UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION

PROJECT DOCUMENT

PROJECT FOR THE GOVERNMENT OF MOROCCO

Project number:	GF/MOR/07/XXX
Project title:	Safe PCB Management Programme in Morocco, Pillar II
GEFSEC Project ID:	3082
Starting date:	July 2008
Duration:	3 years
Project site:	Morocco
Government Co-ordinating agency:	Ministère de l'Énergie, des Mines, de l'Eau et de l'Environnement (MEMEE)
Counterpart: Executing Agency/ cooperating agency:	Directorate for Environmental Monitoring and Prevention of Environmental Risks (DSPR) of MEMEE
Project Inputs:	
GEF grant:	US$ 2,437,600
UNIDO inputs:	US$ 50,000
Support costs (10 %):	US$ 243,760
Counterpart inputs:	US$ 4,806,000
- *Private sector*	*US$ 4,554,000*
- *Government*	*US$ 252,000*
Grand Total:	***US$ 7,537,360***

Brief description:

This project document "Environmentally sound management and disposal of PCB-contaminated transformers in Morocco" proposes the provision of technical assistance to public and private sector actors to increase the in-country capacity for overcoming identified barriers for safe and sustainable management of PCB-contaminated transformers at all stages of their life cycle.

The proposed project is the second pillar of an overarching project on the management of PCBs in Morocco, which is jointly implemented by UNIDO and UNDP. In parallel to the proposed project, UNDP will implement pillar I of the overarching project, which will focus on the strengthening of the legal, regulatory and institutional capacity in Morocco with regard to PCB management and on the disposal of pure PCB-containing equipment.

This project aims at updating the inventory of PCB-contaminated electrical equipment and at establishing a decontamination/treatment facility for the environmentally sound dechlorination and reclamation of PCB contaminated mineral oil as well as at the decontamination, reclamation and recycling of copper and steel recovered from PCB contaminated mineral oil transformers. This will include the cleaning of pure-PCB transformer carcasses and recovery of the metallic components derived from the UNDP implemented pillar I.

The project will consist of 4 Outcomes as follows:

Outcome 1:	Identification process set up for PCB contamination in in-service and decommissioned transformers .
Outcome 2:	Environmentally sound maintenance and treatment of in-service PCB contaminated mineral oil transformers in participating industries set up.
Outcome 3:	Environmentally sound disposal of decommissioned PCB contaminated transformers and material recovery set up
Outcome 4:	Project management, monitoring and evaluation (M&E)

The project is expected to last for 3 years. Upon completion of the project, Morocco would have treated and reclaimed at least 3,000 tons of PCB contaminated mineral oil from in-service equipment. In addition, Morocco would also have the in-the-country capability to deal with PCB contaminated electrical equipment and other related material to ensure compliance with the Stockholm Convention on Persistent organic pollutants.

Approved:

	Signature:	Date:	Name and title:
On behalf of **the Government of Morocco**	____________________	__________	___________________
On behalf of UNIDO:	____________________	__________	___________________ **D. Piskounov** **Managing Director, PTC**

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LIST OF ACRONYMS AND ABBREVIATIONS

AMEDE	Association Marocaine des Expert en Gestion des Dechets et en Environnement
APR	Annual Project Report
BAT/BEP	Best Available Techniques / Best Environmental Practices
CNEDS	Centre National pour l'Elimination des Déchets Spéciaux
CGEM	Confédération Générale des Entreprises du Maroc
COP	Conference of the Parties
DSPR	Directorate for Environmental Monitoring and Prevention of Environmental Risks
EA	Executing Agency
EIA	Environmental impact assessment
GEF	Global Environment Facility
GTZ	German Corporation for Technical Cooperation
IA	Implementing Agency
MEMEE	Ministère de l'Energie, des Mines, de l'Eau et de l'Environnement (Ministry of Energy, Mining, Water and Environment)
MIS	Management Information System
MDG	Millenium Development Goal
M&E	Monitoring and Evaluation
NEA	National Executing Agency
NGO	Non-governmental organization
NIP	National Implementation Plan
NPM	National Project Manager
OCP	Office Chérifien des Phosphates
ONE	Office National de l'Electricité
ONEP	Office National de l'Eau Potable
OP	Operational Program
PCB	Polychlorinated biphenyls
PCDD/PCDFs	Polychlorinated dibenzo-p-dioxins and -dibenzofurans
PIR	Project Implementation Report
PIWR	Project Inception Workshop Report
PM	Project Manager
POPs	Persistent Organic Pollutants
PSC	Project Steering Committee
SC	Stockholm Convention
SEA	Strategic Environmental Assessment
TOR	Terms of Reference
TPR	Tri Partite Review
UN	United Nations
UNDP	United Nations Development Program
UNIDO	United Nations Industrial Development Organization

SECTION A. CONTEXT

1. The management of polychlorinated biphenyls (PCB) has only quite recently found a central role in the environmental debate in Morocco. While some awareness already exist and some isolated PCB management efforts has taken place, the signing and ratification of the Stockholm Convention on persistent organic pollutants (POPs) has raised the PCB issues higher on the agenda. The project, its outputs and its activities are directly addressing the issues regarding the environmentally sound management of PCBs and is in parallel implementing the Stockholm Convention obligations.

A.1 THE STOCKHOLM CONVENTION AND MOROCCO

The Convention

2. POPs possess toxic properties, resist degradation, bioaccumulate and are transported, through air, water and migratory species, across international boundaries and deposited far from their place of release, where they accumulate in terrestrial and aquatic ecosystems. With years of emissions before their environmental risk became known, POPs have already become an international environmental problem that human kind must face.

3. In May 2001, the Stockholm Convention on POPs was adopted with the aim of protecting human health and the environment from POPs. The Convention entered into force on 17 May 2004. Three Conferences of the Parties (COP1, 2 and 3) have been convened to specify detailed requirements and procedures for the implementation of the Convention.

4. The Global Environment Facility (GEF) has been selected as the Convention's financial mechanism. In October 2002, the GEF Assembly approved the addition of POPs as a new GEF focal area, and in November 2003, the GEF Council approved the GEF Operational Program on POPs – OP#14.

Overview

5. The Government of Morocco ratified the Convention on 15 June 2004 and has already co-operated with the Global Environment Facility on PCB issues in the process of investigating the POPs situation and deliberating the National Implementation Plan (NIP) for POPs. The POPs NIP was finalized and submitted to the Stockholm Convention Secretariat on 2 May 2006.

The National Implementation Plan

6. During the NIP process the following priorities were identified: "development of national capacities with regard to POPs management" ;"Updating the national legislation to the Convention obligations into account" and " Development of a strategy for eliminating equipment containing PCBs from the national environment and destruction of oils contaminated by PCBs, in an environmentally sound manner". As a response to these priorities, a three-pronged POPs NIP consisting of 1) Regulatory and institutional measures, 2) Technical aspects of POPs management, 3) Training, Sensitization and Communication; was developed.

7. This project is a direct continuation of the POPs NIP in the area of PCB management.

PCB sources and project strategy

8. Until early 1980s, many of the big electric transformers and capacitors installed in Morocco contained PCB as insulating oils, mainly "Pyralene" and "Askarel". PCBs were filled in imported equipment but were mainly imported as oils to be filled by the local transformer manufacturers. As manufacturing of PCB oils was discontinued at international level, the local manufacturers shifted to non-PCB based alternatives.

9. The local manufacturing base was set up by companies of French origin hence Pyralene was the main type of PCB oil used. Due to the various changes in the ownership of the transformer manufacturers and time period passed since stopping PCB imports, the exact magnitude of the imported PCBs into Morocco is unknown.

10. Moreover, in the preparatory phase of this project from December 2007 to February 2008, more than 100 mineral oil transformers were tested for a possible PCB-contamination. Besides this most recent study, two inventory projects for PCB equipment have been undertaken in Morocco before initiation of this project. MEMEE compiled the first inventory of PCB equipment in 2002, with the assistance of the Swiss Development Cooperation. A second round of investigation was conducted in 2004-2005 within the framework of the POPs Enabling Activity project.

11. The inventory compiled at the end of the Enabling Activity project identified 573 pure PCB transformers containing about 200 tons of PCB. Further, 342 PCB containing capacitors were inventorized which will be collected, drained and dismantled in pillar I implemented by UNDP. While the pure PCB oils will be treated abroad as part of the UNDP pillar I activities, contaminated materials from this part, such as carcasses and copper wires, will be decontaminated in course of the proposed project.

12. Despite of two rounds of PCB investigation, it is still believed that increasing quantities of PCB-contaminated equipment would be discovered, as PCB holders certainly will become more sensitised to the issue, particular during the implementation of pillar I by UNDP.

13. In this regard, it can be noted that some companies have already made some oil analysis and found considerable amounts of contaminated oils. Further, retrofilling of PCB containing transformers have been carried out previously by major PCB holders resulting in transformers that are certain to be contaminated. Companies known to have undertaken transformer retrofilling have been contacted to identify which equipment has undergone oil change.

14. With regard to in- service PCB contaminated mineral oil transformers, some 80,000-100,000 are estimated in the country.

15. Results of the above-mentioned analysis of 100 mineral oil transformers undertaken in the preparatory phase of the proposed project showed that 31 out 100 transformers were contaminated by PCBs. Further analytical results of tested mineral oil transformers confirm that the contamination of PCBs in these transformers is more widely spread that originally thought, exceeding the level of contamination found in other jurisdictions such as Canada and the USA. While, the level of PCB contamination in mineral oil transformers filled is in the order of 15% in North America, the preliminary figures for Morocco seem to be in the order of 20 to 25 %. This significant difference could be based in the delayed of dealing with the PCB issues in Morocco, allowing for further spreading of the contamination problem.

16. Statistical studies to estimate an accurate number of in-service and decommissioned PCB contaminated mineral oil transformers were carried out on the basis of the electricity consumption and on the number of new transformers put in services in the last years. Moreover, this estimation was accompanied by visits to the main companies (ONE - Public electrical company, ONEP - Office for drinking waters, OCP - Office for Phosphates, COSUMAR – and ONCF - National Railways) and to private PCB analysis laboratories (OKSA Maroc and SD Myers) to collect data on the level of contamination.

17. On the basis of the statistical analysis it is estimated that about 100,000 transformers would exist in Morocco. These transformers include a relatively small number (0.5% of total) of power transmission units installed in generating and transmission stations, containing an estimated average of 60,000 kg of mineral oil each, a moderate number (4.5% of total) of medium size distribution transformers installed in distribution stations, containing an estimated average of 1,000 kg of mineral oil and a large number (95% of total) of small distribution transformers, installed in whole country distribution grid, containing an estimated average of about 100 kg of mineral oil.

18. Based on 100,000 transformers, the estimated amount of mineral oil in electrical transformers is 44,000 metric tons. Preliminary results of analytical testing of transformers filled with mineral oil show that about 20 – 25 % of the units tested show PCB contamination above 50 mg/kg or ppm. Based on the results of preliminary testing, the PCB contaminated mineral oil inventory in Morocco is about 13,000 metric tons, distributed in about 30,000 transformers spread in a territory that covers the whole country.

19. In addition to the PCB contaminated mineral oil and based on the weight distribution of mineral oil in transformers (UNEP Workshop on PCB Management and Disposal, Geneva June 9th, 2004) show that the weight distribution in transformers equipment can be calculated as 34% mineral oil, 58% metals, and remaining 8% paper and wood), the 30,000 PCB contaminated transformers also contain about 22,000 metric tons of contaminated metal (cooper and steel) and about 3,000 metric tons of wood and insulating paper.

20. In order to assess available technologies for the disposal of PCB-contaminated electrical equipment in Morocco, several feasibility studies on incineration as well as non-combustion technologies (see Annex C, D and E) were undertaken during the preparatory phase of the proposed project.

