CEIT	Country with Economies in Transition
COP	Conference of the Parties
DDT	1,1,1-trichloro-2,2-bis(4-chlorophenyl)ethane (dichlorodiphenyltrichloroethane)
DE	Destruction Efficiency
DRE	Destruction and Removal Efficiency
DSS	Decision Support System
EA	Environmental Assessment
EMP	Environmental Management Plan
EMS	Environmental Management System
EOL	End of Life
ESM	Environmentally Sound Management
FAO	United Nations Food and Agriculture Organization
GEF	Global Environmental Facility
GPCR	Gas Phase Chemical Reduction
HCB	Hexachlorobenzene
HTI	High Temperature Incineration
IA	Implementing Agency
IHPA	International HCH and Pesticide Association
IPPC	Integrated Pollution Prevention and Control
NIP	National Implementation Plan
ODS	Ozone Depleting Substances
PCDD	Polychlorinated dibenzo-p-dioxin
PCDF	Polychlorinated dibenzo-furan
PCB	Polychlorinated biphenyl
PIF	Project Identification Form
POPs	Persistent Organic Pollutants
ppm	Parts per Million
PRTR	Pollutant Release and Transfer Register
SAICM	Strategic Approach to International Chemicals Management
STAP	Scientific and Technical Advisory Panel of the Global Environment Facility
TEQ	Toxic Equivalent
UNEP	United Nations Environmental Programme
UNDP	United Nations Development Programme
UNIDO	United Nations Industrial Development Organization
USEPA	United States Environmental Protection Agency

Executive Summary

Parties to the Stockholm Convention under Article 6 are obligated to provide for the environmentally sound disposal of POPs stockpiles and wastes. Such disposal[1] is fundamental to achieving the Convention's objective of protecting human health and the environment by permanently eliminating persistent organic pollutants (POPs) that might otherwise be distributed into the global ecosystem. As a consequence, the disposal of POPs stockpiles and waste is a priority component of National Implementation Plans (NIPs) developed by Parties to the Convention.

Much previous and ongoing discussion centers on what constitutes environmentally sound disposal of POPs, and what disposal technologies can achieve it. The Global Environmental Facility (GEF) through the Scientific and Technical Advisory Panel (STAP) contributed to this discussion in 2003/2004 in relation to available non-combustion technologies for POPs disposal. The Basel Convention, acting in concert with the Stockholm Convention, has issued and periodically updates technical guidelines on POPs management, including disposal requirements and listings of technologies that may be applicable. To date, these guidelines have been generally welcomed by the Stockholm Convention as the standard reference.

1. Throughout the study, the term "disposal" is used for consistency with the wording in Article 6 of the Stockholm Convention and applicable Basel Convention Guidelines, but should be generally equated to other commonly used terms such as "destruction" and "elimination"

Additionally, comprehensive reviews of technologies are periodically published, and on-line libraries of technology data sheets are maintained by the Basel Convention and supporting organizations.

Most recently, the Fifth Conference of the Parties (COP-5) to the Stockholm Convention invited the Basel Convention to continue this work, specifically with respect to: (i) establishing the levels of destruction and irreversible transformation of chemicals to ensure POPs characteristics are not exhibited; (ii) considering methods that constitute environmentally sound disposal; (iii) defining low POP-content in wastes; and (iv) updating general technical guidelines, as well as preparing or updating specific technical guidelines for environmentally sound waste management (SC-5/9). Likewise, in its decision SC-5/20, COP-5 further encourages the GEF and parties in a position to do so, to facilitate the transfer of appropriate technologies to developing countries and countries with economies in transition (CEITs).

GEF is the Convention's principal financial mechanism in developing countries and CEITs. It has a strong interest in the process of selecting and implementing POPs disposal technologies, in light of the increasing demand for funding of POPs disposal as countries implement NIPs. To the end of GEF-4, over half of the US$ 412 million allocated to the POPs focal area was directly or indirectly related to stockpile and waste disposal. It is already apparent that funding and project demand is expanding under the current GEF-5 Chemicals focal area. The GEF-5 Chemicals Focal Area Strategy considers the quantity of PCBs and obsolete pesticides including POPs pesticides disposed of as primary performance indicators and sets targets for each. Therefore, it is an appropriate time for the STAP to provide updated, high-level guidance on the selection of POPs disposal technologies for GEF-financed projects. This advisory document builds on the original 2004 STAP study and utilizes experience gained during GEF-4. Developments related to technology availability are updated and issues associated with their application in the context of GEF financing in developing countries and CEITs are discussed.

This advisory document is specifically directed to recipient countries, implementing agencies and the GEF Secretariat but may also serve as guidance to technology developers and proponents. With a view to providing a consistent overall framework for the application of GEF funding in this area, it aims to address general requirements and considerations applicable for selection of POPs disposal technologies. It also places disposal of POPs stockpiles and waste within the broader context of the POPs management process and sound chemicals management.

However, the document is not intended to duplicate or supersede technology evaluations provided by the Basel Convention or other groups which, along with the evolving technical literature on the subject, should remain the principal source of information for comparative assessment of technology options. Therefore, it is emphasized that the document should not be interpreted as excluding or advocating any type or particular technology. Rather, it should be seen as guidance on the attributes that technologies should demonstrate when GEF funding is involved.

This guidance on selection of POPs disposal technology is intended to accomplish the following:

- Ensure any technology chosen meets accepted and consistent environmental performance requirements;
- Define minimum standards and performance requirements applicable to developing countries and CEITs that are consistent with but do not exceed those generally accepted in developed countries;
- Assure that POPs disposal is integrated with the overall POPs management process employed;
- Provide safeguards to assure environmentally sound management throughout the POPs management process, and
- Integrate commercial viability with technical feasibility and environmental performance in technology selection.

In general, the destruction or irreversible transformation of POPs in an environmentally sound manner is not limited by the availability of appropriate technology - there are a number of such technologies.

Rather, it is limited by the practical ability to assemble and apply them - particularly in developing countries and CEIT's - in a manner that is efficacious, timely and economical.

Destruction cannot be addressed in isolation. The application of POPs disposal technology should be viewed as one part of an overall POPs management process or system. This system includes steps taken in advance of the actual disposal or destruction to identify, capture, secure, and prepare POPs stockpiles and wastes for disposal. It also includes post-destruction steps to manage emissions, by-products and residuals. The management process depends upon high-quality information regarding POPs stockpiles and waste, and the effectiveness of the institutional and regulatory framework under which POPs management is undertaken.

Steps Taken in Advance of Destruction. Characterization, Prioritization, Capture, Containment and Pretreatment

A prerequisite for organizing and implementing POPs disposal is an effective legislative and regulatory framework for POPs identification and control. Such a framework allows the assembly of accurate and sufficiently complete inventories of:

(i) POPs stockpiles and waste in terms of quantity, identity and potency, location, owner/custody, and current storage and containment status;
(ii) POPs-containing equipment in service linked to a general plan for its retirement;
(iii) POPs-contaminated sites - known and potential - with assessment of risks and potential remediation requirements, and
(iv) Analytical capacity to characterize and monitor current and future POPs stockpiles and wastes.

Based on inventories, stockpiles that are high in POPs volume, have high POPs content, or present the greatest environmental and health risks, should be dealt with first. Recovering, isolating and storing POPs securely can often be the most cost-effective strategy for immediately mitigating risk consistent with the Conventions' objectives. This requires the physical capacity to identify, capture, transport and contain them, even if disposal cannot occur immediately. It also requires appropriate sustainable care and custody arrangements to ensure no release while materials are stored. Effective capture is also a prerequisite for any intermediate pre-treatment activity that may optimize and support the application of a disposal technology.

Selection and Qualification of a Disposal Technology Including Management of By-Products and Residuals

1) Environmental Performance. POPs destruction technologies should be evaluated on the level of destruction and irreversible transformation they achieve. This requires consideration of all waste output streams from the technology, inclusive of POPs other than those being destroyed, that may be unintentionally produced during the destruction process.

   Destruction Efficiency (DE), which is the percentage of originating POPs destroyed or irreversibly transformed by the technology is the most comprehensive measure of destruction applicable to originating POPs, where it can be reliably and reproducibly measured. Destruction and Removal Efficiency (DRE) is the percentage of original POPs destroyed, irreversibly transformed or removed from the air emission stream. It may serve as a supplementary performance parameter recognizing it only accounts for releases to air and not what could be transferred to other by-products and residuals streams. A DE>99.99% and DRE>99.9999% are recommended as working benchmarks for application in GEF projects. In general, higher DEs are preferred, but technologies should be evaluated on a case-by-case basis. Where large amounts of POPs require disposal and financial capacity is limited, the actual volume of POPs destroyed or irreversibly transformed may be maximized by use of a lower cost option that achieves the minimum DE, rather than a higher cost option that greatly exceeds the minimum DE.

Neither DE nor DRE take into account the potential for transformation of originating POPs to other POPs in the technological process. Therefore, any technology should demonstrate that this potential is minimized and at acceptable levels. Ensuring application of best available techniques and best environmental practices (BAT/BEP) to define safe design and operating conditions specific to the technology involved is recommended to maximize achievable environmental performance. For solid residuals or by-products containing either original or transformation POPs, the current provisional Basel low-POPs content levels should apply as an upper limit, noting that these may be changed and expanded periodically. Lower levels based on BAT/BEP should be attained where practical. Similarly, limits for air release of original and transformation POPs should be set at a level generally accepted in developed countries. For polychlorinated dibenzo-*p*-dioxins and polychlorinated dibenzo-furans (PCDD/PCDF), this is 0.1 ng TEQ/Nm^3 to air, again noting that BAT/BEP applicable to technologies can result in substantially better performance.

2) **Safeguard Measures.** These include documented processes, procedures and oversight actions that should be part of a GEF project's monitoring and evaluation plan, including:

- Institutional/regulatory commitment and capacity to undertake appropriate oversight and enforcement;
- A national POPs inventory and endorsed NIP, regularly maintained and updated consistent with Convention obligations;
- Unambiguous legal custody and ownership of POPs stockpiles and wastes, covering rights of access, assignment of financial liability for disposal and environmental damage, and monitoring and site closure;
- Credible environmental assessment and permitting applied to facilities and activities and benchmarked against international standards and practice;
- Performance monitoring during operations and documentation of the fate of all residues;
- Public participation, consultation and disclosure including timely access to information about POPs stockpile and waste disposal and input on how these activities are conducted;
- Health, safety and emergency response plans covering protection and monitoring of workers involved in operating the technology and any potentially exposed members of the public.

3) **Commercial Viability and Economies of Scale.** Successful, sustainable performance of any technology also depends upon commercial or financial sustainability. In general, projects should employ the most cost effective commercial arrangement that also serves to maximize the quantity of POPs disposed of, and net global environmental benefit at minimum risk to completion. These conditions are most often satisfied where the selected technologies are packaged on a complete turn-key basis operating at a predictable "all inclusive" unit cost, with appropriate performance guarantees, free of any dispute over technology ownership or licensee rights. This generally requires that a vendor possess the rights to the technology, a demonstrated track record, and the capacity to operate it at the required location. It also includes technical support and training capacity, and the financial strength to undertake the proposed work, particularly where 1) the application is to occur in developing countries and CEITs and 2) technology transfer is involved. Where the vendor arrangements involve local partnerships, national government guarantees may be required to ensure the sustainability of local arrangements and completion of the disposal works.

Recognizing the GEF's commitment to technology transfer to developing countries and CEITs, the GEF can also consider some financing of technology demonstration, transfer to, and/or acquisition by GEF recipient countries, or support for the latter stages of commercialization of locally developed technologies. However, this involves assumption of risks in development, performance, cost and timing - something that argues for caution in undertaking such commitments. Mitigation measures, such as ensuring the sharing of financial exposure and phased implementation arrangements, should be included. Such proposals should generally be oriented toward technologies that are compatible with local conditions, and which offer economies of scale and realistic potential for future cost reduction and efficiencies. In particular, such initiatives may be most productively oriented to pre-treatment technologies and longer-term destruction of stockpiles of low-concentration/high-volume contaminated POPs/chemicals waste and sites.

The need for disposal capacity, current and future, and the potential for economies of scale can influence POPs destruction technology choices. That need also guides decisions regarding development of domestic capacity vs. utilization of qualified facilities elsewhere. In many cases, countries should consider combining their disposal requirements with others and cooperating in regional pre-treatment and disposal capability. They may also consider integrating POPs stockpile and waste disposal with development of more broadly-based hazardous and chemical waste management infrastructure so as to maximize the effectiveness of scarce financial resources.

4) Infrastructure considerations. Most qualified POPs disposal technologies have been implemented in developed countries possessing mature regulatory and institutional frameworks, good supporting infrastructure, a strong technical expertise base, and sufficient resources to support their application. However, these supporting attributes may not be as readily available in developing countries and CEITs. High-performance technologies involve complex equipment, sophisticated controls and processes and require such things as reliable power and other utilities for safe and sustainable operation. A technology selection process has to assess these infrastructure needs and prudently balance the decision between technological complexity and practical applicability vs. simplicity of operation.

This document contains a listing of technologies applicable to POPs stockpile and waste disposal that potentially meet environmental performance, safeguards and commercial viability requirements, including technologies that have or are currently being supported in GEF financed projects. It summarizes their principal application characteristics and includes references to detailed fact sheets where available. This listing covers commercial and near-commercial technologies classed as operating in reducing, closed, and/or starved oxygen environment, and commercial technologies operating in open oxidizing environments. A third category covering primary pre-treatment technologies is also included. It is emphasized that this list is illustrative, and users undertaking specific technology selection work should carefully validate information with the referenced documentation and candidate vendors. It is also not intended to exclude any other technologies or variations of those identified that can demonstrate the above requirements. New technologies or modifications of current technologies offering both improved environmental performance and cost-effectiveness will inevitably enter the market and may be considered.