21. The findings of the feasibility study on incineration technologies (see Annex C) showed that incineration plants and cement kilns would represent comparable technological options to dispose of POP wastes, including PCBs in Morocco. However, updated and environmentally sound hazardous waste incinerators are not currently present, or those existing are very old, low sized and poorly equipped. The study concluded that a construction or upgrading of such incineration facilities would result in high investment costs, due to necessary changes (retrofitting) for compliance with the Best Available Techniques / Best Environmental Practices (BAT/BEP) obligations under the Stockholm Convention. Therefore, it was found that the disposal of PCB wastes (either pure PCB oils or contaminated mineral oils) in such facilities would not represent an economically viable option for this project.

22. The feasibility study on non-combustion technologies (see Annex D) and on possible technology options for the environmentally sound management of PCBs in Morocco (see Annex E) revealed that the proposed project for the provision of technical assistance to the public and private sector by establishing a transformer dismantling facility and a PCB contaminated mineral oil dechlorination plant in Morocco is an environmentally and economically sound option for the treatment of PCBs in the country. This option will retain the value of decontaminated mineral oils and scrap metal in the country and will provide a long-term PCB management solution for owners of PCB-contaminated electrical equipment in Morocco by creating local disposal alternatives and increasing employment in the Moroccan waste disposal sector.

23. The technologies outlined in this study, namely the Based Catalyzed Dechlorination, Sodium-Based Processes and the Solvated Electron Technology represent sound, proven dechlorination alternatives that can be adopted and implemented in Morocco.

24. The following figure outlines the treatment of different PCB waste streams in the proposed project:

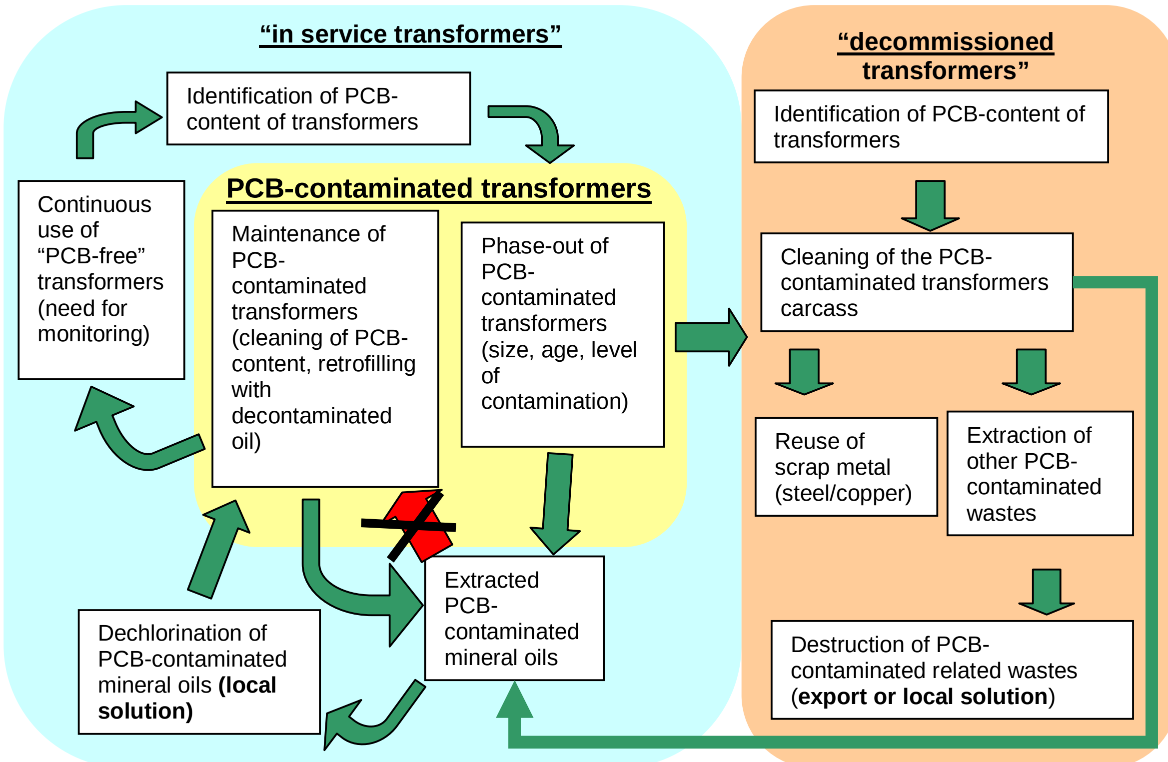

Fig. 1: PCB waste streams

25. The existence of nearly 13,000 metric tons of PCB contaminated mineral oil in Morocco and this GEF co-financed project represent a significant market opportunity for technology vendors to be interested in bringing their technology to Morocco. This market can be complemented by the potential excursion of the technology vendors to neighbouring countries.

26. During the preparatory phase of the proposed project, several providers of technologies for PCB-dechlorination, dismantling of transformers, and PCB analysis, such as Tredi/Séché, Univers Electrique, Nitam/Ducamp, Altair, Edic, and SD Meyrs, expressed their interest in participating in this project.

27. Although the total amount of PCB contaminated mineral oil in Morocco's electrical system is about 13,000 tons, the overall tonnage of PCB contaminated mineral oils that will be treated in the framework of the project and put in service will be at least 3,000 tons. The dechlorination unit set up in this project will assure the environmental sound disposal of the remaining tons of contaminated mineral oils and hence the Project sustainability.

28. Retrofilling of in-service transformers (mainly large transformers in generating and transmission stations; and medium sized transformers in distribution stations), with the treated and reclaimed oil from the dechlorination unit, will leach the PCBs from the metal surfaces and the cellulosic material, to the less than 50 ppm threshold limit.

29. As the amount of PCB contaminated mineral oil to be treated in the framework of the project is only a fraction of the expected material to be found in Morocco, the establishment of the decontamination facilities will allow the remaining PCB contaminated oil to be decontaminated also in the same facilities acquired by the project

30. Additionally the project aims at treating the transformer casings from pure PCB-containing transformers from pillar I implemented by UNDP.

31. The project will therefore cover the maintenance, treatment and final disposal of such contaminated mineral oils transformers and relevant wastes, as well as the recovery of valuable metals from high and low level PCB contaminated transformers.

32. Activities under this project will be integrated as mush as possible with the plans included in the national hazardous waste strategy and the planned Centre National pour l'Elimination des Déchets Spéciaux (CNEDS), which is part of the GTZ assisted Programme de Gestion et de Protection de l'Environnement (PGPE). In order to avoid any duplication of work to dispose PCB- contaminated transformers UNIDO and GTZ-PGPE agreed to collaborate in the following fields (see Annex G):

- Information exchange and sharing of experiences in the PCB management and disposal field;
- Training and outreach of key stakeholders on PCBs; and
- Undertaking of feasibility studies for the selection of PCB destruction technologies (e.g. cement kilns, non- combustion technologies etc.).

33. Moreover, the proposed project, will tie close contacts and exchange of experiences with the UNEP-led regional PCB project, in which Morocco will participate. In order to ensure that project activities of these two projects are fully complementary, it is foreseen to either establish close links between the project management teams of the national UNIDO/UNDP project and the regional UNEP project or to merge these two teams to form a joint management structure for both projects. With the implementation of the UNDP-led pillar I of the overarching PCB project in Morocco and the development of PCB management structures in pillar I and by implementing activities of the proposed project, Morocco will gain vast experience in establishing regulatory regimes and in the environmentally sound management and disposal of PCBs. This experience gained will be shared with participants of the UNEP-led regional PCB project and will therefore provide benefits to the whole region.

34. The project aims at acquiring and installing in Morocco a facility to dismantle and decontaminate PCB contaminated transformer carcasses and a chemical de-chlorination unit to decontaminate PCB contaminated mineral oils. This facility will also treat PCB-containing waste derived from the UNDP implemented pillar I that seeks to dispose of pure PCBs in identified pieces of equipment. While the disposal of pure PCB-oils is foreseen as a waste exportation operation, the residual equipment carcasses will be decontaminated and the metals recovered in the proposed dismantling and decontamination facilities to be built in Morocco as part of this project.

35. It is expected that in the dismantling facilities, following drainage of the PCB liquid, the transformers would be taken apart with metallic and other non-porous components being cleaned on-site using mineral oil or a similar fluid and the porous material (insulating paper, wood, rubber, etc.) could be properly packaged and sent for disposal in an appropriate facility (export or cement kilns in Morocco). The PCB contaminated oil from the cleaning of the non-porous material, as well as the significant volume of PCB contaminated mineral oil from in-service transformers, will be efficiently decontaminated using internationally available chemical PCB destruction processes.

36. As cited above, about 13,000 metric tons of contaminated oils could be found in Morocco. The overall tonnage of PCB contaminated mineral oils that will be treated in the framework of the project and put in service is at least 3,000 tons. The de-chlorination unit set up in this project will assure the environmental sound disposal of the remaining tons of contaminated mineral oils and hence the project sustainability

Country Eligibility and Country Drivenness

37. Morocco signed the Stockholm Convention on 23 May 2001 and ratified the Convention on 15 June 2004. The Moroccan National Implementation Plan for POPs was submitted to the Secretariat of the Stockholm Convention on 2 May 2006. The NIP puts management of PCBs as first priority for a successful implementation of Stockholm Convention obligations and commitments.

38. Consequently, the Government of Morocco directly upon ratification of the Convention applied for preparatory funding for developing the project. The process of preparation of the PCB management project has been implemented through National Execution modality and under

close supervision of MEMEE underlining the commitment of the government to make serious progress on PCB management.

39. The private sector partners (PCB owners and technology providers) have expressed their strong interest in participating in the project and to accelerate the replacement of PCB-contaminated transformers in Morocco. To emphasize their commitment they have put their money behind their commitment, and will invest considerable 2/3 of the total project budget towards the replacement equipment.

A.2 THREATS, ROOT CAUSES AND BARRIERS ANALYSIS

40. There is a generally low level of awareness on the risks and threats stemming from PCB-contaminated electrical equipment. The origin of these risks and threats have not been fully understood and accepted by owners of electrical equipment in Morocco. Some companies have taken voluntary action, however only the recent ratification of the Stockholm Convention has prompted clearer commitment and action from the government's side, as also manifested by this proposal.

41. In most countries, addressing the PCB problem has included the identification, management and treatment of PCB contaminated mineral oil transformers. The early analytical information about the contamination of mineral oil transformers with PCBs indicates that this problem exists in Morocco and the fraction of PCB contaminated mineral oil transformers could exceed the numbers found in other countries. Ignoring this problem threatens the proper care of the PCB issue and will inevitably make the problem bigger and more difficult to resolve in the future.

42. As PCBs has not been produced for some years, equipment containing PCBs have not been renewed and are ageing with potential for leakages and electric failures increasing the risk of fires. Consequently the threat to humans and ecosystems from the PCB equipment is increasing by the day. The significant number of potentially PCB contaminated mineral transformers and the wide distribution of the transformers in the electrical grid network makes this threat even more significant.

43. It is known that catastrophic failure of electrical transformers could involve the burning of the dielectric fluids. As mineral oil has a flash point of about 145 ℃, this fluid would burn if the proper conditions exist within the transformers. When the mineral oil is contaminated with PCBs, the burning of the PCB containing mineral oil would undoubtedly form polychlorinated dibenzo-p-dioxins and -dibenzofurans (PCDD/PCDFs).

44. It is also know that some PCB contaminated mineral oil transformers may contain trace level of PCDDs/PCDFs. The spillage of the PCB contaminated oil containing these even more toxic contaminants will result in the unintentional release of PCDDs/PCDFs, jeopardizing the Moroccan Government intention to curtail such releases.

45. One of the main threats associated with the continuing existence of PCB containing equipment is the potential contamination of waters. The catastrophic failure of the PCB contaminated transformer and the spillage of the dielectric fluid has the potential to contaminate water sources and fertile land. Water, especially fresh water supply and quality issues are very important to Morocco due to rapid population growth and erratic rainfall.

46. Studies show that acute water shortages, often due to drought, have been intensified by soil erosion in recent years, resulting in the silting of reservoirs and salinization caused by inefficient uncontrolled irrigation. Urban and agricultural pollution is contaminating the water sources that supply two-thirds of the country's water.

47. The PCB contamination of fresh water reservoirs and sources is poorly investigated. L'Office National de l'Eau Potable, ONEP, has recently commenced analysis of PCBs in drinking water and have not found elevated levels.

48. On the other hand, sediments outside large cities are highly contaminated with PCBs[1]. The sediment from the Port of Tangier appears very contaminated, values of 164-452 ng/g [2] are recorded even if the trend is towards a decrease.

49. The area of the city of Tetouan is somewhat contaminated, as expected considering the presence of industrial activities. The levels (4.84-8.22 ng/g), however, remain relatively low. It should be noted that the Martil River leading from Tetouan to the Mediterranean Sea shows elevated PCB concentrations.

50. The PCB contamination data is not adequate for making a proper risk assessment. This would require a full contaminant mapping and systematic monitoring with time trends in soils, sediments and biota. However, the limited data indicates frequent releases. The amount of PCB-contaminated equipment as well as the deteriorating condition of the equipment makes the PCBs oils a clear threat for the human health status and environmental quality in Morocco.

51. The root cause to the unsustainable management of PCB-contaminated electrical equipment is a lack of knowledge and poor understanding of the consequences of unsustainable maintenance and disposal practices. Reasons for this can be a generally low level of awareness of decision makers and PCB owners on the consequences of releases of PCBs for human health and the environment; the lack of information on the location and level of contamination of PCB-contaminated equipment; and the lack of know-how and technical training in environmentally sound management of PCB-contaminated electric equipment.

52. Financial considerations are also important contributing root causes for unsustainable maintenance and low replacement rates of PCB equipment. Many companies are unable to find the necessary financial means of replacing and maintaining PCB-contaminated equipment in an environmentally sound manner. Reasons may include a lack of cash flow and profitability; the generally high transformer prices in Morocco; and a lack of legal requirements that impedes the phasing out of PCB-contaminated electrical equipment that has not yet reached the end of its life cycle.

Barriers analysis

53. A number of barriers for safe and sustainable management of PCB and replacement of PCB-contaminated equipment have been identified in Morocco. These barriers can be roughly divided into legal, awareness and know-how related, technical capacity, economic and industry/ trade policy. The barriers can seldom be pinpointed to a specific policy or action but are embedded into overall structures and systems.

Legal barriers:

54. There exists no legislation in Morocco banning or restricting the use of PCBs in any applications before materials are classified as waste. Consequently, the requirements of specific handling precautions or disposal methods are absent in legal documentation or technical guidance. Therefore and quite naturally, the industrial inspections do not include PCB considerations when assessing handling or take into consideration risky situations/operations involving PCBs or PCB containing equipment.

Awareness barriers:

55. One main barrier for not taking action on PCBs is the lack of awareness of the risks and consequences of unsustainable management of PCBs. The largest gap has so far been in awareness among the policy makers at various government institutions as well as among some major industry partners. Progress in understanding the PCB issues have been attained during the NIP and preparatory stages of this project.

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[1] Polychlorinated Biphenyls in Sediments of Selected Sites of the Moroccan Coastal Zone, Rossano Piazza, Bouchta El Moumni et al. ORGANOHALOGEN COMPOUNDS – Volume 66 (2004) 1374-78

[2] European marine sediment upper limit, when dredged material have to be treated, are around 200 ng/g. Limit for concern and detailed impact studies is 25 ng/g.

56. However, the PCB awareness/knowledge level is not at a sufficient level among regional environmental officials or among other government officials, i.e. customs officials who may be come in contact with PCB equipment and are a key group in avoiding further entry of PCBs in the country.

57. Though efforts in educating industrial partners in identifying PCBs and PCB containing equipment has been carried out, notably as part of the POPs Enabling activity project, there still exists public sector entities and companies to which awareness/information has not reached. This is particularly the case for smaller companies who have only few potentially PCB-containing equipment.

58. Awareness barriers also exists in the inability of the PCB owners and transformer service companies to recognize the existence of the PCB-contaminated mineral oil problem and to understand that the significant number of units potentially contaminated with PCBs and their wide distribution in the grid system represents a major environmental threat.

59. Awareness/know-how related barriers exist in the handling, maintenance and storage stages of PCB and PCB contaminated equipment management. As major holders of equipment are getting informed about the risks of PCBs, they are more and more needing advice on how to set-up their maintenance and daily operations in order to avoid exposure and releases. The barrier is hence not technical as the technical solutions are often quite simple; the barriers are related to know-how on good housekeeping and best practices for PCB contaminated material.

60. Also awareness about the different management approaches for identified PCB equipment is a barrier for choosing appropriate solutions. Also the awareness/knowledge of all consequences of PCB management options are not fully understood. For instance , the national water utility has undertaken retrofilling operation for solving their PCB issues without considering the prolonged PCB problem in the form of PCB contaminated equipment and their specific management needs.

61. It has further been identified in NIP, Action 3.5; that national professionals in public and private sector need training and sensitization on POPs issues calling for a systematic introduction of POPs in the educational curricula.

Technical barriers:

62. Technical barriers for PCB management can be found at all stages of PCB management. At government level the technical barriers are mainly related to the lack of routine analyzing various sample matrices for PCB concentrations as well as identification of equipment among officials. These technical deficiencies obviously hinder an effective enforcement at customs entry points and controlling adherence to any planned regulative measures on PCBs.

63. The central laboratory as well as some other laboratories in government, private and academia, have appropriate equipment for conducting PCB measurements, but lack the methods and routines for pre-treatment and analysis. Such methods and routines need to be urgently established and supported. There is, in the medium to long-term, a need to establish a POPs/PCB monitoring system in order to ensure that the exposure of PCBs is achieved through control measures applied. In this regard it is worthwhile noting that the POPs NIP calls for “consolidation and reinforcement of the National Laboratory Network concerned with POPs management. “

64. There is significant knowledge and expertise about transformers and other industrial sized electric equipment available thanks to well-established manufacturing operations in Morocco. However, in many cases smaller companies have problems in taking appropriate action on safety issues for transformer including maintenance and dismantling.

65. At handling level the technical barriers are small and are mainly related to having an understanding of well separated/duplicate hardware for PCB and PCB-free equipment in order to avoid cross-contamination. As to storage, packaging and transportation of PCBs-contaminated equipment there is room for improvement when it comes to storage sites, transportation equipment and associated practices. Apart from storage the barriers are not

actually technical, but more related to know-how and willingness to spend on properly separated equipment and oil management.

66. With regard to analysis and monitoring capacity, some 7-10 laboratories in the country are reported, capable of analysing pesticides but not PCB and PCDD/PCDF. The main laboratory (National Environmental Laboratory) is the only one with dedicated equipment for the analysis of PCBs, but with an insufficiently trained staff.

67. The unavailability of PCB laboratory services in the country creates difficulties and barriers for potential PCB holders to confirm the PCB concentration in their equipment or oils in their possession. Consequently, the technical barrier of laboratory capacity hampers the good intention of transformer owners and oil-recyclers to identify and manage their potential PCB sources properly.

68. Technical barrier may also exist in the lack of proper response to spills involving PCB contaminated mineral oil. The absence of analytical results regarding the potential contamination of the mineral oil may result in leaving PCB contaminated soil unattended following a PCB contaminated mineral oil spill.

69. The Moroccan electrical transmission and distribution system does not possess redundancy in its infrastructure, therefore the replacement or treatment of the PCB contaminated oil transformers will require a long-term, properly planned strategy. The wide territorial distribution of the pieces of equipment throughout the national territory will require that this strategy be thoroughly planned and established.

70. Technical barriers also include the relative absence of treating/disposing PCB contaminated equipment in the country. The private and public sector partners are partly unaware of the different options and even more uncertain which option would be optimal for Morocco and how to get it operational.

71. In Morocco, so far, there is no proper hazardous waste treatment and disposal facility. Some low sized incinerators are currently operating in Morocco, but they are far below the BAT/BEP requirements and unable to co-incinerate PCBs without high costs for retrofitting with both proper advanced burning process and pollution reduction devices.

72. However, a central treatment and disposal facility project has been planned, with the support of GTZ, the German Corporation for Technical Cooperation. The CNEDS will be a centralized facility for physical-chemical treatment, oil-recycling, medical waste treatment and a special engineered landfill for hazardous waste. Its capacity is expected to be 100,000 T/a for industrial hazardous waste and 7,500 T/a for medical hazardous waste. Presently, this project is at the feasibility study stage and it is foreseen to be ready by 2010-2011. A letter of cooperation was signed between UNIDO and GTZ in order to avoid any duplication of work during the implementation of the proposed project.

73. Non-combustion chemical processes for the decontamination of PCB contaminated mineral oil have been widely used in Europe, North America and Japan. The use of these chemical processes for the decontamination of mineral oil allows for the selected destruction of the PCBs and the reclamation and the re-use of PCB-free decontaminate oil in electrical transformers.

74. These proven dechlorination systems can be designed and built as fixed or mobile units. If made mobile, the processing unit can be transported to the location where the PCB contaminated oil exist and operate on site until all the oil at the site is properly decontaminated.

Economic Barriers

75. Replacement of PCB containing transformers is an expensive option for any company in Morocco (see Trade/industrial policy barriers). Such investment in Morocco, being a developing country, is beyond the economic possibilities for many companies and entities.

76. Even if the financial means for replacement of equipment is found, often out of technical necessity because of transformer breakdown, the resources are not enough for

environmentally sound disposal. One should bear in mind that without clear legal requirements and corresponding enforcement, all specific efforts on managing PCBs are based on voluntary action and expense accrued are based on each individual company's willingness of committing financial resources to environmental protection.

77. The implementation of the only available option is the export to European incinerators. This, coupled with the extent of the PCB mineral oil contaminated transformers problem, represent an economic barrier since in addition to the disposal cost for the contaminated oil, the owner has to spend additional resources to buy new insulating oil to replace the contaminated fluid.

Trade/Industrial Policy Barriers:

78. There is considerable in-country manufacturing of industrial sized electrical transformers in Morocco. Industrial size transformers are made by no less than 4 manufacturers. Today all transformers produced in Morocco are PCB free and would, for most applications, be suitable for replacing PCB containing equipment.

79. One would, with such a manufacturing base, expect that the replacement of PCB containing equipment would be facilitated by the easy access both to expertise and affordable equipment. Paradoxically, the prices of transformers are very expensive by international comparison. Protectionist policies are in place to protect the domestic manufacturing sector by imposing 45% import duties on foreign made transformers.

80. Such industrial and trade policies may be job creating, but they are also resulting in high transformer prices and low replacement rate of PCB containing equipment, and increased possibilities of PCB releases.

81. Fortunately, from a PCB management point of view, these trade barriers are slowly decreasing as a part of the overall trade-liberalization, particularly between Morocco and the European Union. By 2010 the import duties for transformers will be brought to zero, creating a level playing for domestic and imported transformers. This was expected to bring down the prices of transformers, but recent large increases in base metal prices will most probably cancel out the anticipated transformer price reduction leaving the future price level largely unchanged and comparable to present costs.

82. The capacitors have not been affected by high import duties upon entry in Morocco. Therefore the price levels have been more or less comparable to international prices.

83. The disposal of pure PCB transformers and the treatment or decontamination of PCB contaminated mineral oil requires two very distinct technological solutions. As incineration is widely applied for the destruction of pure PCBs waste, on the other hand chemical non-combustion technologies have been more widely as economical solutions for the treatment and reclamation of PCB contaminated mineral oil. The absence of local facilities for the treatment of PCB contaminated mineral oil in Morocco also represents a trade/industrial policy and infrastructural barrier.

A.3 INSTITUTIONAL, SECTORAL AND POLICY CONTEXT

84. The sectors most affected by the PCB issues in Morocco are the classic power generation and distribution sectors as well as heavy industries, where power transformers and capacitors can be found.

85. Morocco's electrical power is, with a few exceptions, generated, distributed and transmitted by the state-owned company, l'Office National de l'Electricité (ONE). According to Government estimates, the energy needs of the country should increase on average by 3.2% per year until 2015.

86. The electricity demand should progress at approximately 6% per year until 2015, to reach 35 TWh. To satisfy this demand, ONE needs to install 6 000 MW of additional power capacity in the next 20 years, with the cooperation of private investors.