The document also includes a strategic approach to the technology selection process, noting that the timing constraints of maintaining an efficient GEF project cycle may themselves limit technology selection. A screening stage leading to a short list of technologies or combinations of technologies may be undertaken in advance of Project Information Form (PIF) submission, but will more likely occur during the GEF supported project preparation stage. A final technology selection might be made at this stage, but could also be part of project implementation, involving the formal evaluation of concrete commercial proposals. In some cases, particularly where technology transfer is involved, final selection might proceed in two stages: the first involving a demonstration of the technology, followed by a commitment to completing disposal of the larger volume POPs stockpiles and wastes if successful and cost effective.

Recommendations for the GEF

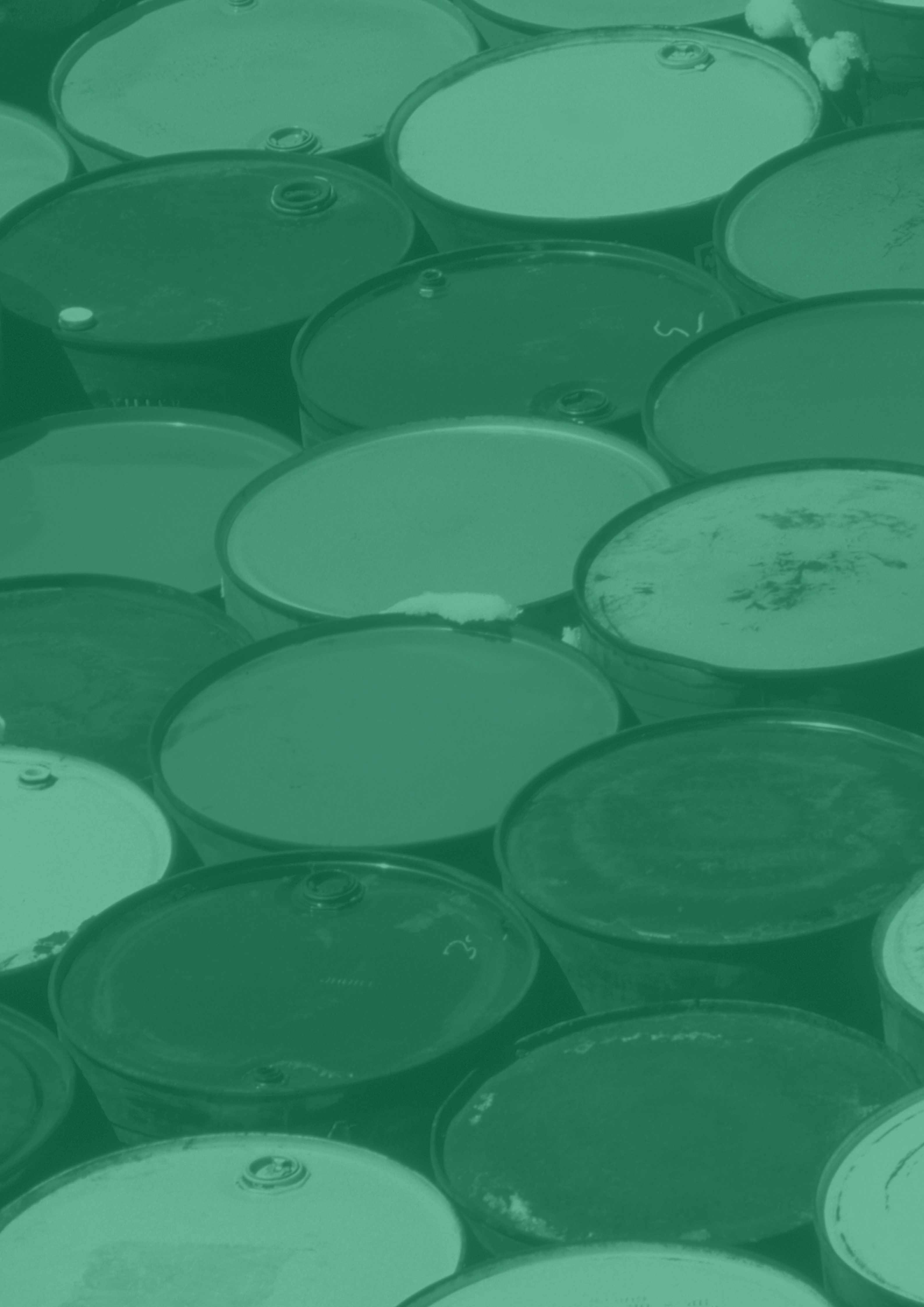
STAP's Advisory Document concludes with the following overarching recommendations respecting the GEF's role in supporting the disposal of POPs stockpiles and waste and specifically the selection of POPs disposal technology:

1) POPs disposal should not be considered in isolation. It is an integral component of environmentally sound POPs management.
2) As a general principle, developing countries and CEITs should not be held to more stringent standards than those accepted and generally applied in developed countries.
3) Environmentally sound disposal of POPs is not generally limited by availability of appropriate and capable commercial and near-commercial POPs destruction technology.
4) Many available technologies are limited largely by their current cost-effectiveness and

commercial maturity. For some, there is also a lack of application experience in developing countries and CEITs, where project risks and cost uncertainty are generally higher.

5) The cost of environmentally sound disposal of the totality of POPs waste in developing countries and CEITs will greatly exceed available GEF resources. Therefore, maximizing the mass of POPs destroyed, and the global environmental benefit achieved from GEF funding, will involve trade-offs in the technology selection process among unit disposal costs, destruction efficiencies, financial risk, application location, and implementation time required.
6) GEF financing may consider i) direct funding of disposal costs based on an all inclusive competitive price offered by a service provider with qualified disposal capability; ii) contribution to new disposal facility development costs; or iii) supporting technology transfer through acquisition and demonstration.

The critical elements in POPs technology selection outlined in this document may be used to help streamline the design, development, review, implementation and execution of GEF funded POPs disposal projects. A more uniform approach to POPs disposal projects will enhance appropriateness of technology to local project conditions. It would also support clearer lessons learned as the portfolio of projects matures, enabling further refinement in the approach to project design, and maximization of impact and sustainability.



1. Introduction

The purpose of this STAP Advisory Document is to provide updated guidance on the selection of disposal technologies for Persistent Organic Pollutants (POPs) as applied in GEF-financed projects undertaken within the Chemicals Focal Area. The target audience for this work is the GEF itself, acting as the financial mechanism for the Stockholm Convention on Persistent Organic Pollutants (Stockholm Convention, 2001), and the family of decision-makers[2] who are involved in implementing it.

The question of what constitutes an appropriate disposal technology for POPs and what barriers exist in applying such a technology has been, and remains, an important implementation issue for the Parties to the Stockholm Convention (the Parties) and the GEF. These questions were the subject of extensive study and debate during the development and negotiation of the Convention in the late 1990s. This discussion has continued since the signing of the Convention in 2001, and is now of immediate practical interest as Convention implementation activities are underway. The GEF, and specifically the STAP, have been active in this discussion, including undertaking a major workshop and study (STAP, 2004a, b) on emerging and innovative technologies, primarily non-combustion technologies.

2. Including, *inter alia*, GEF Secretariat, GEF Implementing Agencies, and GEF's recipient countries

Between 2001 and the end of GEF-4 in mid 2010, the GEF had allocated about US$412 million to a portfolio of 219 POPs projects and secured about US$667 million in co-financing. One hundred thirty-two countries had undertaken enabling activities and other capacity-building projects targeting preparation and submission of NIPs, with about US$69 million in GEF funding. Ninety-seven countries receiving GEF support had submitted completed and endorsed NIPs, 29 counties had pending NIP submissions, while 6 GEF-supported countries had not moved forward with completing NIPs to date. One hundred twenty-eight of the GEF-supported countries had ratified or acceded to the Stockholm Convention. Six countries receiving enabling activity support were not yet Parties to the Convention.

During GEF-4, 85 GEF POPs projects have moved into NIP implementation either as country-specific projects (52 projects) or global or regional projects facilitating implementation (33 projects). These projects accounted for US$343 million or 83% of the GEF's accumulated financial commitment to this focal area at the end of the GEF-4 replenishment period. NIP implementation projects will probably be the main focus in the future. Forty-seven (55%) NIP implementation GEF-4 projects included substantive components related to management and disposal of POPs under Article 6 of the Convention. These projects account for GEF commitments of US$216 million or 63% of the NIP implementation project commitments and 52% of the GEF's overall commitment. These projects typically cover: i) technical assistance for the process of determining disposal strategies including identifying and evaluating disposal technology options; ii) operational activities related to capturing and securing stockpiles; and iii) disposal of POPs material, with the latter generally being the largest expenditure.

An analysis of GEF-4 NIP implementation projects (Appendix 1) shows that 28 projects involve allocation of GEF funds to studies intended to identify, evaluate and/or select disposal technology options. Twenty-six projects have selected or expressed a preference for at least a general class of technology, with 19 selecting combustion and 7 selecting nominally non-combustion options for some disposal requirements. In the case of combustion technology, most have selected high temperature incineration (HTI) at established hazardous waste facilities, although 2 have indicated co-disposal in cement kilns may be used. Three non-combustion projects[3] have progressed to technology specification and two are moving forward to actually having demonstration facilities in place. Others have generally short-listed candidate technologies, subject to more detailed assessment.

Where a preference is specified, 25 GEF-4 projects indicate plans to export stockpiles for disposal, while 18 are pursuing in-country disposal options. Smaller and less industrially developed countries are electing export, while larger countries with more substantial industrial capacity are favoring existing or proposed new domestic disposal facilities, often with linkages to broader hazardous waste management capability. At least 24 projects have also included pre-treatment of POPs stockpiles and waste, typically related to decontamination of PCB-containing electrical equipment and contaminated oils. Similarly, many of these projects include capacity-strengthening related to POPs-contaminated sites.

In addition to the practical experience associated with NIP implementation, a number of other developments and broader trends have emerged since 2004 that influence selection of disposal technology. The Basel Convention on the Control of Transboundary Movement of Hazardous Waste and their Disposal (Basel Convention), as mandated under Article 6 of the Stockholm Convention, has prepared and periodically updates guidance for the overall management of POPs, as well as for specific POPs substances, including consideration of disposal technology options encompassing both combustion and non-combustion systems (Basel Convention, 2011). This guidance (Basel Guidelines) has been formally endorsed for use by the Parties and is considered the compliance benchmark. As such, the Basel Guidelines should be used in conjunction with this document in undertaking GEF-financed POPs disposal projects. There has also

3. Non-combustion demonstration projects in Slovakia (GEF ID 1692) and the Philippines (GEF ID 2329), and the Agent Orange clean-up project in Vietnam (GEF ID 3032)

been an expansion of the substances covered by the Convention (Stockholm Convention, 2009) which may impact disposal technology selection options as countries begin to undertake management of stockpiles and waste associated with them.

Global attention to sound chemicals management has progressed significantly. In particular, the SAICM framework serves to link and find synergies among a number of chemicals-related Conventions and international agreements, including the Stockholm Convention. Consistent with sound chemicals management, there is increasing recognition that management of POPs stockpiles and wastes should be integrated into the development of environmentally sound hazardous waste management capacity and infrastructure. While not explicitly addressed in this work, many of the technologies available for POPs disposal also have potential application to the broader end management of hazardous and chemical wastes.

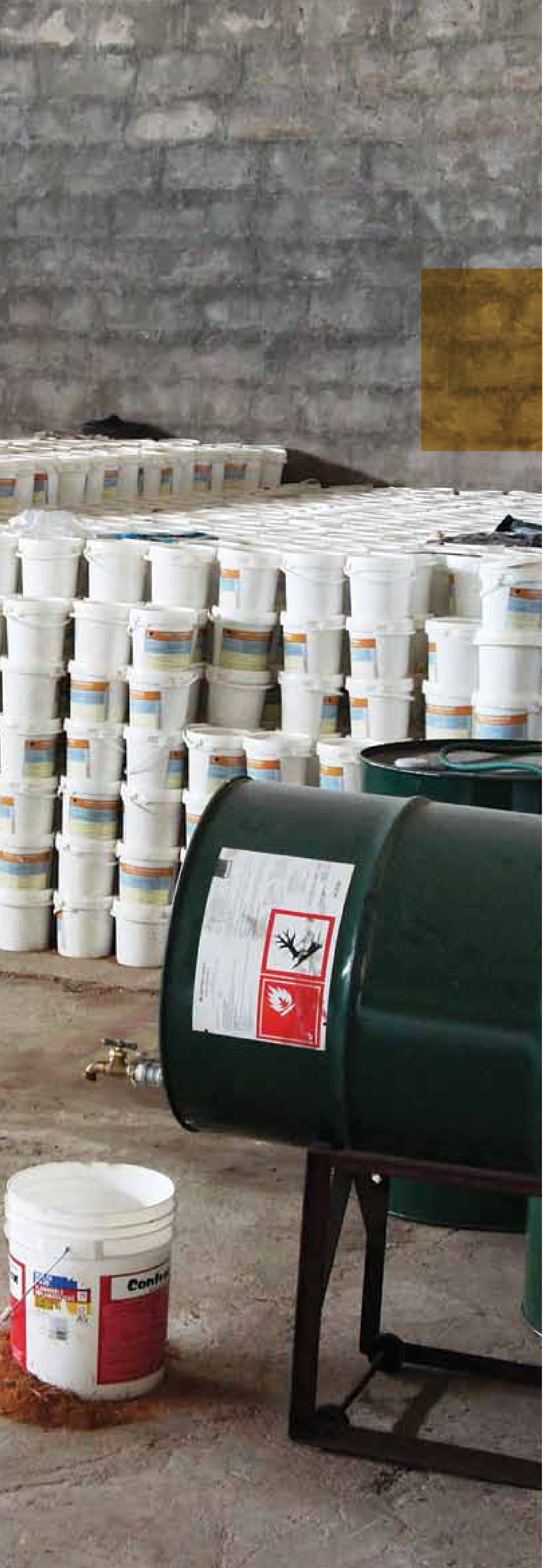
These linkages are reflected in the GEF-5 Focal Area Strategies (GEF, 2009) and Final GEF-5 Programming Document (GEF, 2005) with creation of a combined Focal Area covering sound chemicals management and encompassing the previously separate POPs and Ozone Depleting Substance (ODS) Focal Areas. With respect to ODS, an emerging priority of the Montreal Protocol is the environmentally sound destruction of "end of life" (EOL) ODS, which involves technology selection issues similar to those associated with POPs. Nevertheless, phasing out POPs and reducing POPs releases remains a primary objective (Chem-1) of the GEF-5 Chemicals Focal Area strategy with the large majority of resources being programmed toward that objective. More specifically, the amount of POPs waste prevented, managed, and disposed of, and the number of POPs-contaminated sites managed in an environmentally sound manner is a defined outcome (Outcome 1.4). The amounts of PCBs and obsolete pesticides, including POPs pesticides, disposed of are listed as the primary performance indicators.