87. Today, ONE owns most of the transformer networks and many of the individual client's transformers apart from big electricity clients who also own and maintain their power

distribution networks. The Office National de l'Eau Potable (ONEP) has already decommissioned many of its transformers and is pushing its clients to better manage their transformers and eliminate those containing PCB.

88. Large independent utility companies typically own their own transformers. Examples of these type of companies would be LYDEC (Casablanca) and Redal (Rabat Sale, Tangiers), major industries such as the Office Chérifien des Phosphates (OCP) running phosphate mines, sugar producers, etc. Also the public sector has a sizeable transformer networking in its possession. Apart from defense use, railways, airports and Radio-TV stations operate their own transformers. Another important sector in Morocco is the water supply sector as the water supply company ONEP is independently managing all stages of water supply including the electric supply to the pumping network.

89. Government entities with primary responsibility for industrial regulation relating to potentially PCB containing equipment are the Ministries of Energy and Mines and Industry, Commerce and Handicraft. The Ministry of Energy and mines is responsible for defining government policy on energy generation and distribution and the Ministry for Industry, Commerce and Handicraft is directing industrial development and related regulations.

90. As the use of PCBs has not been directly regulated in Morocco, their potential environmental and public health impacts are not fully acknowledged. Consequently the Government environment and health stakeholders have not been fully integrated in the control of potentially PCB containing equipment holders. These regulatory shortcomings have also resulted in a poor uptake of PCB issues in industrial and environmental inspection activities. The most recent overarching National Planning of waste including hazardous waste such as PCB waste was done in the framework of the National Environmental Action Plan of 2002.

91. In the solid wastes sector, an integrated approach is planned, including improvement of collection efficiency, closure of unauthorised dumps and creation of controlled sanitary landfills for major urban areas. The proposed actions include:

- National plan for the management of dangerous wastes
- Cadastre of solid waste generation and measures for minimisation
- Realization of pilot projects, demonstration actions, sensitisation and environmental education
- Projects aiming at improving citizens environmental behaviour
- Reduction of solid wastes volume applying the “producer-pays” and “polluter-pays” principle.

92. As a response to the national plan on hazardous waste, the creation of a national waste centre/structure (CNEDS) has been started in cooperation of MEMEE and the German Development bank KfW. CNEDS is intended to cover all main hazardous waste streams in Morocco and oversee their safe management and disposal.

A.4 STAKEHOLDER ANALYSIS

93. The table below summarizes the roles and motivations of various stakeholders affected by a strengthened PCB management structure and decreased PCB releases

Table 1: Stakeholder analysis

Category	Stakeholder	Role/responsibility	Project specific issues
Government	Ministry of Environment	Protect and monitor the environment of the country, enforce environmental laws, implement International Conventions.	Ministry works towards minimizing PCB releases and ensuring adherence to Stockholm Convention by completing legal environmental framework to fully cover PCBs.
		"Direction Réglementation et Controle" : is responsible for PCB legislation	

Category	Stakeholder	Role/responsibility	Project specific issues
	Ministry of Industry	Ensure competitiveness of the industrial sector.	Supports development of stricter PCB management legislation and system, but demand financial support for the elimination of PCB equipment in the smallest industries.
	Ministry of Interior	Management of emergency and risk situations, rescue operations and recovery. This Ministry is also the official authority of the local electricity distribution companies	Strongly supports the project
	Ministry of Health	Co-ordinating authority for national public health.	Strongly supports the project particularly the parts dealing with human exposure i.e. handling and release minimization, limit values for food and waters
	Ministry of Energy	Official authority for "Office National de l'Electricité" (main electrical company in the country and electrical grid owner)	Supports the project as ONE already initiated its PCB elimination.
	Office Chérifien des Phosphates (OCP)	This big mining company is a major PCB holder, it produces its own electricity in several sites	Supports stricter PCB management as part of environmental policy.
	Office National de l'Eau Potable (ONEP)	Authority for potable water supply in Morocco, is a major PCB holder	PCB issues a part of its environmental policy.
	Other governmental major PCB equipment holders :	ONDA : airport authority SNRT : National Radio broadcasting Air force bases	Support stricter PCB management but rely on the government budget, asking for financial for the elimination aspect
Private sector	Confédération Générale des Entreprises du Maroc (CGEM)	Industry association.	Concerns about financial burden for eliminating PCB transformers, oil analysis etc.
	Elimination and PCB treatment companies	Univers electric, Maroc transfo, representatives of international disposing re-processing companies (TREDI/Séché, ORION, SD Meyrs, etc.)	Support the project, ready to implement additional safety measures in PCB operations. Project will strengthen the business and lower the prices of elimination.
	Laboratories	SD-Myers, Oksa Maroc, LPEE, laboratoire de la gendarmerie, laboratoire de l'environnement	Indicated willingness to invest in chromatographs to analyze PCBs if there is a new regulation concerning PCBs
Electrical companies	Electricity production and national grid (ONE)	Secure electricity production and distribution in the country	ONE has already eliminated many of its transformers and is pushing its clients to better manage their transformers and eliminate those containing PCB.
	Private electricity distribution companies (LYDEC, REDAL, AMENDIS, RÉGIES……)	Electricity Distribution in major cities like Casablanca, Rabat, Tangier	They support the project as part of their environmental policy.
Others	Environmental Organizations		
	Professional Expert associations	ADEME	

A.5 DOMESTIC, REGIONAL AND GLOBAL BENEFITS

94. During the preparatory phase of the proposed project, a Strategic Environmental Assessment (SEA) was undertaken to assess the environmental as well as the socio economic impacts of the planned project activities (see Annex F).

95. The results of this study showed that the current contamination of the Moroccan environment with PCBs has a negative impact particularly on regions in the more industrialized northern part of Morocco known for their importance for national drinking water supply and their biodiversity.

96. In the absence of project activities, the contamination of the Moroccan environment with PCBs will remain at current levels in the best case scenario and, in the worst case scenario, increase in the future.

97. A study of the World Bank assessed the costs for improvement of ecosystems in Morocco[3], with particular focus on ground and surface water as well as soils. Due to lack of awareness regarding the negative impact of PCBs as well lack of capacity for the environmentally sound management of PCBs in Morocco, the above-mentioned particularly vulnerable regions will be continuously contaminated with PCBs through spillages and other environmental releases, which will in turn result in increased costs of activities that aim at improving affected ecosystems.

98. With regard to the socio economic impacts of the proposed project, the SEA found that PCB-contaminated electrical equipment is recycled and reused in the informal sector. While the metallic parts are sold as scrap metal - most likely without prior decontamination - PCB-containing oils are reportedly found to be used in household burning appliances, such as Hamams. As the dismantling of PCB-contaminated equipment within the informal sector is often performed by welding, there is an elevated risk of emissions of PCDD/PCDFs.

99. The study concluded that it is likely that scrap metal obtained from such practices will be reintroduced without prior decontamination not only in the national metallurgical industry but also exported to neighbouring countries as well as to global markets. In the absence of project activities, these practices will persist and possibly PCB-contaminated metals might be circulated on a global scale.

100. Moreover, it was found that the lack of awareness and capacity to manage PCB-contaminated electrical equipment in an environmentally sound manner, at the same time, increases the risk of electrical failures and explosions, which may result in releases of PCDD/Fs to the environment.

101. The project will strengthen Morocco's capacity to manage and dispose of PCBs by establishing a local facility to treat PCB contaminated mineral oil and by decontaminating a surplus PCB contaminated carcasses. The project approach represents a long-term, economical and flexible solution that will help in the effort to eradicate all PCB contaminated electrical transformers from Morocco.

102. Moroccan electrical utilities and industrial electrical consumers consulted during the preparation of this proposal have realized the importance of having a long-term, economical, local solution for the management of PCB contaminated mineral oil transformers. These potential users of the dechlorination and transformer carcasses decontamination units have pledged their support for this initiative and indicated their intentions to utilize these solutions in managing their PCB programs within their organizations.

103. Service companies such as analytical laboratories and waste disposal companies have also pledged their support and indicated their desires to be part of this project.

[3] The study "Cost assessment of environmental degradation" can be found at the following link: http://www-wds.worldbank.org/external/default/main?menuPK=2823806&pagePK=64193027&piPK=64670046&theSitePK=2721269&menuPK=64187510&searchMenuPK=2823884&theSitePK=2721269&entityID=000012009_20050929100043&searchMenuPK=2823884&theSitePK=2721269

104. It can be expected that the impetus given by the project will mobilize additional resources to identify and subsequently dechlorinate and/or dispose of a large amount of PCB-contaminated transformers and capacitors during the project. At the same time, the project will provide a local, economical and environmentally friendly option to Moroccan PCB owners to implement a comprehensive program to permanently eradicate PCBs from their systems.

105. Management and disposal operations implemented in this project are targeting PCB-contaminated equipment in order to reduce PCB sources as effectively as possible.

106. Globally, the project will ensure that sizeable quantities of PCBs and PCB-contaminated scrap metals are taken out from use and global circulation. The technical preparation in this project will include a full option screening ranging from export of waste to the ranking and value engineering for commercially viable PCB destruction technologies. A facility for the decontamination of metallic surfaces and PCB contaminated mineral oils from transformers will be considered in partnership between the government, potential bi-lateral donors and the private sector.

107. In these considerations, cross-contaminated PCB-containing equipment and other similar hazardous and highly obsolete toxic chemicals identified in the NIP and during the preparatory phase of the project will be taken into account as well as the decontamination and/or elimination legislation, policy and criteria to be developed during pillar I implemented by UNDP. A possible facility would extend its technical scope to dispose of PCBs wastes and other highly obsolete toxic chemicals during its lifetime in the country.

108. It can also be expected that the installation of the dechlorination and dismantling unit will also boost the national market for the environmentally sound management and disposal of PCBs and other hazardous chemicals, with an estimated annual growth of 6-8 % per year during the implementation of the project.

109. Moreover, it is likely that due to improved capacity for the management of PCBs in Morocco the amount of PCB-contaminated equipment identified in the first component of the proposed project will be higher than the projected quantities at the time of project preparation. This in turn will positively affect the sustainability of the operation of the facilities after the completion of the proposed project after three years.

110. The project will further represent one of the first comprehensive government-lead PCB management projects in Africa and possible even in other continents such as South America. This will give an impetus to PCB management on a wider scale and potentially catalyze actions in the region contributing to greater risk reduction and disposal of sizeable quantities of PCBs with considerable global benefits.

111. The project will also support and contribute towards implementation of the Millenium Development Goals (MDGs). The clearest linkage is with MDG 7 that aims at ensuring environmental sustainability. While all environmental projects can be claimed to contribute to this MDG, the protection of water resources from PCB contamination will directly contribute to the Goals of MDG 7, which are by the year 2015 to:

- Integrate the principles of sustainable development into country policies and programmes; reverse loss of environmental resources.
- Reduce by half the proportion of people without sustainable access to safe drinking water.

SECTION B. REASONS FOR UNIDO ASSISTANCE

112. UNIDO has recently been granted the status of direct access to POPs-related GEF resources based on its ability to implement projects in priority areas of the Stockholm Convention. A pipeline was developed to respond to the needs of the developing countries in three categories: capacity building, implementation of post NIP enabling activities and technology demonstration projects.

113. In addition, UNIDO is executing or developing a range of demonstration and capacity building projects geared to support the implementation of the Convention. UNIDO has made considerable effort to build this assistance programme. This commitment is based on a clear understanding that these activities are compatible with UNIDO's mandate and corporate strategy and will lead towards the implementation of the Millennium Development Goals.

114. Morocco is an important partner in UNIDO's technical cooperation assistance. Activities undertaken in Morocco by UNIDO include a range of measures related to cleaner production, industrial efficiency and the management of hazardous substances. The experience gained in these projects will be of relevance in the proposed project in Morocco.

115. In parallel to the proposed project, UNDP will implement pillar I of the overarching PCB management project that will focus on the strengthening of the legal, regulatory and institutional capacity of Morocco with regard to PCB management as well as on the disposal of pure PCB-containing equipment. As some of the waste generated in the UNDP executed part will be treated in the proposed project, both projects are complementary in nature.

SECTION C. THE PROJECT

C.1. OBJECTIVE OF THE PROJECT

116. The overall objective of this project is to assist Morocco to effectively and efficiently implement the Stockholm Convention by strengthening its capacities for the sound management and disposal of PCB-contaminated electrical equipment.

117. The concrete objectives of this project are to treat and reclaim nearly 3,000 tons of PCB-contaminated mineral oil from in-service equipment and to decontaminate 2,000 tons of PCB wastes by establishing the in-the-country capacity to deal with PCB contaminated electrical equipment and other related material.

C.2. THE UNIDO APPROACH

Project Implementation Arrangement

118. ***UNIDO*** will be the ***GEF Executing Agency*** (EA) for the project. UNIDO is well positioned to act as an effective implementer of project activities based on its comparative advantage in the area of environmentally sound management and disposal of PCB-contaminated electrical equipment. It will be responsible for the overall management of the project and its funds. It will assist the National Executing Agency (NEA) in the execution of the project through the provision of timely assistance at key phases of project implementation, in the review of investigations and reports prepared as outcomes to the project, in the disbursement of funds necessary for the recruitment of international experts and other related international expenditures and in guiding the NEA to fulfil its obligations under the Stockholm Convention. UNIDO will provide periodic progress and financial reports to the GEF, as required.

119. A project focal point will be established within UNIDO to assist in the project execution. This focal point will be comprised of a part-time professional and support staff engaged in the management and coordination of UNIDO's programme of support to the Stockholm Convention. UNIDO will make these services available as part of its in-kind contribution to the project.

120. The Ministry of Energy, Mines, Water and the Environment (MEMEE) is the designated national leading agency and focal point of the implementation of the Stockholm Convention in Morocco. The project will be executed and implemented through MEMEE. The actual project components will be directly implemented by the Directorate for Environmental Monitoring and Prevention of Environmental Risks (DSPR) of MEMEE. Though the responsibility for execution lies with MEMEE several project components will be implemented in close cooperation with other Ministries. Indeed the project success and sustainability relies heavily on a close cooperation between a number of ministries and institutions as well as private sector partners.

121. Of the Ministries the cooperation will be particularly close with Ministry of Industries for cooperation on PCB identification and control of safe practices with PCB equipment still in use and various stages between decommissioning and final disposal.

122. Overall, the management arrangement of this project is aiming at supporting the long-term needs for managing PCBs in Morocco and creating a solid and sustainable foundation for sound PCB management. Hence the project management arrangements are sub-ordinated the PCB management Committee as proposed to be established in the PCB framework regulation as shown in the schematic picture below.

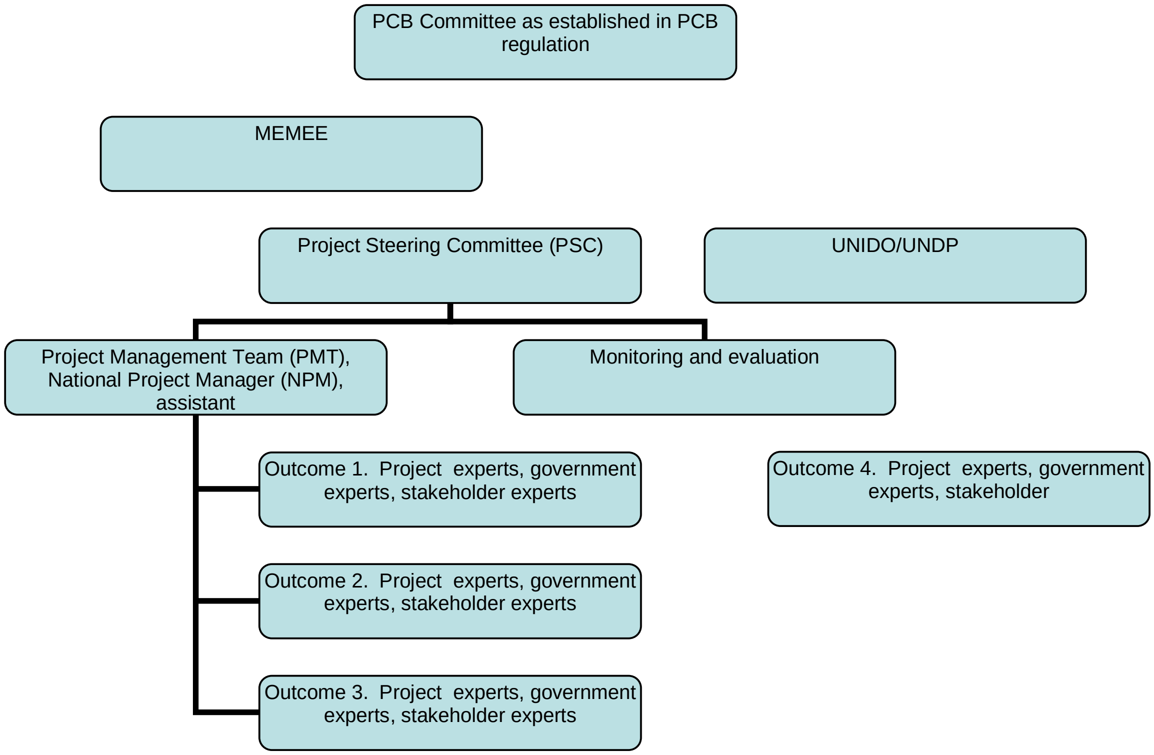


Fig. 2: Proposed Management Structure for the project

123. MEMEE will coordinate the project and chair the Project Steering Committee (PSC) that in the short-term will provide the technical support for the Regulation while gradually shifting the responsibility toward the permanent government structures.

124. The PSC will have representation from other ministries relevant to different project activities such as the Ministry of Industry, Ministry of Interior, Ministry of Equipment and Transports, Ministry of Energy and Mining and Ministry of Health.

125. The PSC will be further strengthened by representatives of key industrial stakeholder as major contributors of the project as well as representatives from civil society organizations particularly involved in hazardous waste and chemical safety issues.

126. The PSC will further be strengthened by representatives of independent technical experts. The access to these experts can be ensured by including AMEDE (Association Marocaine des Expert en Gestion des Dechets et en Environnement) in the steering structure of the project.

127. Managerial responsibilities for the full project will be delegated to a Project Management Team (PMT) to be established within MEMEE/DSPR, and a National Project Manager (NPM) will be recruited for the day-to-day project management. A resource person competent in project management will assist the NPM. The PMT will manage all national activities of the project including the recruitment and supervision of national experts. It will cooperate with UNIDO in the procurement and delivery of project inputs and the organisation of project activities. The PMT will prepare periodic forward planning and progress reports through MEMEE/DSPR to UNIDO. The PMO will provide periodic financial reports to UNIDO.

C.3 RATIONALE FOR GEF INTERVENTION

128. This project will respond effectively to the articles and Annexes of the Convention, including:

- Article 3: Each Party shall take measures to reduce or eliminate releases from intentional production and use of POPs.
- Article 6: Each Party shall take measures to reduce or eliminate releases from POPs

stockpiles and wastes

- Article 7: Each Party shall review and update, as appropriate, its NIP on a periodic basis.
- Annex A, Part II: Each Party shall with regard to the elimination of the use of polychlorinated biphenyls in equipment (e.g. transformers, capacitors or other receptacles containing liquid stocks) by 2025 take action in accordance with the following priorities:

  (i) Make determined efforts to identify, label and remove from use equipment containing greater than 10 per cent polychlorinated biphenyls and volumes greater than 5 litres;

  (ii) Make determined efforts to identify, label and remove from use equipment containing greater than 0.05 per cent polychlorinated biphenyls and volumes greater than 5 litres;

  (iii) Endeavour to identify and remove from use equipment containing greater than 0.005 percent polychlorinated biphenyls and volumes greater than 0.05 litres.

  Moreover, Parties shall promote the following measures to reduce exposures and risk to control the use of polychlorinated biphenyls:

  (i) Use only in intact and non-leaking equipment and only in areas where the risk from environmental release can be minimised and quickly remedied;

  (ii) Not use in equipment in areas associated with the production or processing of food or feed;

  (iii) When used in populated areas, including schools and hospitals, all reasonable measures to protect from electrical failure which could result in a fire, and regular inspection of equipment for leaks.

129. In response, the Council of the GEF agreed at its 19th meeting in May 2002 to amend the Instrument of the Facility to enable it to serve as an entity entrusted with the operation of the financing mechanism of the Convention. The Council having reviewed document GEF/C.19/14 recommends that the GEF Assembly designate “Persistent Organic Pollutants (POPs)” as a focal area (OP#14) in support to the implementation of the Convention.

130. According to OP#14, the GEF will provide funding, on the basis of agreed incremental costs, for three types of Strategic Programmes (SP) to address POPs issues – capacity building, on-the-ground interventions and targeted research.

131. Whereas GEF-3 efforts focused on supporting NIPs, activities from GEF-4 are characterized by a shift from preparation to implementation. In order to achieve the long-term success of the Stockholm Convention, strong emphasis will be placed on the sustainability of GEF interventions, focusing especially on countries whose policies and actions demonstrate their firm intention to follow-through on their commitment to the Convention.

132. The proposed project activities fall under the SP-2 “Partnering in investments for NIP implementation”. It is in line with SP-2 through partnering in future investment projects that aim at eliminating the use and releases of PCBs to the environment. This objective will be reached through the private sector involvement in the construction and operation of a facility for the decontamination of cross-contaminated PCB-containing transformers and for the final disposal of related PCB wastes and other highly toxic obsolete chemicals.

C.4 RBM CODE AND THEMATIC AREA CODE

133. B16 - Environment

C.5 EXPECTED OUTCOMES, OUTPUTS AND ACTIVITIES

134. The outcomes of the project are:

Outcome 1: ***Identification process for PCB contamination in in-service and decommissioned transformers established***

Outcome 2: ***Environmentally sound maintenance and treatment of in-service PCB contaminated mineral oil transformers in participating industries carried out***

Outcome 3: ***Environmentally sound disposal of decommissioned PCB contaminated transformers and material recovery system established***

Outcome 4: ***Project management, monitoring and evaluation (M&E)***

135. For achieving these outcomes, a number of outputs will be carried-out. These project outputs can be further divided into activities as presented below.

Outcome 1 ***Identification process for PCB contamination for in-service and decommissioned transformers established***

Output 1.1: Identifying analytical laboratories for assessing PCB level in transformers

Output/Activities		Responsibility
1.1.1	Drafting Terms of Reference	UNIDO, DSPR

Output 1.2 *Establishment of Standard Method of Analysis for PCBs*

Output/Activities		Responsibility
1.2.1	Review of Moroccan analytical requirement based on PCB regulatory requirements	UNIDO, DSPR
1.2.2	Review of Internationally accepted PCB analytical methods	UNIDO, DSPR
1.2.3	Harmonization and upgrading of Moroccan analytical standard methods	MEMEE

Output 1.3 *Samples collection and analysis*

Output/Activities		Responsibility
1.3.1	Sampling protocols for in-service and decommissioned transformers	UNIDO, DSPR
1.3.2	Analysis of mineral oil filled in-service transformers	DSPR
1.3.3	Analysis of mineral oil-filled surplus transformers and bulk storage mineral oil	DSPR
1.3.4	Analysis of related waste coming from dismantled transformers before final disposal	DSPR

Outcome 2 ***Environmentally sound maintenance and treatment of in-service PCB contaminated mineral oil transformers in participating industries carried out.***

Output 2.1 *Establishment of PCB contaminated mineral oil treatment facility and PCB contaminated metal recovery system*

Output/Activities		Responsibility
2.1.1	Drafting Terms of Reference	UNIDO, DSPR
2.1.2	Preparation of Tendering Documents for technology providers	UNIDO, DSPR
2.1.3	Assessment and selection of the most technically and economically viable option	UNIDO, DSPR
2.1.4	Plant acquisition	UNIDO, DSPR

Output 2.2 *Treatment of defined volume of PCB contaminated mineral oil and PCB contaminated metals*