Therefore, it is propitious for GEF/STAP to examine the current status of disposal technologies and their application through GEF financial support in developing countries and CEITs. The work expands the

guidance of the original GEF STAP study to reflect experience gained during GEF-4. This includes recognition that disposal technology should not be viewed in isolation. Other aspects of the waste management process also have a significant bearing on disposal system decision-making. The practical aspects of applying technology in a cost-effective and environmentally sound manner in developing countries and CEITs also deserve serious consideration.

While the focus of this document is on performance-based selection and application of disposal technology to POPs stockpiles and wastes, it also provides guidance regarding activities required to support disposal. It defines "safeguards": that is, measures assuring environmentally sound management during disposal of POPs stockpiles and waste. Safeguards guide implementing agencies and GEF beneficiaries as they prepare, approve, implement, monitor and evaluate GEF financed projects. Finally, there is a need to integrate commercial performance and economic-viability criteria into the technology selection process. Sustainable financial operation of a facility, regardless of the assessed technical and environmental performance potential, is critical to achieving ultimate environmentally sound disposal.

This work does not attempt to duplicate other detailed technology studies, the line libraries of technology assessments available, particularly those maintained by the Basel Convention (Secretariat of the Basel Convention, ND) the International HCH and Pesticide Association (IHPA, 2011), the comprehensive technology options study undertaken as part of several GEF-4 supported initiatives such as the Africa Stockpiles Programme (Africa Stockpiles Programme, 2011) and the recent comprehensive updated review of non-combustion technologies prepared by the United States Environmental Protection Agency (USEPA) (USEPA, 2010). Likewise, it does not create an expert Decision Support System (DSS) that could be utilized in screening, and ultimately selecting, disposal technologies. However, such a DSS may find application in conjunction with this guidance document on an application-specific basis, if it will be developed in the future.



2. Definitions Related to POPs Disposal

Article 6 of the Convention addresses measures to reduce or eliminate releases of POPs[4] in the form of stockpiles of Annex A and B chemicals, and wastes containing Annex A, B and C chemicals. It requires Parties to manage POPs stockpiles and wastes in a manner protective of human health and the environment. Management of POPs stockpiles and wastes includes their identification, as well as identification of products and articles in use that may become POPs stockpiles and wastes, and their physical management in a safe, efficient and environmentally sound manner, inclusive of handling, collection, transportation storage and disposal.

In the case of disposal, Article 6 states that this must occur so that *"the persistent organic pollutant content is destroyed or irreversibly transformed so that they do not exhibit the characteristics of persistent organic pollutants or otherwise disposed of in an environmentally sound manner when destruction or irreversible transformation does not represent the environmentally preferable option or the persistent organic pollutant content is low, taking into account international rules, standards, and guidelines."*

Article 6 also: i) excludes disposal operations that may lead to recovery, recycling, reclamation, direct re-use or alternative uses of POPs; ii) prohibits transport of POPs stockpiles and wastes across international boundaries without consideration of

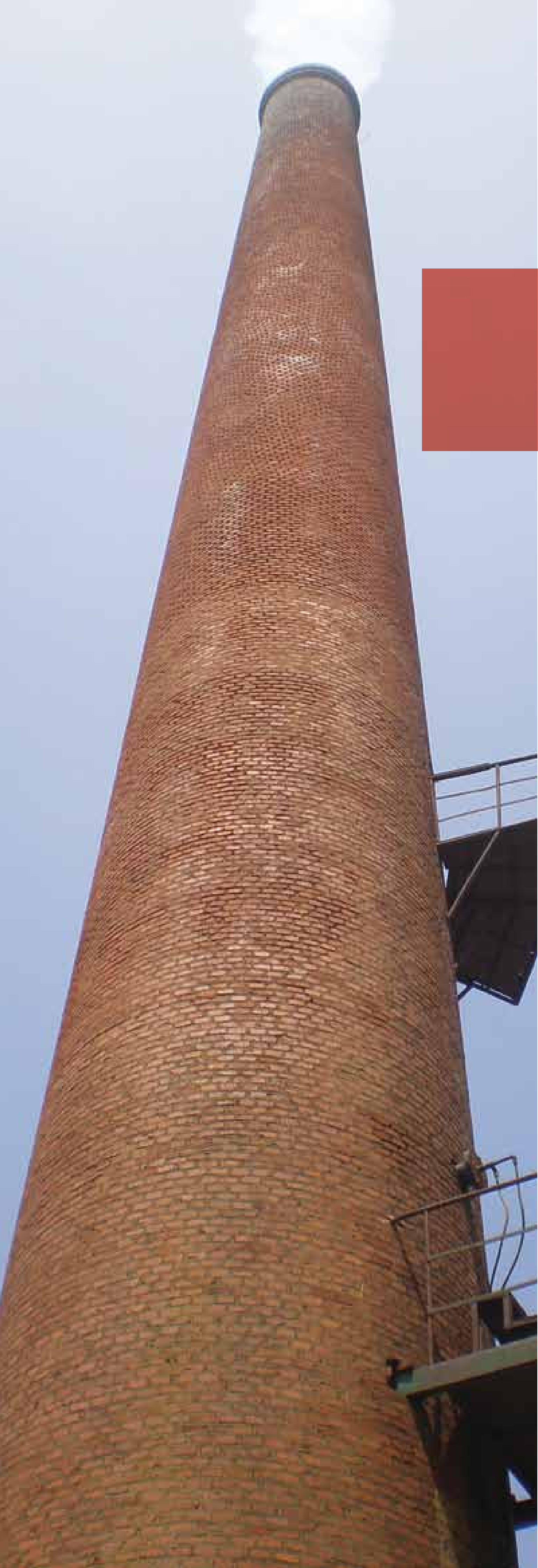
4. For purposes of this document POPs shall be those substances specifically defined as such in the Annex A, B and C of the Convention.

international rules, standards and guidelines; and iii) requires the identification and remediation of POPs contaminated sites in an environmentally sound manner. The referenced international rules, standards and guidelines encompass regional and global regimes governing the management of hazardous waste as well as guidance developed cooperatively with the Basel Convention.

The key criteria needed to assess the acceptability of disposal and the technologies applied are : i) the required level of destruction and irreversible transformation that is considered to eliminate the characteristics of POPs as defined in Annex D of the Convention; ii) standards for environmentally sound management of POPs stockpiles and wastes generally and specifically as may be defined by BAT/BEP standards where possible; and iii) acceptably low POPs content both in the context of defining what is to be considered as POPs stockpiles or wastes, and acceptable as residual POPs content in residues and releases after application of a disposal technology. The Stockholm and Basel Conventions share the mandate for determining these criteria. They are addressed on an interim basis in the Basel Guidelines for the originally designated Annex A, B and C POPs, with continuing joint work by technical bodies mandated by both conventions providing refinement and expansion on an ongoing basis. Ongoing guidance on these criteria can be expected in relation to "new" POPs, new and emerging technologies, and BAT/BEP standards applicable to them as they mature.

In addition, there is a need to integrate destruction technology evaluation and selection with techniques for other POPs management activities that are implicitly or explicitly covered by Article 6. Pre-treatment of POPs waste and stockpiles should be considered, both in terms of its environmentally sound performance but also in terms of its impact on selection, practicality, and performance of technologies considered for subsequent disposal. Similarly, management and disposal of residuals from destruction activities must be considered.

Article 6 also encompasses remediation of POPs-contaminated sites - soil, sediment or water - to a level defined by a cleanup standard, possibly the Basel low-POPs-content level. This may involve a mix of technologies that can either: i) remove POPs from the contaminated medium for subsequent destruction/irreversible transformation (i.e. disposal); and/or ii) destroy or irreversibly transform the POPs contaminant in-situ. While, remediation technologies cannot be strictly equated with disposal technologies applied directly to POPs stockpiles and wastes, in many cases they will be common, particularly where they complete environmental sound destruction or irreversible transformation to the cleanup standard meeting an accepted definition of low POPs content.



3. Strategy Options for the Overall Management of POPs Stockpile and Waste

The POPs waste management process encompasses roughly sequential phases of identification, capture and containment, pre-treatment (if applicable), and disposal inclusive of disposal verification, residuals management, and post disposal monitoring. The first three phases are undertaken prior to the disposal phase, and pre-existing infrastructure for residual management may also be required. Pre-treatment may be a distinct phase in advance of disposal or part of disposal *per se*. In any event, the "front end" phases, pre-treatment, and residuals management can each significantly impact the approach to disposal and the associated technology selection.

Identification. The first phase in management entails accumulating detailed knowledge of existing and potential POPs stockpiles and wastes. Potential wastes include POPs-contaminated equipment and products either still in use or which might be identified in the future. A baseline inventory of production and use of POPs, some knowledge of past POPs contamination of sites, and the location of current and potential stockpiles and waste form the starting point for NIP development.

Ideally, the NIP baseline inventory includes specific locations, current physical condition and custody of stockpiles, and potential risks if released. Similarly, the inventory should quantify POPs containing products in use. The principle example of this is PCB-containing equipment in service that will require some forecast of the rate at which it will be retired and added to the inventory for disposal. Similarly, some knowledge of potentially contaminated sites should be provided. This baseline inventory can help define disposal requirements sufficiently to allow planning for the needed scale and timing, as well as technical attributes required of the disposal technology and supporting infrastructure.

However, baseline POPs inventories are often less detailed than described above, and may require further data collection. In turn, this is often dependent on developing institutional capacity and legislative and regulatory tools to formalize identification and registration of POPs for control purposes. It also may require acquisition of analytical capability to support waste identification and prioritization. Therefore, additional refinement of the POPs inventory, inclusive of supporting information and capacity strengthening, may be needed before moving forward with the disposal phase. This will vary from country to country.[5]

Regardless of the complexity, GEF support for disposal should depend upon a reasonably accurate definition of the quantities of POPs targeted for disposal, their characteristics, their location, the feasibility of accessing them, and a forecast of future disposal requirements as a function of time and quantity. This will require critical assessment of the inventories as part of finalizing disposal strategy and detailed technology selection. For purposes of evaluating a country's readiness for funding the following should be considered:

i) The *legislative and regulatory framework* for control of POPs, including sites where POPs stockpiles and waste are located or sites that are contaminated with POPs, registration/labeling/status reporting of POPs-containing equipment and products in use, and provisions for enforcement of such controls;
ii) Current, creditable *inventory of POPs stockpiles and wastes* including quantity, general analytical characterization, location, owner, and assessment of current storage and containment status;
iii) Formal *inventory of POPs-containing products in use* linked to a general plan for their capture and removal from service in accordance with national phase out objectives and those required under the Convention;
iv) Formal *inventory of potential POPs-contaminated sites* with preliminary assessment of impact and risk;
v) Provision for maintaining and regularly updating inventories; and
vi) Availability of *qualified sampling and analytical capacity* to characterize POPs wastes and assess POPs content in POPs containing equipment, inclusive of institutional arrangements that provide for access to this capability.

Capture and Containment. Identified POPs stockpiles and waste should be captured and contained in a secure fashion, so as to immediately mitigate near-term risk and prevent release of POPs into the environment. Containment is particularly important as there may be significant delay between identification of POPs stockpiles and wastes, and the availability of financial resources for disposal.

Capture and containment involves securely packaging or containerizing these materials as required at their current locations, characterization via an itemized inventory, and protection against release during handling and storage. Packaging or containerization may also involve clean up and packaging of surface site contamination and isolation of consumables used in the packaging process. If the material is to remain at its original location, it may be necessary to provide secondary containment and security; however, it will more often be transported to a centralized secure transitional storage site. All practices, procedures and standards for these activities, including training and occupational health and safety provisions, should be established in national hazardous waste regulations and these regulations should be benchmarked against international standards. Substantial published guidance is referenced in the Basel Guidelines and, for POPs pesticides, in the guidance and training materials published by the United Nations Food and Agriculture Organization (FAO) (FAO, 2011).

5. It should be noted that the GEF-5 Focal Area Strategy makes provision for updating of NIP's which potentially allows resources to be directed to this kind of NIP refinement and should be coordinated with NIP implementation proposals.

The choice between locating transitional secure storage at the original location of the stockpiles, or a centralized designated facility will be a function of a variety of factors including, *inter alia*:

- i) Condition of POPs stockpiles and wastes any acute risks they pose;
- ii) Proximity to sensitive human or environmental receptors;
- iii) Physical state of the waste;
- iv) Public reaction to their presence;
- v) Quantity;
- vi) Existence of clear sustainable custody arrangements including appropriate training and equipment;
- vii) Pre-treatment considerations if applicable;
- viii) Estimates of future stockpiles and waste generation with associated storage requirements;
- ix) Availability of acceptable centralized storage or resource requirements to develop it, and
- x) Likely timing of undertaking actual disposal.

Large industrial or communal infrastructure facilities holding POPs stockpiles and wastes may be appropriate locations for transitional storage until disposal. Choice of such facilities must consider whether: i) the storage facility operator is financially stable; ii) the ownership and custody arrangements covering the subject POPs stockpiles and wastes are clear and undisputed; and iii) there is an ongoing need for such capacity for future POPs stockpiles. As an example, this option for storage could be appropriate where a major electrical utility holds significant stockpiles, has pre-existing maintenance infrastructure, and the technical capability to manage it.

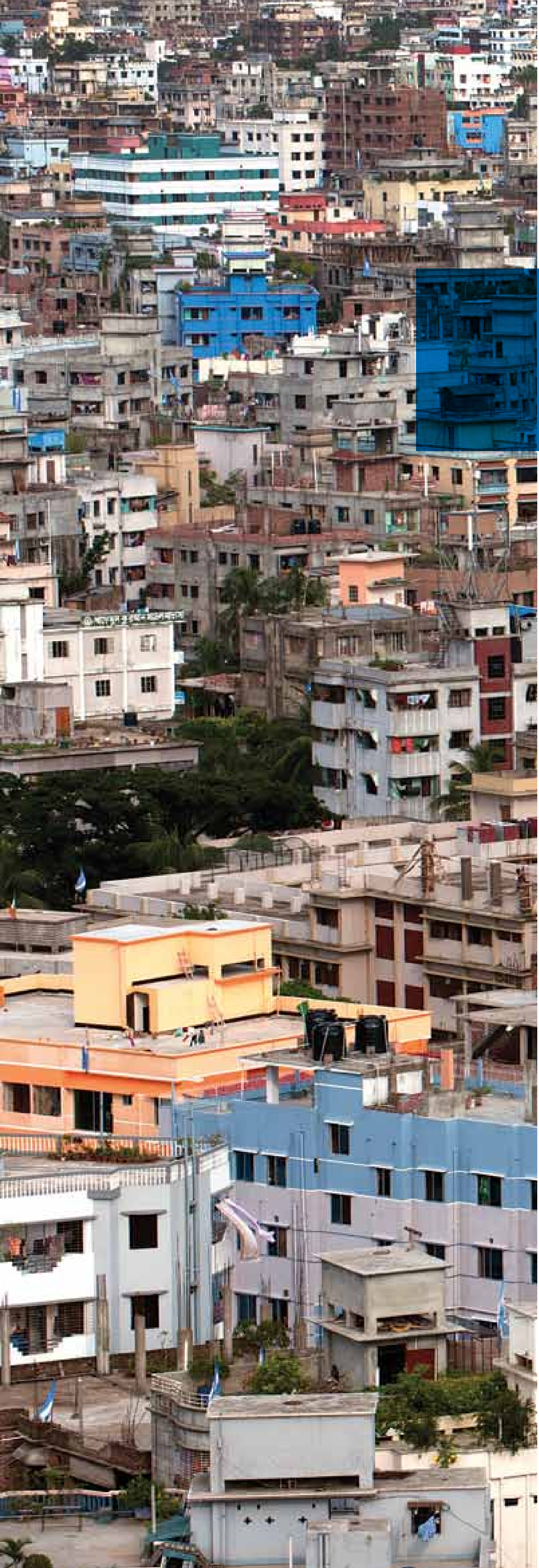
However, POPs stockpiles and wastes are often comprised of widely distributed small quantities with no clear custody or ownership, and thus are difficult to monitor. Such distributed stockpiles constitute a public liability, and a state responsibility is implied for re-packaging, local cleanup of contaminated material and consolidation at a centralized storage facility. Furthermore, this kind of secure transitional

storage may form part of a more general transfer station system developed as part of broader national chemical and hazardous waste management infrastructure. They may also serve as a basis for incremental development of pre-treatment and ultimately disposal facilities.

In summary, sustainable "front end" capability and capacity for identification, capture and secure containment/storage should be in place or committed to as a condition of major commitment to high cost disposal, and included in NIP implementation proposals.

The quantities of POPs waste and stockpiles will largely determine whether a country elects to develop its own disposal capacity to or access facilities elsewhere. NIP inventories show that POPs stockpiles and waste vary greatly, country to country, but estimated quantities are generally small compared to hazardous waste generated in even moderately industrialized countries, and would generally require a small portion of the broader commercial treatment and disposal capacity might be available or would developed. Thus, many countries should look to combining their POPs disposal requirements with others, either through exporting to existing facilities or collaborating in development of regional facilities. It also suggests that countries should carefully evaluate upstream pre-treatment as a means of reducing the amount of material requiring transfer elsewhere.

Initial system investment should commonly be for capture and containment via a secure transitional storage facility. In practice, the need for such capacity exists in virtually any country. Ultimately, the goal is disposal consistent with elimination of the materials, but secure storage may reduce the time pressure on selection of disposal technology. Further, high concentration POPs or those with particularly high risks for near term destruction - should be the priority, even if it means shipment to existing facilities - while storing lower concentration contaminated materials for future disposal.



4. Disposal Technology Performance, Safeguard and Commercial Requirements.

This section provides guidance on "environmentally sound disposal" and on "environmentally sound technology" utilized for disposal. It also introduces guidance for determining commercial sustainability.

Technical and Environmental Performance

As an overall principle, the Basel Guidelines, as periodically amended and adopted by the Convention, should constitute basic guidance and minimum standards applied to POPs stockpiles and waste disposal technology used in GEF funded projects. These may also be supplemented by other applicable internationally-accepted guidance. Similarly, credible national regulatory standards and applicable BAT/BEP standards, where available, should govern compliance with environmental performance parameters not related to POPs emissions or discharges. Likewise, a basic assumption in this work is that more restrictive technical and environmental performance standards would not be applied to GEF financing of POPs disposal in developing countries and CEITs than are applied in developed countries.[6]

6. This should does preclude or discourage developing countries or CEITs from adopting more stringent standards where as a policy this is felt appropriate and such standards can be achieved in a cost effective manner.

Environmentally Sound Technologies

Environmentally Sound Technologies maximize environmental protection, minimize environmentally damaging emissions, use resources in a sustainable manner, minimize waste generation, maximize waste/by-product recycling, and responsibly handle what residual wastes that are generated.

Environmentally Sound Technologies are complete systems that include know-how, technical procedures, goods and services, equipment, organizational/managerial procedures and a supporting sustainable commercial base. Consequently, the assessment, transfer and assimilation of these technologies involve human resources development, local capacity building needs, institutional and regulatory context, and sufficient and sustainable financing and commercial arrangements. Moreover, such technologies need to be compatible with nationally determined socioeconomic, cultural and economic development priorities while maintaining recognized environmental, human health and safety standards.

Environmentally Sound Technologies meet standards of environmental performance. Appropriateness of technologies for specific situations is determined by consistent, comparative evaluation of their environmental performance and impacts, and a range of technical, commercial and external factors. An expert Decision Support System (DSS) could be a useful tool for such a comparative evaluation.

Pursuant to Article 6 of the Convention, environmental performance standards should be applied to the following interrelated areas: i) degree of destruction or irreversible transformation required; ii) low POPs content; iii) permitted level of unintended POPs releases; and iv) environmentally sound disposal in the absence of destruction and irreversible transformation. In effect, the overall criteria for environmental performance of POPs destruction technologies should be based on the achieved level of destruction and irreversible transformation. That includes consideration of all waste output streams from the technology, inclusive of POPs other than those being destroyed that may be unintentionally produced during the destruction process.

Degree of destruction or irreversible transformation. The most comprehensive available parameter applicable to originating POPs stockpiles and waste is Destruction Efficiency (DE)[7] which is the percentage of originating POPs destroyed or irreversibly transformed by a particular technology. Destruction and Removal Efficiency (DRE)[8] which is the percentage of original POPs destroyed, irreversibly transformed and removed from the air emission stream, is also a commonly used parameter for degree of destruction in developed countries. Both parameters have limitations. Neither DE nor DRE take into account the potential for transformation of originating POPs to other POPs in the technological process. DE can be difficult to reliably and reproducibly measure. DRE only accounts for releases to air and not what could be transferred to other by-products and residuals streams. Recognizing the aforementioned limitations, these parameters are generally used as a technology performance measure in the destruction and irreversible transformation of originating POPs. Therefore this work recommends that an acceptable and demonstrated level of DE be used and that DRE may be used <u>in conjunction</u> with DE. This recognizes that, while the achievement of high DREs demonstrates minimal POPs release to air, this must not be accomplished via transfer of releases to other environmental paths. In practice, developed countries accept less than 100% destruction with some release from the process and retention of some level of POPs content in residuals. Based on the review of available commercial and near commercial technologies contained in

7. Calculated on the basis of the mass of the POP content within the waste, minus the mass of the remaining POP content in the gaseous, liquid and solid residues, divided by the mass of the POP content within the waste, i.e., DE = (POP content within waste – POP content within gas, liquid and solid residual) / POP content within the waste.
8. Calculated on the basis of mass of the POP content within the waste, minus the mass of the remaining POP content in the gaseous residues (stack emissions), divided by the mass of the POP content within the wastes, i.e., DRE = (POP content within waste – POP content within gas residual) / POP content within the waste.

Section 5, an attainable minimum DE is 99.99%, with 99.9999% DRE as a supplemental requirement where applicable provides practical benchmark parameters for assessing disposal technology performance. Higher demonstrated DEs may be preferred on a case-by-case basis. Conversely, where large amounts of POPs require disposal, and financial capacity is limited, the actual volume of POPs destroyed or irreversibly transformed may be maximized by use of a lower cost option that achieves the minimum DE, rather than a higher cost option that greatly exceeds the minimum DE. In any situation, best available techniques and best environmental practices (BAT/BEP), and a facility designed for safe operation of the specific technology involved, should be applied to ensure the anticipated environmental performance is achieved. Guidance on the actual residual POPs levels that need to be met is addressed below.

Low POPs Content. The Convention and the Basel Guidelines, sets out provisional limits for low POPs content, and the mechanism to review, expand and potentially revise these levels as required has been established jointly between the two conventions. The provisional levels currently adopted and which would apply for purposes of this guidance are: i) PCBs: 50 mg/kg; ii) PCDDs and PCDFs: 15 µg TEQ/kg; and iii) Aldrin, chlordane, DDT, dieldrin, endrin, heptachlor, HCB, mirex and toxaphene: 50 mg/kg for each. As of yet, low POPs content has not been defined for new POPs added to the Convention in 2010.

Unintentional releases from environmentally sound disposal. Recognizing that neither DE nor DRE take into account the potential for transformation of originating POPs to other POPs in the technological process, such releases should be accounted for in the assessment of technologies. Most commonly, this refers to atmospheric emission of PCDD/PCDF and other Annex C materials created during destruction processes. Generally, the benchmark level in developed countries and the Basel guidelines for PCDD/PCDF is 0.1 ng TEQ/Nm^3; however, state-of-the-art performance may be substantially lower and should be considered in comparative assessment of technologies. Standards for other unintended POPs release both to air and other media should be governed by pertinent national legislation and international rules, standards and the Basel Guidelines as they may cover such releases in the future.

Environmentally sound disposal in the absence of destruction or irreversible transformation. Most often, this refers to disposition of destruction residuals having POPs content below the low POPs content. It could also apply where financial resources are not available to for immediate POPs destruction but prompt interim action is needed. It may also apply when destruction is not an environmentally sound or practical option.

In the case of solids, the Basel Guidelines identify engineered landfills and permanent storage in underground mines and formations as technology options. The intent of the guidelines is that such disposal should minimize the risk of release of residual POPs to the environment, primarily to surface or ground water, and wider transfer into the open environment.

The guidance prohibits land disposal of liquid or semi-liquid POPs containing wastes or residues, and limits of solid disposal to facilities that meet accepted international or developed country requirements for hazardous waste land disposal (Basel Convention, 1995; EU, 1999; USEPA, 2011). These requirements should specifically cover: i) the natural hydrogeological setting and barriers it provides; ii) engineered barriers that limit infiltration into leachate and leachate escape from the landfill; iii) leachate collection and treatment capability; iv) POPs waste location identification in the landfill; v) ground and surface water monitoring; vi) closure requirements; and vii) post closure custody, monitoring, land use restriction, and liability arrangements.