Output/Activities		Responsibility
2.2.1	Collection and transportation of PCB contaminated mineral oil from participating industries sites to mineral oil decontamination facilities	UNIDO, DSPR
2.2.2	Decontaminate at least 3,000 tons of PCB contaminated mineral oil within the project life	UNIDO, DSPR

Outcome 3: ***Environmentally sound disposal of decommissioned PCB contaminated transformers and material recovery system established.***

Output 3.1 *Establishment of PCB contaminated mineral oil dismantling facility and PCB contaminated metal reclamation system*

Output/Activities		Responsibility
3.1.1	Drafting Terms of Reference	UNIDO, DSPR
3.1.2	Preparation of Tendering Documents for technology providers	UNIDO, DSPR
3.1.3	Assessment and selection of the most technically and economically viable option	UNIDO, DSPR
3.1.4	Plant acquisition	UNIDO, DSPR

Output 3.2 *Treatment of defined volume of PCB contaminated mineral oil and PCB contaminated metals*[4]

Output/Activities		Responsibility
3.2.1	Dismantle decommissioned transformers	UNIDO, DSPR
3.2.2	Metals recovery	UNIDO, DSPR

[4] Plant operation for limited period of time to decontaminate up to 2,000 metric tons of PCB contaminated transformer carcasses, including 446 metric tons from the UNDP implemented part

Outcome 4 Project management, monitoring and evaluation (M&E)

Output 4.1 Development and implementation of Project Monitoring management structure according to GEF M&E procedures

Output/Activities		**Responsibility**
4.1.1	Establish the Project steering committee by relying on resources from related ministries or commissions at the national level and from local governmental agencies	UNIDO, MEMEE, DSPR
4.1.2	Establish the Project Management Team	UNIDO, MEMEE, DSPR
4.1.3	Recruit a CTA, technical experts in PCB management, and evaluation and programming experts to form a project expert team	UNIDO
4.1.4	Carry out training for the national and local project management staff	UNIDO, DSPR
4.1.5	Designate a project focal point within UNIDO to provide project management and coordination, recruit international experts and provide technical advice and other services as necessary to assist DSPR.	UNIDO

Output 4.2 Design and implement an M&E mechanism according to GEF M&E procedures

Output/Activities		**Responsibility**
4.2.1	Hold the Inception Workshop	UNIDO, DSPR
4.2.2	Prepare the Inception Report	DSPR, CTA
4.2.3	Measure impact indicators on an annual basis	UNIDO, DSPR
4.2.4	Prepare Annual Project Reports and Project Implementation Reviews	UNIDO, CTA
4.2.5	Hold annual tripartite review meetings	UNIDO, DSPR
4.2.6	Hold biannual Project steering committee meetings	UNIDO, DSPR

Output 4.3 External evaluation

Output/Activities		**Responsibility**
4.3.1	Carry out mid-term external review	UNIDO
4.3.2	Carry out final external evaluation	UNIDO
4.3.3	Complete the Terminal Report	UNIDO, CTA
4.3.4	Carry out annual project financial audits	UNIDO, DSPR
4.3.5	Carry out biannual visits to selected field sites	UNIDO, DSPR
4.3.6	Establish a project management information system (MIS), including a project website to disseminate information to various stakeholders	UNIDO, DSPR

C.6 TIMELINE OF THE PROJECT ACTIVITIES

Table 2: Timeline of the project activities

Outcomes	Outputs	Activities	Year 1				Year 2				Year 3			
			Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Outcome 1: Identification process for PCB contamination in in-service and decommissioned transformers set up	1.1 Identifying analytical laboratories for assessing PCB level in transformers	1.1.1 Drafting Terms of Reference												
	1.2 Establishment of Standard Method of analysis	1.2.1 Review of Moroccan analytical requirements based on PCB regulatory requirements												
		1.2.2 Review of internationally accepted PCB analytical methods												
		1.2.3 Harmonization and upgrading of Moroccan analytical standards												
	1.3 Sample collection and analysis	1.3.1 Sampling protocols for in-service and decommissioned transformers												
		1.3.2 Analysis of mineral oil filled in-service transformers												
		1.3.3 Analysis of mineral oil filled surplus transformers and bulk storage mineral oil												

Outcomes	Outputs	Activities	Year 1				Year 2				Year 3			
			Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
		1.3.4 Analysis of related waste generated from transformer dismantling activities												
Outcome 2: Environmentally sound maintenance and treatment of in-service PCB contaminated mineral oil transformers in participating industries carried out	2.1 Establishment of PCB contaminated mineral oil treatment facility	2.1.1 Drafting Terms of reference												
		2.1.2 Preparation of tendering documents for technology providers												
		2.1.3 Assessment and selection of the most technically and economically viable option												
		2.1.4 Plant acquisition												
	2.2 Pilot project for the treatment of defined volume of PCB contaminated mineral oil	2.2.1 Collection and transportation of PCB contaminated mineral oil from participating industries sites to mineral oil decontamination facilities												
		2.2.2 Decontaminate at least 3,000 tons of PCB contaminated mineral oil												
Outcome 3: Environmentally sound disposal of	3.1Establishment of PCB contaminated dismantling facility	3.1.1 Drafting Terms Of Reference												

Outcomes	Outputs	Activities	Year 1				Year 2				Year 3			
			Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
decommissioned PCB contaminated transformers and material recovery set up	and PCB contaminated metal reclamation system	3.1.2 Preparation of tendering documents for technology providers												
		3.1.3 Assessment and selection of the most technically and economically viable option												
		3.1.4 Plant Acquisition												
	3.2 Pilot project for the treatment of defined amount of PCB contaminated transformer carcasses	3.2.1 Plant operation for dismantling decommissioned transformers												
		3.2.2 Plant operation to recover metals												
Outcome 4: Project management, monitoring and evaluation (M&E)	4.1 Development and implementation of Project Monitoring management structure according to GEF M&E Procedures	4.1.1 Establish the project steering committee by relying on resources from related ministries or commissions at the national level and from local government offices												
		4.1.2 Establish the Project Management Team												

Outcomes	Outputs	Activities	Year 1				Year 2				Year 3			
			Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
		4.1.3 Recruit a CTA, technical expert in PCB waste management, and evaluation and programming experts to form a project expert team	■											
		4.1.4 Carry out training for the national team and local project management staff	■	■										
		4.1.5 Designate a project focal point within UNIDO	■											
	4.2 Design and Implement an M&E mechanism according to GEF M&E procedures or dissemination of results and experiences	4.2.1 Hold the inception workshop	■											
		4.2.2 Prepare the inception report	■											
		4.2.3 Measure impact indicators on an annual basis	■	■	■	■	■	■	■	■	■	■	■	■
		4.2.4 Prepare annual project reports and project implementation reviews				■				■				■
		4.2.5 Hold annual tripartite review meetings				■				■				■
		4.2.6 Hold biannual project steering committee meetings		■		■		■		■		■		■
	4.3 External evaluation	4.3.1 Carry out mid-term external review					■	■						

Outcomes	Outputs	Activities	Year 1				Year 2				Year 3			
			Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
		4.3.2 Carry out final external evaluation												
		4.3.3 Complete the terminal report												
		4.3.4 Carry out annual project financial audit												
		4.3.5 Carry out biannual visits to operating facilities												
		4.3.6 Establish a project management information system (MIS) including a project website to disseminate information to various stakeholders												

C.7 RISKS, SUSTAINABILITY, REPLICABILITY AND COST-EFFECTIVENESS

Possible Risks

136. Potential risks and the mitigation measures to be taken into account for this project are described in the table below.

Table 3: Potential risks and mitigation measures

Outcomes	Potential Risks	Proposed Mitigation Measures	Level
Identification process for PCB contamination in in-service transformers set up	Lack of adequate monitoring (sampling and analysis) capacities	Timely identification of the required monitoring and testing laboratories	Low
Environmentally sound maintenance and treatment of in-service PCB contaminated mineral oil transformers in participating industries carried out	Establishing adequate treatment facility for PCB contaminated mineral oil is delayed; lack of interest of technology providers because of lack of clarity on commercial and investment parameters	Permitting process of the PCB treatment facility is carried out in time; awareness raising and sensitisation of technology providers in time	Low
Environmentally sound disposal of decommissioned PCB contaminated transformers and material recovery set up	Establishing adequate dismantling and recovery facility for PCB contaminated equipment is delayed; lack of interest of technology providers because of lack of clarity on commercial and investment parameters; decreasing market prices for scrap metal	Permitting process of dismantling and recovery facility for PCB contaminated equipment is carried out in time; awareness raising and sensitisation of technology providers in time; thorough planning and calculation of decontamination and recycling process	Moderate
Project management, monitoring & evaluation (M&E)	Lack of coordination in the project management team; missing regular reporting responsibilities	Proper communication channels are established	Low

Sustainability

137. In the UNDP implemented project, PCB holders will be trained to manage PCB containing equipment. Practices introduced will be valuable also for PCB contaminated equipment, on which the proposed project will focus. It can be expected that the ameliorated practices introduced by the project will be integrated maintenance and decommissioning practices among the PCB holders and service companies.

138. For ensuring sustainability, the PCB holders will be required to continue to manage the PCB contaminated equipment until end of service and appropriate disposal will be developed during this project. The project will ensure that safe maintenance and handling of all types of PCB equipment is introduced and integrated in the PCB holders' practices. As these practices do not entail any additional financial resources it can be assumed that the raised awareness and built in practices will continue well after the project closure.

139. As the project will introduce disposal technologies for the dechlorination and decontamination of PCB-contaminated electrical equipment in Morocco, major concern lies with potential PCB contamination from the disposal activities and the economic viability of the operation or scheme. These issues were addressed by a SEA of the project (see Annex E) and will be taken up during the implementation of the project.

Replicability

140. The project replicability has two dimensions. Replication in other countries as well as replication within Morocco. The project outcomes/outputs can to a varying degree be replicated internationally and nationally.

141. With very few PCB management projects approved to date in the GEF context, the first issue to consider is the replicability of the project approach. As the project combines the updating of the preliminary PCB inventory and minimization of releases and disposal, it could well present an ideal case for a holistic approach to PCB management.

142. As the baseline situation is very comparable to neighbouring countries and countries in a similar development context, the approach and most of the actions can, after project evaluation and appropriate lessons learnt screen, be applied wider in the region.

143. Also the more hands-on project components can be replicated internationally, however their main replicating effect will be in introducing sustainable and releases minimizing action among companies that have not taken part in the current project due to financial or other constraints. Once the proper work practices introduced by the project, both when it comes to maintenance as well as disposal stages are well integrated by the stakeholders it can be expected that these safer methods and practices be replicated after conclusion of the project.

144. With an early recognition that PCB-contaminated mineral oil transformers represent a serious problem, the management of such a problem by establishing local, economical and flexible alternatives can be replicated in other countries thereby becoming a model approach for the for the environmentally sound management of PCBs.

Cost-effectiveness

145. The cost-effectiveness regarding the decontamination of PCB-containing equipment and destruction of related PCB wastes is considerably lower than for waste export. This was shown by a two feasibility studies that were undertaken in course of the preparation of this project (see Annex C and D).

146. An indicator for the decontamination part of this project will be the price (in US$) to decontaminate a ton of PCB-contaminated mineral oils. For the destruction part of this project, the indicator will be the price (in US$) per disposed of ton of related PCB waste.

147. Steps undertaken to present cost-effectiveness include the identification and evaluation of suitable PCB destruction and decontamination technologies and the evaluation of their effectiveness regarding the irreversible destruction of the POPs content (including unintentionally produced POPs, such as dioxins and furans) with the overarching goal to minimize adverse effects of POPs to human health and the environment.

148. Inclusion of treatment and disposal of other highly toxic wastes matrices will also contribute to the effectiveness estimations of the possible treatment facility.

SECTION D. INPUTS

D.1. COUNTERPARTS INPUTS

Incremental Cost and project financing

149. The GEF, as the financial mechanism for the Stockholm Convention will provide a proposed budget of US$ 2,437,600 incremental cost funding for the project. The Government of Morocco has committed US$ 252,000 in-kind contribution to the project. It is expected that the private sector will contribute US$ 4,554,000 as cash and in-kind contribution to the project.

Baseline

150. Under the Baseline Scenario and absence of this project, Morocco would face a significant shortage of capacities at various levels and would continue to encounter the existing barriers to cost-effective implementation of the Stockholm Convention, including:

- Lack of in-country capacity for the environmentally sound management and disposal of PCB-contaminated electrical equipment
- Lack of knowledge about the quantities of PCB-contaminated transformers

151. Without the GEF-assisted project, it is likely that some companies or waste and scrap recyclers will drain the PCB–contaminated equipment, incinerate or dilute the oils and sell the casings as scrap metal, due to*, inter alia,* lack of information on the level of PCB-contamination of their electrical equipment. This would lead to deterioration of the transformer and capacitor casings with resulting leakages and release of PCBs in the environment.

152. Further, some companies have been knowledgeable of PCB issues and tried different means of managing the problem. While assessing such companies and their management practices it can be noticed that the steps taken are not fully rolled-out over all operations or the actual consequences or follow-up activities have not been fully understood. E.g. after retrofilling PCB transformers, this equipment have not been particularly monitored and have been maintained as any totally PCB free equipment. This can be assumed to have lead to further cross-contamination as well as exposure and recycling of PCB contaminated oils at waste/oils recycling stage. It is to be expected that the above practices that lead to the ongoing contamination of electrical equipment with PCBs will persist without GEF assistance.

153. Only a small fraction of the existing PCB contaminated mineral oil would be identified due to a lack of analytical capacity and standard methods for the analysis of PCBs. As a consequence, only a small fraction of the existing PCB contaminated mineral oils as well as contaminated transformers (in-service and surplus) would be dechlorinated or disposed of.

154. The PCB contaminated copper, wrapped with PCB contaminated paper would be probably be burnt to recover the metal in open fires or unsuitable PCB incinerator with the potential of forming and releasing significant amounts of PCDDs and PCDFs. Moreover, PCB contaminated mineral oils would continue to be a major source for an ongoing cross contamination of PCB-free equipment and releases into the environment.

Alternative

155. The project activities pertaining to the environmentally sound management of PCB-contaminated electrical equipment are incremental from a GEF perspective.

156. The identification of analytical laboratories for assessing PCB level in transformers and the related updating and expansion of the inventory of PCB-contaminated electrical equipment is a crucial follow-up activity to the initial PCB inventory compiled under the POPs Enabling Activity project. As a follow-up to the Enabling Activities project, it is fully incremental to the baseline. Without this activity much of the information compiled in this project would not benefit future activities with the objective of avoiding exposure and releases of PCBs.

157. The Establishment of a PCB dechlorination unit in Morocco in which 3,000 metric tons of PCB contaminated oil in in-service and surplus transformers can be efficiently and economically

decontaminated and reclaimed for use in electrical transformers is an important follow-up activity to the Enabling Activities project and therefore is fully incremental to the baseline.

158. Moreover, the establishment of a PCB decontamination unit where the carcasses from PCB contaminated transformers can be decontaminated in an environmentally safe manner allowing for the recovery and recycling of copper and steel from decommissioned PCB contaminated transformers (446 metric tons from the UNDP implemented part and estimated 1,554 tons from the proposed project) is another important follow-up activity to the Enabling Activities project and therefore is fully incremental to the baseline.

159. With this project, Morocco will be enabled to respond effectively to the obligations of the Stockholm Convention regarding the environmentally sound management and disposal of PCB-contaminated electrical equipment. The strengthened capacity of Morocco to dechlorinate and decontaminate PCB-contaminated equipment in the country will help to reduce releases of PCBs into the environments through spillages, poor condition of equipment and ineffective maintenance procedures.

160. Globally, the project will ensure that sizeable quantities of PCBs in Morocco are taken out from use and global circulation. The technical preparation in this project will include a full option screening ranging from export of waste to the ranking and value engineering for commercially viable PCB destruction technologies. A facility for the decontamination of metallic surfaces and PCB contaminated mineral oils from transformers will be considered in partnership between the government, potential bilateral donors and the private sector.

161. In these considerations, cross-contaminated PCB-containing equipment and other similar hazardous and highly obsolete toxic chemicals identified in the NIP and during the preparatory stage of the project will be taken into account as well as the decontamination and/or elimination legislation, policy and criteria to be developed during the UNDP implemented pillar I of the overarching project. A possible facility would extend its technical scope to dispose of PCBs wastes and other obsolete POPs chemicals during its lifetime in the country.

162. The project will further represent one of the first comprehensive government-lead PCB management projects in Africa and possible even in other continents such as South America. This will give an impetus to PCB management on a wider scale and potentially catalyze actions in the region contributing to greater risk reduction and disposal of sizeable quantities of PCBs with considerable global benefits.

163. The project will also support and contribute towards implementation of the Millenium Development Goals (MDGs).

Summary Incremental Cost Matrix in US$

Table 4: *Incremental Cost Matrix*

Outcome	Baseline	Increment		Alternative
		GEF	Co-financing (other sources)	
Outcome 1: Identification process for PCB contamination in in-service and decommissioned transformer set up	60,000	217,800	0	277,800
Outcome 2: Environmentally sound maintenance and treatment of in-service PCB contaminated mineral oil transformers in participating industries carried out	63,000	1,339,800	3,000,000	4,402,800
Outcome 3: Environmentally sound disposal of decommissioned PCB contaminated transformers and material reclamation set up	69,000	639,800	1,554,000	2,262,800
Outcome 4: Monitoring and evaluation (M&E) Project management	60,000	240,200	50,000	350,200
Total	**252,000**	***2,437,600***	**4,604,000**	**7,293,600**

D.2. UNIDO INPUTS

164. UNIDO will provide an in-kind contribution of US$ 50,000 for managerial and technical oversight and supervision to project management, and M&E.

SECTION E: BUDGET

E.1 PROJECT BUDGET (GEF ONLY) IN US$

Outcome	Budget line	Description	Year 1		Year 2		Year 3		Total	
			US$	w/m	US$	w/m	US$	w/m	US$	w/m
Outcome 1: **Identification process for PCB contamination in in-service and decommissioned transformer set up**	15-00	Project travel (national experts)	1,000		2,500		2,500		6,000	
	17-50	National experts	72,000	24.0	18,000	6.0	18,000	6.0	108,000	36.0
	21-01	Subcontracts on PCB laboratories	6,000		0		0		6,000	
	21-02	Subcontract on the analysis of PCBs	0		48,000		48,000		96,000	
	51-00	Translation/printing	500		500		800		1,800	
	Sub-total		***79,500***	***24.0***	***69,000***	***6.0***	***69,300***	***6.0***	***217,800***	***36.0***
Outcome 2: **Environmentally sound maintenance and treatment of in-service PCB contaminated mineral oil transformers in participating industries carried out**	11-50	Short-term consultants (international)	30,000	3.0	15,000	1.5	9,000	0.9	54,000	5.4
	15-00	Project travel (national experts)	2,500		2,000		1,500		6,000	
	17-50	National experts	36,000	12.0	22,500	7.5	19,500	6.5	78,000	26.0
	21-03	Subcontract on plant acquisition	600,000		600,000		0		1,200,000	
	51-00	Translation/printing	500		500		800		1,800	
	Sub-total		***669,000***	***15.0***	***640,000***	***9.0***	***30,800***	***7.4***	***1,339,800***	***31.4***

Outcome	Budget line	Description	Year 1		Year 2		Year 3		Total	
			US$	w/m	US$	w/m	US$	w/m	US$	w/m
Outcome 3: **Environmentally sound disposal of decommissioned PCB contaminated transformers and material reclamation set up**	11-50	Short-term consultants (international)	30,000	3.0	15,000	1.5	9,000	0.9	54,000	5.4
	15-00	Project travel (national experts)	2,500		2,000		1,500		6,000	
	17-50	National experts	36,000	12.0	22,500	7.5	19,500	6.5	78,000	26.0
	21-03	Subcontract on plant acquisition	250,000		250,000		0		500,000	
	51-00	Translation/printing	500		500		800		1,800	
	Sub-total		***319,000***	***15.0***	***290,000***	***9.0***	***30,800***	***7.4***	***639,800***	***31.4***
Outcome 4: Project management, monitoring and evaluation (M&E)	11-01	Chief Technical Advisor	12,000	1.0	12,000	1.0	12,000	1.0	36,000	3.0
	11-50	Short-term consultants (international)	27,000	2.7	18,000	1.8	18,000	1.8	63,000	6.3
	13-00	Administrative support	3,000	3.0	3,000	3.0	3,000	3.0	9,000	9.0
	15-00	Project travel (national experts)	5,000		3,000		3,000		11,000	
	17-01	National Project Manager	5,400	1.2	5,400	1.2	5,400	1.2	16,200	3.6
	17-50	National experts	30,000	10.0	16,500	5.5	22,500	7.5	69,000	23.0
	35-00	Workshops/meetings	15,000		2,500		2,500		20,000	
	45-00	Equipment	10,000		0		0		10,000	
	51-00	Translation/printing	1,000		1,000		4,000		6,000	
	Sub-total		***108,400***	***17.9***	***61,400***	***12.5***	***70,400***	***14.5***	***240,200***	***44.9***
TOTAL PROJECT COSTS			***1,175,900***	***71.9***	***1,060,400***	***36.5***	***201,300***	***35.3***	***2,437,600***	***143.7***

E.2 CO-FINANCING BUDGET BY ACTIVITY (IN US$)

Outcomes	Outputs	Activities	Co-finance (US$)			
			UNIDO	Private Sector	MEMEE	TOTAL
Outcome 1: Identification process for PCB contamination in in-service and decommissioned transformer set up	1.2 Establishment of standard method of analysis for PCBs	1.2.1 Review of Moroccan analytical requirements based on PCB regulatory requirement			24,000	**24,000**
		1.2.2 Review of international accepted PCB analytical methods			12,000	**12,000**
		1.2.3 Harmonization and upgrading of Moroccan analytical standard method			12,000	**12,000**
	1.3 Sample collection and analysis	1.3.1 Sampling protocols for in-service and decommissioned transformers			12,000	**12,000**
Sub-total			**0**	**0**	**60,000**	**60,000**

Outcomes	Outputs	Activities	Co-finance (US$)			
			UNIDO	Private Sector	MEMEE	TOTAL
Outcome 2: Environmentally sound maintenance and treatment of in-service PCB contaminated mineral oil transformers in participating industries carried out	2.1 Establishment of PCB contaminated mineral oil treatment facility and PCB contaminated metal recovery system	2.1.1 Drafting Terms of Reference			12,000	**12,000**
		2.1.2 Preparation of Tendering Documents for technology providers			6,000	**6,000**
		2.1.3 Assessment and selection of the most technically and economically viable option			18,000	**18,000**
		2.1.4 Plant acquisition			9,000	**9,000**
	2.2 Pilot project for the treatment of defined volume of PCB contaminated mineral oil and PCB contaminated metals	2.2.1 Collection and transportation of PCB contaminated mineral oil from participating industries sites to mineral oil decontamination facilities		3,000,000*	18,000	**3,018,000**
		2.2.2 Decontaminate at least 3,000 tons of PCB contaminated mineral oil				
Sub-total			**0**	**3,000,000**	**63,000**	**3,063,000**

* private sector co-funding for carcass decontamination at US $ 1000/t

Outcomes	Outputs	Activities	Co-finance (US$)			
			UNIDO	Private Sector	MEMEE	TOTAL
Outcome 3: Environmentally sound disposal of decommissioned PCB contaminated transformers and material reclamation set up	3.1 Establishment of a treatment facility for decontamination and recovery of PCB contaminated metals	3.1.1 Drafting Terms of Reference			12,000	**12,000**
		3.1.2 Preparation of Tendering Documents for technology providers			12,000	**12,000**
		3.1.3 Assessment and selection of the most technically and economically viable option			18,000	**18,000**
		3.1.4 Plant acquisition			9,000	**9,000**
	3.2 Pilot project for the decontamination of defined amount of PCB contaminated transformer carcasses	3.2.1 Dismantle decommissioned transformers* 3.2.2 Metals recovery*		1,554,000**	18,000	**1,572,000**
Sub-total			**0**	**1,554,000**	**69,000**	**1,623,000**