As a general practice in relation to GEF Projects, land disposal options should be limited to solid waste that meets the Basel Guidelines' provisional low POPs content if considered anything but a transitional step to destruction. Solid wastes above the low POPs content level should be pre-treated to remove residual POPs, or ensure their potential release from the waste is minimized (USEPA, 1992; Environment Canada, 2002; European Communities, 2003). Where solid waste exceeds the low POPs content level, a specific justification and risk assessment for land disposal should be provided on a case-by-case basis. In no case should the POPs content exceed the level allowable consistent with international best practice. Similarly retained POPs content in liquid discharges to the general environment should be governed by credible national and/or international waste water discharge standards, and where practical subject to pre-treatment removal.

While the above guidance does not differentiate between combustion and non-combustion technologies, in reality, the majority of POPs disposal capacity in place globally is currently based on combustion, typically as part of broader commercial hazardous waste management systems. The majority of this capacity is based on high temperature incineration (HTI) designed generally for destruction of organic hazardous waste with some capacity provided through co-disposal in cement kilns. As a consequence, POPs actually disposed of using GEF support to date has relied on commercially-available combustion based facilities with demonstrated environmentally sound performance, meeting developed country regulatory standards. However, it is recognized that combustion technologies may underperform, particularly with respect to unintended POPs releases under Convention Article 5 and Annex C. For this reason, it is recommended that their use be consistent with the guidance on best available techniques (BAT) and best environmental practice (BEP) for provided by the Convention (Stockholm Convention, N.D.), and the European Commission IPPC BREF for BAT applicable to waste incineration (European Commission, 2006). In this regard, particular attention should be paid to facility-specific performance demonstration data, including emission monitoring practices and history, demonstration of performance on test burns, evaluation of residual POPs content in solid and liquid residuals and discharges results of test burn, and operating condition monitoring practice.

Safeguards Measures

The actual performance and effectiveness of a disposal technology is a function of its capability and its implementation, including controls, procedures, organizational arrangements and external stakeholder relationships. Best practice requirements applied to technology implementation are called "safeguard measures" for purposes of this work. Safeguard measures provide assurance that the disposal technology selected will be implemented as proposed and will perform as expected. GEF-financed projects should include the following:

National Regulatory Control System. A regulatory system, supported by legislation, at least potentially consistent with international practice and guidance, should be in place. This includes demonstrated government oversight and enforcement, whether disposal is taking place inside or outside the beneficiary country. Disposal arrangements must explicitly demonstrate compliance with Basel Guidelines Parts IV.A.1 and IV.B.2. POPs wastes above the low content level should be classified as hazardous waste for purposes of regulatory control. Regulations should require identification, labeling, registration and status reporting of POPs containing equipment and specify the types of containers, storage areas, transportation practice, acceptable sampling, analytical methods and safety procedures for each POP waste. A functioning environmental assessment and permitting system must be in place as well.

National Inventory of POPs Stockpiles and Waste. A comprehensive inventory of POPs wastes and POPs-containing equipment is needed. It should be current (beyond the initial NIP) and compliant with Convention reporting requirements (Section 3). Ideally, the national inventory should also cover POPs-contaminated sites and sources of unintended POPs release, integrated with a Pollutant Release and Transfer Register (PRTR) system and a broader chemicals management program.

National Implementation Plan. An endorsed NIP must be on file with the Convention[9]; however, it should be viewed as a living document and updated periodically.

Custody, Ownership and Liability. Legal custody and ownership of POPs stockpiles and wastes, inclusive of rights of access, must be clear. Similar clarity should exist with respect to financial liability for disposal, any environmental damage that may occur in the process or as a result of it, and any applicable monitoring and site closure requirements. In the absence of validated clarity the government should assume the default liability.

Environmental Assessment and Permitting. Disposal facilities, domestic or foreign must be specifically permitted for the disposal activities proposed. This includes an internationally benchmarked environmental assessment (EA) and Environmental Management Plan (EMP). An EMP would include regular performance evaluations validating compliance with permits and monitoring of POPs releases via analytical capability accredited to recognized standards. The World Bank provides an example of safeguards-oriented EA and EMP (World Bank, 1999) requirements which might be bolstered by an environmental management system (EMS) such as ISO 14000 (ISO, 2011).

Environmental Performance Demonstration. In many cases, technologies are screened and selected on the basis of past evaluations of facilities analogous to those proposed; however, such demonstrations may be based upon destruction of other POPs, in other forms or other concentration from those anticipated for the proposed facility. The "gold standard" for evaluation is demonstrated environmental performance by a facility operating according to the anticipated conditions, and is preferred. Where an existing facility is proposed to receive candidate wastes, selection should be based on documented performance. Where a new facility is involved, trials should be conducted during development, demonstrating compliance with environmental performance criteria. In either case, periodic monitoring of performance should be undertaken with lot-by-lot certification documentation of performance and fate of all residues and releases.

Public participation, consultation and disclosure. Public participation is a basic obligation and principle in the Convention (Article 10) with general guidance on it is provided in Part K of the Basel Guidelines. GEF supports the inherent right of the public and external stakeholders to timely access to information about POPs stockpile and waste disposal and to provide input on preparatory activities associated with the capture, transportation and secure storage of POPs stockpiles and wastes, as well as the fate and impact of releases and residues.

Thus, any facility, whether existing or proposed, must have a public participation, consultation and disclosure program. This program, including operating practices, emissions performance and decommission, if applicable, is a joint responsibility of the proponent organization and the authorities. The various tools include public hearings and meetings, media publicity, information brochures and documentation, and public access to project documentation in hard copy and electronic form. The government should monitor and facilitate public participation consistent with the Aarhus Convention on Access to Information, Public, Participation in Decision-making and Access to Justice in Environmental Matters (UNECE, 1998), or equivalent.

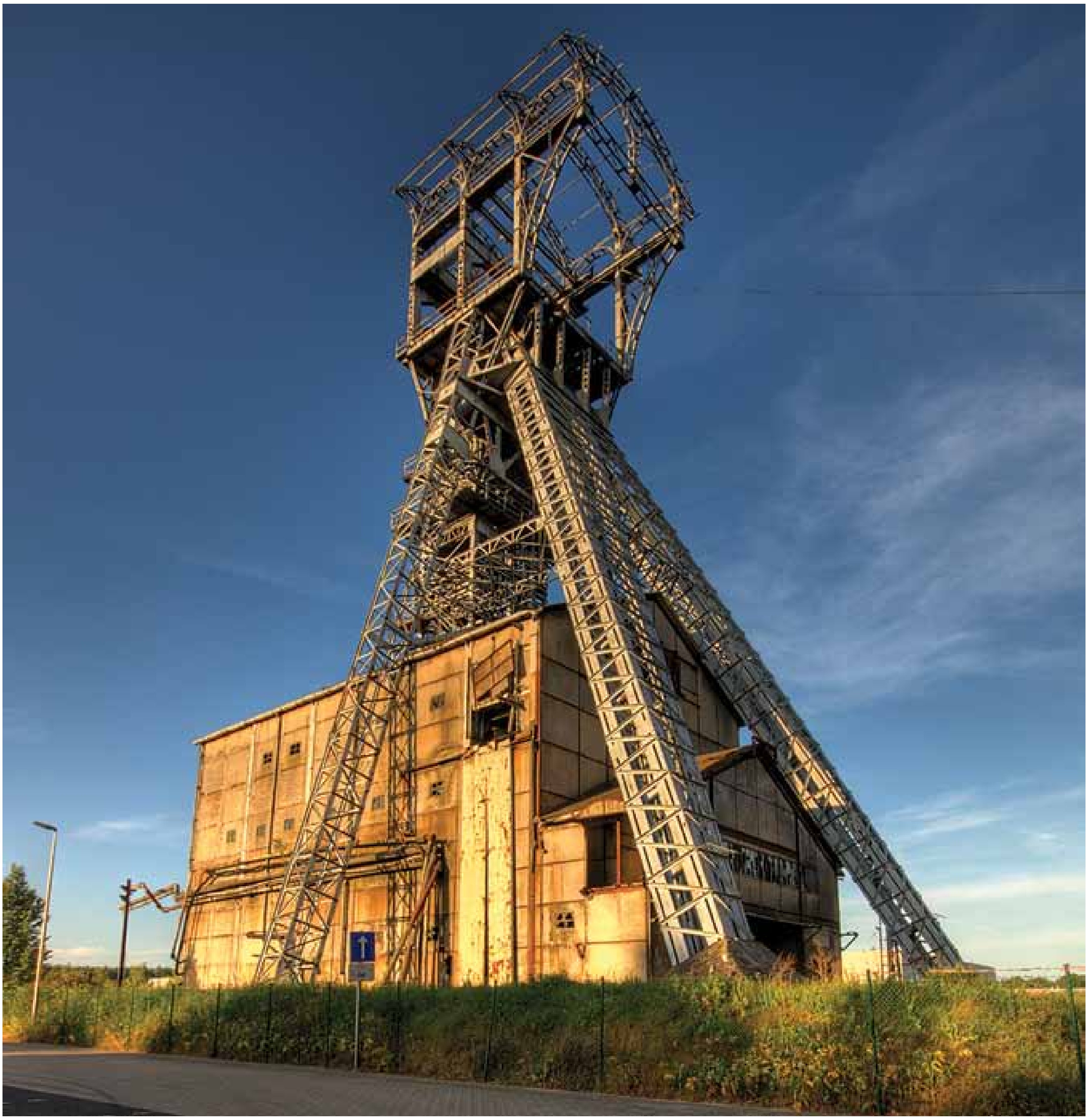
Health, safety and emergency response plans. Health and safety protection plans for workers and potentially exposed members of the public are required. The geographical extent of such plans should be determined by public concern and risk assessment methods. Health monitoring specifically related to potential impacts of exposure to POPs should be applied to workers; plants should be designed to avoid meaningful exposure to the public. Emergency response plans covering accidents and upset conditions must be in place. Specific guidance on the scope and content of these plans is provided in Sections I and J of the Basel guidelines along with international references.

9. It has generally been assumed that this is an eligibility condition for GEF funding although some flexibility has been provided where endorsement and submission is pending.

Commercial Viability

A successful POPs disposal project not only requires environmentally sound technology, but also a commercial arrangement that provides for disposal reliably at a predictable and affordable cost, and with assured completion. It must do so utilizing the available local supporting infrastructure, human resources and institutional and regulatory framework. This is most easily achieved by collaboration of the technology vendor, operating licensee and a local partnership with whom a viable commercial agreement can be negotiated. Experience shows that commercial viability rather than technical and environmental performance is the main barrier to practical application of POPs disposal technologies in developing countries and CEITs.

Said another way, despite GEF funding, where stable business and financial relationships are absent, the GEF investment may not result in any POPs disposal and the continuing risk of POPs release. Even if successfully implemented, a poor commercial arrangement under financial pressure can lead to compromised environmental performance and circumvention of required safeguards.



Examples of possible commercial arrangements where GEF financing could be involved include:

i) Reimbursement of Direct Disposal Costs. GEF financing is applied to actual disposal costs charged by a qualified commercial service provider offering environmentally sound disposal technology and the operational capacity to implement it. This will typically be provided on turnkey, unit cost basis, and be selected on a cost-competitive basis[10]. This is appropriate where wastes are directed to existing qualified domestic or foreign facilities or to a facility at an advanced stage of development using non-GEF financing.

ii) Contribution to New Disposal Facility Capital Development Costs. GEF financing could form a portion of the capital investment in new disposal facilities employing established fully commercialized technology in a developing country or CEIT for subsequent purposes of POPs disposal.

iii) Acquisition, Development and/or Demonstration of Disposal Technology. GEF could also contribute to acquisition of commercial technologies and their demonstration in the recipient country. Similarly, financing demonstration of a technology under development and/or commercialization within a recipient country might be proposed.

In general, the GEF objectives of maximizing the quantity of POPs eliminated (i.e. immediate global environmental benefit) and cost effectiveness, will be best achieved under the first scenario listed above; and ultimately, in the near term, may be where its resources are focused, recognizing this entails the least risk and greatest compatibility with the time frames dictated by the GEF project cycle. However, the GEF also has objectives related to facilitating technology transfer to developing countries and CEITs, hence the possibility of the second and third scenarios above. In both cases, it is prudent for GEF to approach such interventions cautiously, particularly noting higher risks and potentially longer time periods before concrete results are achievable.

GEF financing of capital investment in new disposal facilities should only be done selectively based on demonstrated country need and/or particular risk avoidance. GEF financing could assist as leverage to supplement a financing package where the majority of financing is committed by other credible funding sources. In such cases, the GEF may want to consider targeting its contribution to specific aspects such as qualification of the facility and technology such that it meets international standards or specific incremental components required to do so. It may also want to focus its contributions on facility development having broader national or regional application. In general, the GEF should avoid being the "the first money in" in such cases.

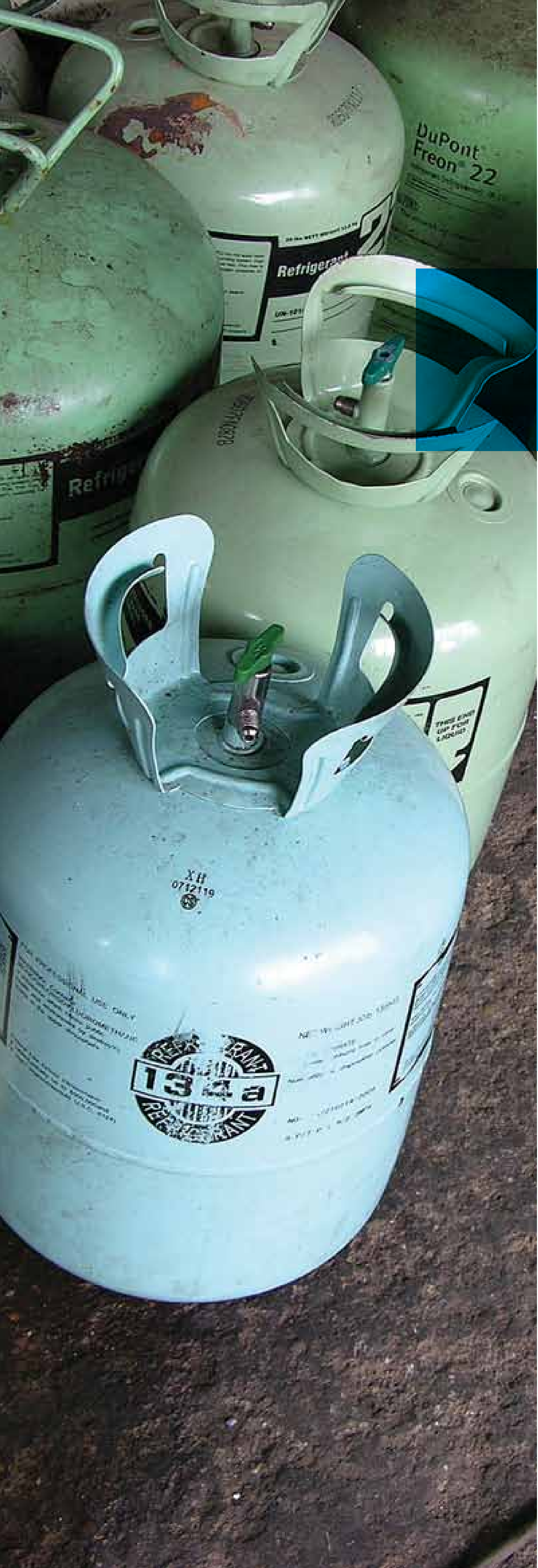
Notwithstanding the legitimate GEF objectives related to technology transfer, it should be recognized that technology acquisition is essentially a commercial business decision by its proponents within a country, and those proponents should lead the financing. Development and/or demonstration of technologies involve significant risks, potentially open-ended cost exposure, and uncertain time frames. For this reason, only such projects demonstrating technical, environmental and safeguard characteristics, as well as stable and sustainable business arrangements should be undertaken. Economic risk mitigation options include assurance of significant levels of co-financing, avoidance of large upfront financial exposure, and phasing of project activities. Similarly, such initiatives might focus on demonstrating smaller-scale and lower-cost technologies applicable to pre-treatment of POPs stockpiles and wastes, or demonstrations of site remediation exhibiting unique challenges and involving high environmental and health risk.

10. Recognizing that hazardous waste disposal has often been subsidized in developed countries, application of subsidies by national governments or waste generators to utilize locally qualified facilities could occur as matter of local policy, but the GEF funding should generally remain limited to a reasonable level based on what may be commercially available.

In any event, the justification for both direct capital investment in facility development, and technology transfer/ acquisition interventions should be clear in terms of global, as opposed to strictly local benefits. Such global benefits might include replication potential or utilization as regional infrastructure. Similarly, such a justification should include cost comparisons with alternatives such as using existing domestic or available external facilities employing qualified environmentally sound disposal technology.

An assessment of the commercial viability of any proposed POPs disposal technology should include:

- The degree to which the technology is, or can be made, available as a complete commercial offering applicable to the POPs stockpile and disposal requirement at the selected location and at reliability capped cost, inclusive of any set up, pre-treatment, training and operational supervision required, and with appropriate performance guarantees and monitoring.
- The level of technology maturity in the market place, its availability free of any dispute over technology ownership or licensee rights, its being offered by a commercial entity with a demonstrated relevant track record, technical support capacity and financial strength to undertake the proposed work, inclusive of the necessary local partnership arrangements, where applicable.
- Strength of local partnerships, where involved, measured in terms of relevant technical/operational experience and financial capacity, and potentially including backstopping by government to ensure the sustainability of local arrangements and completion of the disposal works.



5. Overview of Available Disposal Technologies

This section identifies and categorizes a number of available POPs disposal technologies that potentially meet technical and environmental performance requirements, and safeguard measures, as identified above. Appendix 2 provides an indicative candidate list of such technologies, from which a selection for purposes of screening might be made, followed by a more detailed comparative technical, environmental and commercial selection process. However, users undertaking specific technology selection work should carefully validate the general and indicative information provided with the referenced documentation and candidate vendors themselves. It is also not intended to exclude any other technologies or variations of those identified that can demonstrate the above requirements. New technologies or modifications of current technologies offering both improved environmental performance and cost-effectiveness will inevitably enter the market and may be considered.

In general, most of the technologies identified in Appendix 2 have been applied commercially, although in most cases not in developing countries or CEITs. The listed candidate disposal technologies generally encompass those identified in the Basel Guidelines, the 2004 GEF/STAP Report and other previously referenced technology reviews including the recent review by USEPA (USEPA, 2006). The principal ones are included in the Basel Convention and IHPA catalogues of technology specifications and data sheets (IHPA, 2011; Secretariat of the Basel Convention N.D.b). For the most part, this list is applicable to technology options of applying the technology on-site or off site in relation to the location of the subject POPs stockpiles and waste, and in the case of off-site applications, deployment in the beneficiary country or at a facility elsewhere. In most cases, they may also have application beyond POPs disposal and could address broader hazardous/chemical waste treatment and disposal requirements.

In using this information, it should be understood that application of POPs disposal technologies can present unique challenges in developing countries and CEITs. Available disposal technologies generally involve complex equipment, sophisticated controls and processes involving definable risks. They often require extensive support infrastructure, such as a reliable power supply and other utilities, for safe and sustainable operation. These kinds of factors represent potential barriers to application of technologies in developing countries and CEITs, even though they are in commercial or pilot scale operation in developed countries. Depending on local infrastructure, technical knowledge and expertise, it will be necessary to balance the general trend of increasing complexity associated with nominally higher performance technologies, with the situation in countries that may tend to favor simplicity to support their sustainability.

The list has been divided into four categories. The first three categories might be considered technologies intended specifically for destruction/irreversible transformation. They are differentiated between reducing, closed and/or oxygen starved operations (nominally non-combustion technologies), and oxidizing environments (nominally combustion technologies). The nominally non-combustion technologies are further differentiated between commercial and potentially commercial, noting that commercial viability should be validated for each specific application.

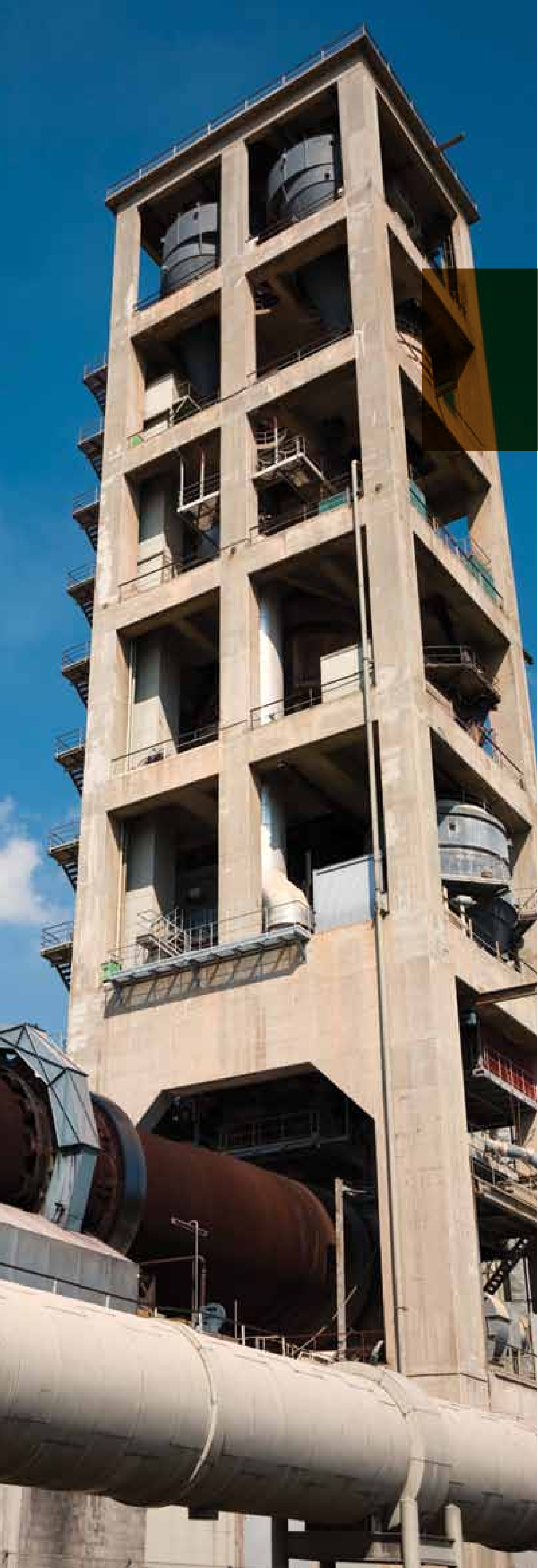
The last category applies to commercial pre-treatment technologies to separate and concentrate POPs for destruction/irreversible transformation. These technologies involve relatively sophisticated design and equipment. Other more common waste pre-treatment techniques may also be integrated into the primary pre-treatment and destruction/irreversible transformation technologies.

Appendix 2 does not include post-treatment disposal technologies typically applied to destruction residues that exceed the low-POPs concentration, nor to circumstances where destruction or irreversible transformation is not an environmentally sound option. For GEF recipient countries, an acceptable strategy is most often the provision of secure transitional storage until destruction capacity is available, rather than permanent land disposal in engineered landfills or underground mines and formations.

Solidification/stabilization techniques might apply as post-treatment technology to add containment assurance for disposal of low-POPs content waste or residuals, although engineered landfills are currently the preferred containment for such material, particularly if enhanced by passive biological processes.

Neither does Appendix 2 include biological, photochemical and phytoremediation technologies. While all these show promise and may have application as part of a menu of technologies, none is deemed mature enough as a process for inclusion herein. They could, however, be applied in combination with direct disposal technologies for bulk residual soil or waste solids after segregation from higher concentration POPs, or have application as a post treatment technology. Similarly, they may apply as a completion step where secure landfills are used for immediate containment. As the GEF may increasingly address POPs contaminated sites in the future, STAP may wish to consider a more detailed assessment of these types of technologies in the context of site remediation.

The technologies listed range from those provided by a sole vendor to those offered by multiple vendors in various configurations on a proprietary basis. Finally, it includes generic, well-established, widely available technologies replicable by experienced practitioners such that any potential end user could choose to adopt and develop facilities using them.



6. Disposal Technology Selection Process and the GEF Project Cycle

Technology selection will generally involve two stages. The first is a screening stage where a disposal technology is assessed on a coarse inclusion/exclusion basis. This should result in a short list of technologies anticipated to meet the stipulations of Sections 4.1, 4.2 and 4.3. Where it is to be applied in a GEF-beneficiary country, screening should also include assessment of the practicality of application under conditions prevailing in that country. The second stage is a detailed comparative assessment of technical and commercial proposals solicited for a site-specific application.

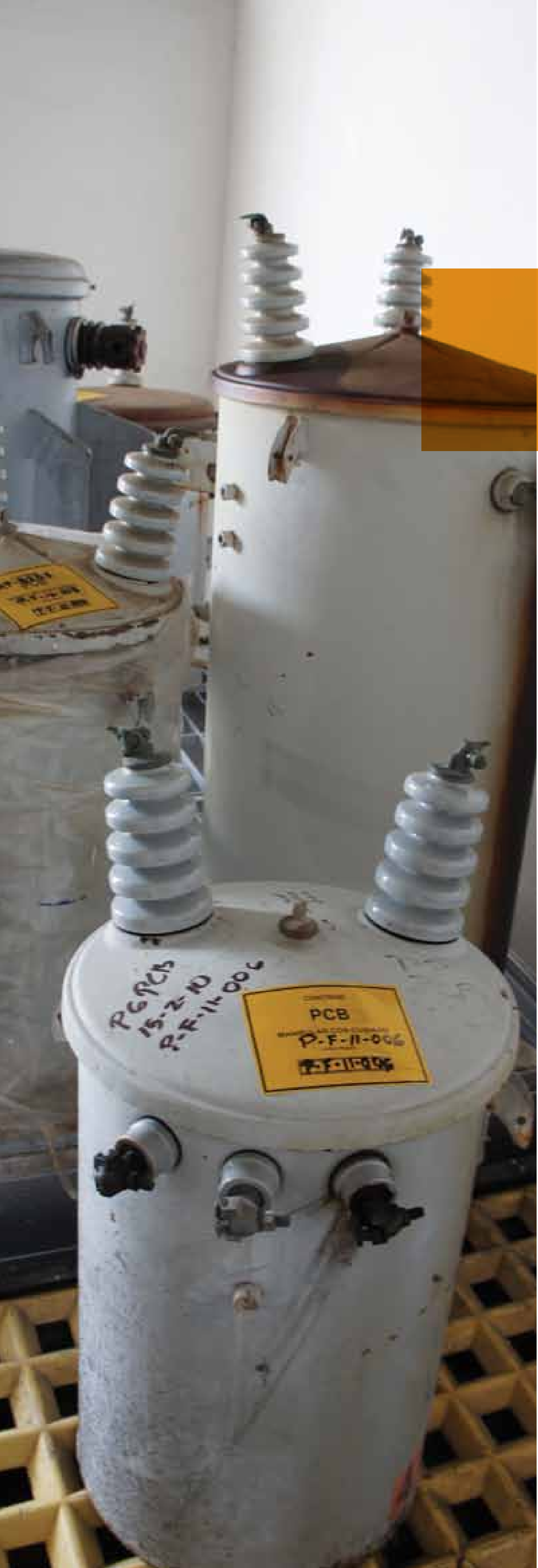
In the screening process, minimum performance standards can be assessed based on published and vendor-supplied information, to validate that requirements for such parameters as: DE; low-POPs content of residues and unintended releases; and management of residues and by-products, are achievable in the particular application. At this stage, a country may also apply exclusions dictated by national policy to classes of technology, such as exclusion applied to combustion technologies[11].

11. It is recommended that GEF's position on this be entirely neutral given its recommendation that selection be environmental performance based.

It may also consider domestic policy regarding application of the technology on-site (i.e. brought to the location of a specific POPs stockpile) or off-site, in either the GEF recipient country or elsewhere. If an exclusively in-country option is selected, the comparative analysis should include cost-comparison with export, and practical consideration of local support infrastructure, pre-treatment capacity, utility/consumables availability, and human resources, all of which may narrow the siting options. It may also include evaluation of the need for a technology demonstration step. Similarly, broader policy decisions related to development plans for general hazardous waste management infrastructure and stimulation of technology transfer should be covered. The screening stage should cover the probability of commercial viability being achieved, according to the criteria cited above.

The second stage of the technology selection process is a formal evaluation of proposals solicited from short-listed vendors/service providers and specific to a POPs stockpile and waste application. This should include technical, execution and commercial proposal components, and if required, proposals related to technology transfer. The basis for such proposals should be a comprehensive technical specification setting out the application requirements and conditions, and scope of work to be undertaken. The evaluation should involve well-defined decision factors and weightings based on expert judgment. Initially, this stage should verify the qualification results from the first screening stage. Where the application is deemed to require a demonstration step, it should include a proposal for the demonstration independent of a final commitment for its full scale application.

For GEF financed projects, the screening stage could be completed prior to the project's preparation stage, and be included with the Project Identification Form (PIF) submitted for entry of a project into the GEF work program. However, in many cases formal screening may occur during the project's detailed preparation stage, with results presented in the Implementing Agency's Project Document and Request for CEO Endorsement. The second stage (development of detailed specifications and formal solicitation/evaluation of proposals from short-listed vendors) might also be undertaken in whole or in part during detailed project preparation. However, the final selection of technologies and/or service providers could also be part of the competitive procurement process applied by the Implementing Agency and GEF beneficiary during project implementation. The complexity of final selection will vary depending on the specific application, commercial approach, the need for technology demonstration and inclusion of technology transfer provisions.



7. Recommendations and Conclusions

The principal findings of this work in relation to the selection of disposal technology applied to POPs stockpiles and waste in the context of GEF financed projects are:

- Technical and environmental qualification of POPs disposal technology should be performance-based.
- The evaluation of safeguards provisions and commercial viability should also be included in the selection process.
- Developing countries and CEITs should not be held to higher standards than those accepted in developed countries.
- Disposal is only part of the POPs management process and must be integrated with steps involving some or all of capture, containment, secure storage, pre-treatment, transport, and post disposal residuals management/monitoring.
- Economies of scale should be considered in any decision to build new or use existing facilities.
- Integration of POPs disposal requirements with those required for environmentally sound chemical/hazardous waste management should likewise be considered as part of broader national or regional infrastructure development.
- Inventories of POPs stockpiles and waste subject to disposal should be prioritized in terms of POPs concentration and risk of release to optimize the GEF interventions global environmental benefit and cost effectiveness.
- Environmentally sound disposal of POPs is not generally limited by availability of suitable

technology, but rather by the current cost-effectiveness and commercial maturity of the available technologies. This is particularly true when considering application in developing countries and CEITs where implementation and financial risks are generally higher.

- Primary Environmental Performance requirements recommended are:
  - Current Basel Guidelines should apply.
  - As a general principle, levels of POPs destruction and irreversible transformation should consider all POPs in waste output streams of a technology.
  - POPs destruction efficiency (DE) applicable to the originating POPs should be >99.99% with Destruction Removal Efficiency (DRE) >99.9999% as a supplemental requirement, particularly in relation to POPs release to air.
  - Low POPs content as specified in the current Basel Guidelines should apply as an upper limit for residuals.
  - Unintended release limits should be set at nominal developed country standards; i.e., 0.1 ng TEQ/Nm^3, for PCDD/PCDF air emissions.
- Specification of BAT/BEP for design and operating conditions on a technology-specific basis, where practical. While the highest overall destruction efficiency possible is preferable, where large amounts of POPs require disposal and financial capacity is limited, the actual volume of POPs eliminated and associated global environmental benefit may be maximized by use of a lower cost option that achieves the minimum DE, rather than a higher cost option that greatly exceeds the minimum DE.
- Safeguard measures are needed to assure implementation and achievement of performance as specified:
  - Institutional/regulatory commitment and capacity for oversight and enforcement.
  - Linkage to a national POPs inventory and endorsed NIP, regularly maintained and updated.
  - Undisputed legal custody and ownership of stockpiles and wastes with attendant financial responsibility.
  - Credible environmental assessment and permitting process.
  - Environmental performance demonstration.
  - Provision for operational monitoring of performance and tracking of POPs from acquisition to final disposition.
  - Public participation, consultation and disclosure.
  - Health, safety and emergency response plans.
- An evaluation of commercial viability and sustainability should be applied in the selection of POPs disposal technology including consideration of:
  - Availability of the commercial offering at predictable and competitive cost, inclusive of set up, pre-treatment, training and operational supervision, including appropriate performance guarantees.
  - Technology maturity in the market place.
  - Technology ownership or licensee rights.
  - Capacity of vendor/operator in terms of relevant track record, technical support capacity and financial strength to undertake the proposed work.
  - Local partner capability, including relevant technical/operational experience and financial capacity, as applicable.
  - Backstopping in the form of completion guarantees, as applicable.
- GEF financing may consider i) direct funding of disposal costs based on an all inclusive competitive price offered by a service provider with qualified disposal capability; ii) contribution to new disposal facility development costs; or iii) supporting technology transfer through acquisition and demonstration.
- In considering the above, a balance needs to be struck between the GEF objectives associated with maximizing the quantity of POPs eliminated (i.e. immediate global environmental benefit) in the near term as obtained through direct funding of disposal costs, and the objective of facilitating technology transfer and development of local infrastructure where completion, cost and timing risks are inherently greater, and POPs elimination is less in the near term.

Appendix 1

Summary Analysis of GEF POPs Funding to the End of GEF-4

	No. of	Commitments (Million US$)		
	Projects	GEF	Co-Financing	Total
Overall GEF Portfolio	219	412.2	666.5	1,078.7
Enabling Activities Portfolio	134	69.0	24.4	93.4
Country Specific Projects	133	63.2	21.3	84.5
Project less than US$0.5 million	130	54.3	5.8	60.1
Large Country Projects	3	8.9	15.5	24.4
Regional/Global Projects	1	5.8	3.1	8.9
NIP Implementation Portfolio	85	343.2	642.2	985.4
Country Specific	52	248.5	512.9	761.3
Regional/Global	33	94.6	129.2	223.8
Projects on Alternatives	7	44.4	55.7	100.1
Projects on Medical Waste	3	32.0	76.7	108.7
Projects on Unintended Releases	5	10.8	24.5	35.3
Projects on NIP Implementation Support/Capacity Building	22	37.5	45.4	82.9
Projects Including POPs Stockpile/Waste Disposal	47	215.8	433.2	649.0
Analysis of POPs Stockpile/Waste Disposal Project Scope				
Projects Undertaking Technology Selection Studies	28			
Projects Selecting/Favoring Combustion Technology	19			
Projects Selecting/Favoring Non-Combustion Technology	7			
Projects with No Stated Technology Preference	15			
Projects Based on Export for Disposal	24			
Projects based on In-Country Disposal	18			
Projects including Pre-Treatment	24			

Appendix 2

Summary Characteristics of Potentially Applicable Commercial or Near Commercial POPs Disposal Technologies (Destruction/Irreversible Transformation and Pre-Treatment)

Technology[12]	Application	Indicative Cost[13]	Pre/Post Treatment Requirements	Reported DE %	Reported DRE %	Residue POPs Release	State of Commercialization/ Adaption
1. Commercial Destruction/Irreversible Transformation Technologies Operating in Reducing, Closed, and/or Starved Oxygen Environments							
Alkali Metal/ Metal Hydroxide Reduction (Sodium Reduction, A-PEG)[14,15]	• PCB transformers (in-situ) • PCB contaminated oils (<10,000 ppm) • PCB contaminated soils • Capacitors/Ballasts • POPs pesticides and PCDD/PCDF contaminated materials	• PCB Oil US$0.5-0.7/kg • Mineral Oil U$0.2/kg • Soils $US 0.2-0.5/kg • Capacitors US$5.10/kg • Ballasts US$1.10/kg	• Dewatering (mitigate risk of explosive reaction) • Contaminated soils require pre-treatment by thermal or solvent extraction. • Re-treatment of transformers where leach back from internals occurs. • Transformer internals require environmentally sound disposal if equipment is waste	99.9- 99.999	99.9999	• Solid and liquid materials treated to 0.5-2 ppm	• Fully commercial and well established with multiple technology vendors and stable licensee arrangements capable of competitive tendering worldwide. • Fixed and mobile facilities possible. • Require secure infrastructure, trained technical staff, laboratory support, utilities and re-agent supply. • Moderate level of complexity but safety risks require mitigation

12. Information based primarily on the POPs Technology Specification and Data Sheets issued or provisionally developed by the Basel Convention, IHPA and USEPA per footnoted references except where noted.
13. Costs are representative based on literature and vendor indicative numbers, and will vary with specific application and location.
14. Secretariat of the Basel Convention (N.D.). Destruction and Decontamination Technologies for PCBs and other POPs Wastes under the Basel Convention. A Training Manual for Hazardous Waste Project Manager. Volume C. Alkali-Metal Reaction. Available at: http://cop10.basel.int/Portals/4/Basel%20Convention/docs/meetings/sbc/workdoc/TM-C%20Annexes.pdf
15. FRTR (ND). Remediation Technologies Screening Matrix and Reference Guide Dehalogenation. Available at: http://www.frtr.gov/matrix2/section4/4-17.html

Summary Characteristics of Potentially Applicable Commercial or Near Commercial POPs Disposal Technologies (Destruction/Irreversible Transformation and Pre-Treatment)

Technology[12]	Application	Indicative Cost[13]	Pre/Post Treatment Requirements	Reported DE %	Reported DRE %	Residue POPs Release	State of Commercialization/ Adaption
Base-catalyzed decomposition (BCD)[16]	• PCBs, POPs pesticides, PCDD in soil, solid, sludge and liquids	• US$0.7-2.2/kg depending on waste • US$300/$m^3$ (Soil) • 1.4-1.7 Euro/ kg. (2004)	• PH adjustment • Moisture control • Size segregation/ reduction • Thermal desorption step prior to treatment. • ESM disposal of treated material required. • Chemical additions (sodium hydroxide)	99.99-99.9999	>99.9999	• <2 mg/kg HCB/ lindane in soil • <3 mg/kg PCCD in soil • <60 mg/ kg PCCD in demolition waste	• Commercially available through established technology vendor/ licensee arrangements. • Several facilities operating worldwide. • Suitable for establishment in many countries provided volumes justify supporting high capital cost infrastructure. • Moderate to high complexity.
Gas Phase Chemical Reduction (GPCR)[17]	• PCBs, POPs pesticides, PCDD in spoil, solid, sludge and liquids.	• US$0.4-2.0/ kg (based on operating cost) • Capital cost US$5-10 million depending on mobile or fixed	• For solids requires thermal desorption separation prior to treatment.	>99.9999	>99.9999	• No residual POPs content or releases noted.	• Demonstrated in pilot and small commercial facilities in developed countries. • Fixed and mobile configurations available. • Require secure infrastructure, trained technical staff, laboratory support, utilities and re-agent supply. • High level of complexity including safe handling of hydrogen.

16. Secretariat of the Basel Convention (ND). Destruction and Decontamination Technologies for PCBs and other POPs Wastes under the Basel Convention. A Training Manual for Hazardous Waste Project Manager. Volume C. Base catalyzed decomposition. Available at: http://cop10.basel.int/Portals/4/Basel%20Convention/docs/meetings/sbc/workdoc/TM-C%20Annexes.pdf
17. Secretariat of the Basel Convention (ND). Destruction and Decontamination Technologies for PCBs and other POPs Wastes under the Basel Convention. A Training Manual for Hazardous Waste Project Manager. Volume C. Gas-phase chemical reduction. Available at: http://cop10.basel.int/Portals/4/Basel%20Convention/docs/meetings/sbc/workdoc/TM-C%20Annexes.pdf

Summary Characteristics of Potentially Applicable Commercial or Near Commercial POPs Disposal Technologies (Destruction/Irreversible Transformation and Pre-Treatment)

Technology[12]	Application	Indicative Cost[13]	Pre/Post Treatment Requirements	Reported DE %	Reported DRE %	Residue POPs Release	State of Commercialization/ Adaption
Plasma Arc [18,19]	• PCBs, POPs pesticides, PCDD in soil, solid, sludge and liquids	• US$0.5 to 3.0/ kg • US$1.0 million for 150 kW unit	• For solids requires thermal desorption separation prior to treatment. • ESM disposal of treated material required.	>99.9999	n/a	• <0.5mg/l POPs in liquid effluent • <1 ng/m^3 POPs in air. • <0.1 ng PCDD TEQ/Nm^3 • Solidified residuals generally meet leachate limits	• Commercially available technology with a number of operating facilities in developed countries. • Technology vendors with stable licensee arrangements capable of competitive tendering worldwide. • Fixed and mobile facilities potentially available. • Require secure infrastructure, trained technical staff, laboratory support and utilities and re-agent supply. • High level of complexity.
Pyrolysis/ Gasification	• PCBs, POPs pesticides, PCDD in soil, solid, sludge and liquids (in principle)	• US$0.75 – 1.00/kg (Based on operating costs) • US$275-500/ m^3 (Soils)	• Low moisture content required - drying • ESM disposal of treated material required. • High energy costs	99.974	99.9999	• Claimed to meet US/EU emission and disposal limits	• Commercial units from a number of technology vendors but limited application to POPs wastes. • Subject to demonstration of stable licensee arrangements should be capable of competitive tendering worldwide. • Fixed and mobile facilities potentially available. • Require secure infrastructure, trained technical staff, laboratory support and utilities and re-agent supply. • High level of complexity. • Moderate power consumption with reliable water and electrical supply.

18. For purposes of this work, Plasma arc technologies are those where organic destruction occurs within the arc itself while a number of technologies called Pyrolysis/Gasification involve a plasma arc but destruction results from the heat generated by the arc, generally at lower temperature
19. Secretariat of the Basel Convention (N.D.). Destruction and Decontamination Technologies for PCBs and other POPs Wastes under the Basel Convention. A Training Manual for Hazardous Waste Project Manager. Volume C. Plasma Arc. Available at: http://cop10.basel.int/Portals/4/Basel%20Convention/docs/meetings/sbc/workdoc/TM-C%20Annexes.pdf

Summary Characteristics of Potentially Applicable Commercial or Near Commercial POPs Disposal Technologies (Destruction/Irreversible Transformation and Pre-Treatment)

Technology[12]	Application	Indicative Cost[13]	Pre/Post Treatment Requirements	Reported DE %	Reported DRE %	Residue POPs Release	State of Commercialization/ Adaption
Mechanochemical Principle (Mechanochemical Dehalogenation, Mechanochemical Conversion, High Energy Ball Milling)[20,21,22]	• POPs contaminated soils (DDT, chlordane, PCDD, PCBs) • Potentially POPs containing liquids and solids.	• US$200-500/ m^3 (Soils using EDL MCD units) • Capital cost US$2-6 million depending on vendor	• Primarily for contaminated soils • Waste packaged in small containers. • Some configurations require de-watering and particle size reduction • Needs chemical inputs (i.e. hydrogen, magnesium, sodium)	99.99 - 99.999	99.9999	• Assessment required for secondary emissions and effluent contained in the closed system	• An emerging technology with pilot and limited commercial application to date. • Potentially a relatively simple, cost effective technology in developing countries in some configurations.
GeoMelt™[23]	• PCBs, POPs pesticides, PCDD contaminated soils or granulated solids	• US$200-500/ m^3 (soils)	• Batch mixing. • Dewatering/drying • Off gas emission control required • ESM disposal of treated material required.	90 to 99.99	99.99-99.9999 (with off gas treatment)	• Negligible air emission claimed. • Solidified residuals generally meet leachate limits	• Commercial operating facilities in a number of developed countries. • Require secure infrastructure, trained technical staff, laboratory support and utilities and re-agent supply. • Technology vendor with stable licensee arrangements capable of competitive tendering worldwide. • High power consumption. • High level of complexity.
2. Near/Potential Commercial Destruction/Irreversible Destruction Technologies Operating in Reducing, Closed, and/or Starved Oxygen Environments							
Mediated Electrochemical Oxidation	• PCBs, POPs pesticides, PCCD wastes in liquid or slurry form	• Not available	• Waste preparation to meet feed requirements.	>99.995	n/a	• Negligible in theory. • Requires assessment	• Pilot scale technology yet to be fully demonstrated or commercialized. • High use of energy and consumables. • High level of complexity.

20. Secretariat of the Basel Convention (ND). Destruction and Decontamination Technologies for PCBs and other POPs Wastes under the Basel Convention. A Training Manual for Hazardous Waste Project Manager. Volume C. Radicalplanet Technolog. Mechanochemical Principle. Available at: http://cop10.basel.int/Portals/4/Basel%20Convention/docs/meetings/sbc/workdoc/TM-C%20Annexes.pdf
21. Secretariat of the Basel Convention (ND). Destruction and Decontamination Technologies for PCBs and other POPs Wastes under the Basel Convention. A Training Manual for Hazardous Waste Project Manager. Volume C. Mechanochemical Dehalogenation. Available at: http://cop10.basel.int/Portals/4/Basel%20Convention/docs/meetings/sbc/workdoc/TM-C%20Annexes.pdf
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23. Secretariat of the Basel Convention (ND). Destruction and Decontamination Technologies for PCBs and other POPs Wastes under the Basel Convention. A Training Manual for Hazardous Waste Project Manager. Volume C. GeoMelt. Available at: http://cop10.basel.int/Portals/4/Basel%20Convention/docs/meetings/sbc/workdoc/TM-C%20Annexes.pdf

Summary Characteristics of Potentially Applicable Commercial or Near Commercial POPs Disposal Technologies (Destruction/Irreversible Transformation and Pre-Treatment)

Technology[12]	Application	Indicative Cost[13]	Pre/Post Treatment Requirements	Reported DE %	Reported DRE %	Residue POPs Release	State of Commercialization/ Adaption
Molten Salt Oxidation	• PCBs, PCB contaminated solid, Chlordane in trails	• US$1.0-1.5/kg (estimated)	• Waste preparation to suit process unit configuration	>99.9999	>99.9999	• Requires assessment	• Pilot/laboratory scale technology requiring commercial scale demonstration. On a broader range of POPs • Availability of stable licensee arrangements capable of competitive tendering uncertain. • High level of complexity.
Solvated Electron[24]	• PCBs, POPs pesticides, PCDD in soil, solid, sludge and liquids	• Not available	• Dewatering • Waste size reduction	99.999 (PCB Oils)	Not available	• Requires assessment	• Commercial scale operation plus pilot operations • High level of complexity.
Supercritical water oxidation (SCWO)[25]	• PCBs, Chlordane, PCDD, PCDF. • Liquid and slurries with <20% organic content, and particle size under 200um • Vendor reports capability for 100% organic content	• Capital costs US$1.2-1.5 million	• Waste preparation to meet feed requirements.	98.7-99.8 Vendor reports higher DE potential	>99.9999	• Requires assessment	• Specialized commercial plants operating in a number of developed countries. • Remains under evaluation and demonstration for more general POPs applications. • Technology vendor with stable licensee arrangements that should be capable of competitive tendering worldwide. • High level of complexity.
Thermal Retorting	• Primarily POPs contaminated soils and obsolete pesticides.	• US$0.75-1.82/ kg	• Thermal desorption built into process. • ESM disposal of treated material required.	99.9999	n/a	• PCDD Air emissions < 0.01 ng TEQ/ m^3	• Demonstrated at a relatively small scale facility in commercial quantities of POPs contaminated soils. • Potential for stable commercial arrangements suitable for broad international application exists but status uncertain. • Moderate level of complexity.

24. Secretariat of the Basel Convention (ND). Destruction and Decontamination Technologies for PCBs and other POPs Wastes under the Basel Convention. A Training Manual for Hazardous Waste Project Manager. Volume C. Solvated Electron Technology. Available at: http://cop10.basel.int/Portals/4/Basel%20Convention/docs/meetings/sbc/workdoc/TM-C%20Annexes.pdf
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Summary Characteristics of Potentially Applicable Commercial or Near Commercial POPs Disposal Technologies (Destruction/Irreversible Transformation and Pre-Treatment)

Technology[12]	Application	Indicative Cost[13]	Pre/Post Treatment Requirements	Reported DE %	Reported DRE %	Residue POPs Release	State of Commercialization/ Adaption
Copper Mediated Destruction (CMD)	• PCBs, POPs pesticides, PCCD/F wastes in solid, liquid and gaseous form	• Not available	• Size reduction/ homogenization for solids to meet feed requirements • Preliminary thermal desorption in some applications	99.0 to 99.999 depending on POPs based on solid residues	n/a	• Negligible in theory • Requires assessment	• Pilot scale technology yet to be fully demonstrated or commercialized. • Mobile containerized basic unit for batch application constructed (10 m^3 batch capacity, 1.25-2.5 m^3/hr). • Claimed scale up potential to 100 m^3 • Energy and consumables not well defined. • High level of complexity.
• Commercial Destruction/Irreversible Destruction Technologies Operating in Open Oxidizing Environments							
Cement Kiln Co-disposal[26]	• PCBs and POPs pesticide wastes in liquid and solid form	• US$1.0-5.0/kg • Facility specific.	• Specialized size reduction and injection measures. • Blending to meet chlorine content limitations on process	<99.9999	<99.9999	• Air emissions <0.1 ng PCDD-I/m^3	• Commercial application in developed countries and demonstrations in developing countries. • Generally limited to relatively modern rotary kiln units with overall BAT/BET environmental performance equipped with appropriate POPs waste handling/ injection infrastructure as well as monitoring capacity. • Application requires case by case assessment and performance demonstration.
High Temperature Incineration (HTI)[27]	• All POPs wastes in any physical form	• US$ 0.1-2.5/kg depending on waste type and form	• Depending on facility, size reduction, dewatering, and waste blending. • ESM residue disposal capacity required.	99.88-99.999	99.9999	• Air emissions <0.1 ng PCDD-I/m^3 • Low discharges to water effluent. • 1,500 ng PCDD TEQ/ kg for APC residues. • 50 ng PCDD TEQ/kg ash.	• Extensive commercial application on developed countries. • High capital and operating costs. • Sophisticated emission controls and monitoring required. • Economies of scale >30,000 t/ year generally required for development with broad application to hazardous organic wastes generally. • Mobile/semi-mobile 2-5,000 t/year capacity available but with cost premium and potential environmental performance penalties.

26. Secretariat of the Basel Convention (ND). Destruction and Decontamination Technologies for PCBs and other POPs Wastes under the Basel Convention. A Training Manual for Hazardous Waste Project Manager. Volume C. Cement Kiln Co-Processing (High Temperature Treatment). Available at: http://cop10.basel.int/Portals/4/Basel%20Convention/docs/meetings/sbc/workdoc/TM-C%20Annexes.pdf
27. Secretariat of the Basel Convention (ND). Destruction and Decontamination Technologies for PCBs and other POPs Wastes under the Basel Convention. A Training Manual for Hazardous Waste Project Manager. Volume C. Hazardous Waste Incineration. Available at: http://cop10.basel.int/Portals/4/Basel%20Convention/docs/meetings/sbc/workdoc/TM-C%20Annexes.pdf

Summary Characteristics of Potentially Applicable Commercial or Near Commercial POPs Disposal Technologies (Destruction/Irreversible Transformation and Pre-Treatment)

Technology[12]	Application	Indicative Cost[13]	Pre/Post Treatment Requirements	Reported DE %	Reported DRE %	Residue POPs Release	State of Commercialization/ Adaption
• Commercial Primary Pre-Treatment Technologies							
Autoclaving[28]	• PCB contaminated equipment.	• US$1-1.5/kg • Capital costs of US$1 million (Mobile unit)	• Equipment draining/rinsing, dismantling, size reduction, non metallic separation • Environmentally sound Disposal of drained oils, rinsing solvent, non-metallic components	99.999	n/a	• None from process. • Residuals require ESM Disposal	• Fully commercial and well established • Fixed and mobile facilities. • 2,000 t required to establish facility. • Access to environmentally sound disposal through export or locally required.
Thermal Desorption[29,30]	• PCB and POPs pesticides contaminated solids. • Generally applied to soil.	• US$0.1-0.2/kg • US$200-600/ m^3 (soils)	• Materials handling and possible de-watering. • ESM destruction of recovered POPs. • ESM treatment/disposal of treated material depending on removal rates achieved.	n/a Removal rates in soils of 95%-99.99%	99.9999 (Based on vendor input)	• Residual levels in soils of PCBs <2 ppm and PCDD/F <0.003 µg/kg.	• Well established technology that can be engineered for specific applications or acquired from equipment vendor/commercial service providers • Potential to provide some destruction at elevated temperatures used in in-situ or in-pile soil treatment configurations.
Solvent Extraction/ Washing	• POPs contaminated soils. • PCB contaminated equipment.	• US$125-225/ m^3 (soils)	• Materials handling. • ESM destruction of recovered POPs (often integrated with destruction processes). • ESM disposal of treated material.	Removal rates to 99%	n/a	• Residual levels of PCBs or POPs pesticides in soils <50ppm. • Equipment surfaces to local regulatory limits (10 µg PCB/100 cm^2	• Well established technology that can be engineered for specific applications or acquired from equipment vendor/commercial service providers.

28. Secretariat of the Basel Convention (ND). Destruction and Decontamination Technologies for PCBs and other POPs Wastes under the Basel Convention. A Training Manual for Hazardous Waste Project Manager. Volume C. Autoclaving. Available at: http://cop10.basel.int/Portals/4/Basel%20Convention/docs/meetings/sbc/workdoc/TM-C%20Annexes.pdf
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