* Plant operation for limited period of time to decontaminate up to 2,000 tons of PCB contaminated transformer carcasses (including 446 metric tons from the UNDP implemented part, which, however, is not considered as co-funding for pillar II)
** private sector co-funding for carcass decontamination at US $ 1000/t

Outcomes	Outputs	Activities	Co-finance (US$)			
			UNIDO	Private Sector	MEMEE	TOTAL
Outcome 4: Project management, monitoring and evaluation (M&E)	4.1 Development and implementation of Project Monitoring management structure according to GEF M&E Procedures	4.1.1 Establish the project steering committee by relying on resources from related ministries or commissions at the national level and from local government offices			6,000	6,000
		4.1.2 Establish the Project Management Team			6,000	6,000
		4.1.4 Carry out training for the national team and local project management staff			3,000	3,000
		4.1.5 Designate a project focal point within UNIDO	50,000		0	50,000
	4.2 Design and Implement an M&E mechanism according to GEF M&E procedures for dissemination of results and experiences	4.2.1 Hold the inception workshop			3,000	3,000
		4.2.2 Prepare the inception report			3,000	3,000
		4.2.3 Measure impact indicators on an annual basis			3,000	3,000
		4.2.4 Prepare annual project reports and project implementation reviews			9,000	9,000
		4.2.5 Hold annual tripartite review meetings			3,000	3,000
		4.2.6 Hold biannual project steering committee meetings			3,000	3,000

Outcomes	Outputs	Activities	Co-finance (US$)			
			UNIDO	Private Sector	MEMEE	TOTAL
	4.3 External evaluation	4.3.2 Carry out final external evaluation			3,000	3,000
		4.3.3 Complete the terminal report			3,000	3,000
		4.3.4 Carry out annual project financial audit			3,000	3,000
		4.3.5 Carry out biannual visits to operating facilities			3,000	3,000
		4.3.6 Establish a project management information system (MIS) including a project website to disseminate information to various stakeholders			9,000	9,000
Sub-total			**50,000**	**0**	**60,000**	**110,000**
GRAND TOTAL			**50,000**	**4,554,000**	**252,000**	**4,856,000**

SECTION F: MONITORING AND EVALUATION, REPORTING AND LESSONS LEARNED

165. The PSC, which will meet at least once annually, will be responsible for the overall policy guidance of the Project. A detailed schedule of project reviews will be developed by the project management team, in consultation with project implementation partners and representatives of the participating communities, during the early stages of project initiation, and incorporated in the Project Inception Report. Such a schedule will include methodologies and tentative timeframes for PSC meetings, and participatory Monitoring and Evaluation of the Project by the participating communities. The project will be subject to GEF Monitoring and Evaluation rules and practices of the GEF and UNIDO.

166. The project management team and the UNIDO focal point will develop criteria for participatory monitoring of the project activities. Appropriate participatory mechanism and methodology for performance monitoring and evaluation will be established at the very outset of the project. Monitoring and Evaluation (M&E) activities will be based on the Logical Framework Matrix. The overall M&E format for the project will follow the instructions and guidelines of the GEF M&E unit and will be laid out in detail at the Inception Workshop.

167. In accordance with the GEF requirements, Quarterly Progress Reports will also be provided to GEF during the course of the project. Table 6 provides simplified impact indicators with, targets, and means of verification for selected indicators. These indicators will form the basis for the project's M&E system.

168. In particular, the project management team will be responsible for the preparation and submission of the following reports:

Project Inception Workshop Report (PIWR)

The inception report prepared by the project team will take place no later than three months after the project start-up. The report will include a detailed annual work plan with clear indicators and corresponding means of verification for the first year of the project, fine tuning of Terms of Reference (TOR) for project professionals, TOR for sub-contractual services, progress to date on project establishment and start up activities, amendments to project activities/approaches, if any. The report will be submitted to GEF.

Annual Project Report (APR)/Project Implementation Report (PIR)

APR/PIR in a prescribed format will be prepared and submitted annually by the project management as per guidelines set for the same. APR/PIR will inform the Tri Partite Review (TPR) at the annual Steering Committee meetings and should therefore be circulated to TPR/PSC participants well in advance. Final APR/PIR will be submitted to GEF as per standard procedures.

169. The independent mid-term project evaluation would focus on the cost-effectiveness and sustainability of the establishment of the PCB dechlorination and decontamination unit, and would emphasize identification for dissemination of lessons learned from programme and project experience to date, including lessons about project design, implementation and overall management both at the project and programme levels. The final evaluation would focus on similar issues but will give strong emphasis to the potential for replicability of the project in other countries of the region and on the global scale. Recommendations for follow-up activities would be included in each of these review processes.

170. As important as the undertaking of effective and thorough M&E will be the effective communication of the results of these activities is equally important. This will be accomplished by making certain that ongoing M& E results are included on the agendas of planned workshops and also posted in a regular basis on the project website (see activity 4.3.6).

171. UNIDO will arrange an independent international terminal evaluation of the project according to M&E procedures established by the GEF.

172. The project's indicative M&E workplan is shown in Table 5 below.

Table 5: Indicative M&E work plan and corresponding budget

Type of M&E activity	Responsible Parties	Budget US$ *Excluding project team Staff time*	Time frame
Inception Workshop (IW)	▪ National Project Manager (NPM) ▪ UNIDO Project Manager (PM)	None	Within first two months of project start up
Inception Report	▪ Project Management Team ▪ UNIDO PM	None	Immediately following IW
Measurement of Means of Verification for Project Purpose Indicators	▪ UNIDO PM will oversee the hiring of specific institutions and delegate responsibilities to relevant team members	To be finalized in Inception Phase and Workshop. Indicative cost $20,000	Start, mid and end of project
Measurement of Means of Verification for Project Progress and Performance (measured on an annual basis)	▪ Oversight by NPM and UNIDO PM	To be determined as part of the Annual Work Plan's preparation. Indicative cost $20,000	Annually prior to APR/PIR and to the definition of annual work plans
APR and PIR	▪ NPM	None	Annually
Steering Committee Meetings	▪ NPM ▪ UNIDO PM	None	Following Project IW and subsequently at least once a year
Quarterly progress reports	▪ UNIDO PM	$6,000 (average $2,000 per year)	Every three months
Technical reports	▪ Project Management Team ▪ Hired consultants as needed	None	To be determined by Project Team and UNIDO PM
Mid-term Review and External Evaluation	▪ UNIDO PM and M&E Branch ▪ GEF M&E Unit ▪ External Consultants (i.e. evaluation team)	$4,000	At the mid-point of project implementation or after two years of the start of the project.
Terminal Project Evaluation and Report	▪ Project Management Team ▪ UNIDO PM and M&E Branch ▪ GEF M&E Unit ▪ External Consultants (i.e. evaluation team)	$8,000	At the end of project implementation
Terminal Project Report	▪ NPM ▪ UNIDO-PM	None	At least one month before the end of the project
Lessons learned	▪ Project Management Team	$6,000 (average $2,000 per year)	Yearly
Audit	▪ UNIDO ▪ Project Management Team	$3,000 (average $1,000 per year)	Yearly
Visits to field sites (UNIDO staff travel costs to be charged to IA fees)	▪ UNIDO PM ▪ Government representatives	None	Yearly
TOTAL INDICATIVE COST *Excluding project team staff time and UNIDO staff and travel expenses*		**US$ 67,000**	

Table 6: Selected Impact indicators

Outcomes	Indicator	Target	Sources of Verification
Outcome 1: **Identification process for PCB contamination in in-service and decommissioned transformers set up**	1. level of contamination for in-service transformers to be cleaned and for decommissioned transformers to be dismantled evaluated 2. number of laboratories identified and contracted	Proper routine analysis process for every transformer in the electrical grid system Sufficient number of laboratories 3,000 tons of contaminated oils analyzed for contamination 1,000 large and medium size in-service and all surplus transformers evaluated for PCB content	Terms of Reference reviewed Contracts signed with selected laboratories Monthly progress reports Evaluation reports
Outcome 2: **Environmentally sound maintenance and treatment of in-service PCB contaminated mkineral oil transformers in participating industries carried out.**	1. PCB contaminated mineral oil treatment facility established	Transformers analyzed in previous outcome correctly maintained and managed after cleaned oil refilling Pilot Project for the treatment of defined volume of PCB contaminated mineral oil set up and working routinely Plant operation for limited period of time to decontaminate up to 3 millions kg of PCB contaminated mineral oil	Terms of Reference reviewed Tendering document reviewed Contracts signed with selected facilities Progress reports Evaluation report
Outcome 3: **Environmentally sound disposal of decommissioned PCB contaminated transformers and material recovery set up**	1. Decommissioned transformers dismantling centre established 2. PCB contaminated metal recovery facility established	Pilot Project for the treatment of defined amount of PCB contaminated metals set up and working routinely. Plant operation during life of project to decontaminate 446 tons of drained high level PCB equipment removed in the UNDP implemented part and all surplus, drained low level PCB contaminated equipment	Terms of Reference reviewed Tendering document reviewed Contracts signed with selected facilities Progress reports Evaluation report
Outcome 4: **Project management, monitoring and evaluation (M&E)**	1. Project monitoring management structure established 2. Project monitoring and evaluation procedures established	Establishment of Project Steering Committee and National Project Management Team Recruiting of technical experts to form the project expert team Training of all members of project management teams Holding Inception Workshop Issuing Inception Report Issuing Project Annual Reports Holding review meetings Carrying out visits to operating facilities Preparing and issuing Project Terminal Report	Working rules of the Project steering committee TORs of the project management staff and experts Inception workshop meeting minutes Inception Report Annual Project Reports and Project Implementation Reviews Mid-term and terminal external evaluation reports Terminal Report Annual project financial audit reports Field inspection reports

SECTION G: PRIOR OBLIGATIONS AND PREREQUISITES

173. The Project Document will be signed by UNIDO and the Government of Morocco. GEF assistance will be provided subject to UNIDO being satisfied that the obligations and pre-requisites listed below have been fulfilled or are likely to be fulfilled. When fulfilment of one or more of these prerequisites fails to materialize, UNIDO may, at its discretion, either suspend or terminate its assistance.

G.1 PRIOR TO PROJECT EFFECTIVENESS

174. Legally binding co-financing agreements are signed for the private/public sector participation in the project.

G.2 DURING PROJECT IMPLEMENTATION

175. Annual Project Implementation Review report and Report of the Annual Review meeting prepared. The workplan and consequently the project budget will be updated annually.

SECTION H: LEGAL CONTEXT

137. The project document shall be the instrument referred to the Standard Basic Agreement between the Government of Morocco and UNIDO. The project objectives shall be in line with the objectives of the Policies of the Government of Morocco.

138. The following types of revisions may be made to this Project Document with the signature of the Project Manager, provided he or she is assured that the other signatories of the Project Document have no objection to the changes as follows:

- Revision in, or addition of, any of the annexes of the Project Document; and
- Revisions that do not involve significant changes in the immediate subcomponents, objectives, outcomes or activities of the project, but are caused by rearrangement of the inputs already agreed to or by cost increases due to inflation.

ANNEXES:

ANNEX A: PROJECT LOGICAL FRAMEWORK

Interventions	Objectively Verifiable Indicators	Sources of Verification	Assumptions and Risks
Overall objective			
Effective and efficient implementation of SC&NIP Treat and reclaim nearly 3,000 tons of PCB-contaminated mineral oil from in-service equipment and decontaminate related PCB wastes by establishing the in-the-country capacity to deal with PCB contaminated electrical equipment and other related material.	Steady and smooth progresses in SC compliance and NIP implementation reflected by the following indicators: ➢ Amount of PCB-contaminated mineral oil from in-service electrical equipment reclaimed ➢ Amount of related PCB-contaminated material and wastes treated and decontaminated	Performance appraisal reports for SC compliance and NIP implementation Project progress reports by evaluations	Assumptions: ➢ Enduring and effective Government support in base line funding can be secured ➢ Sufficient number of transformers to be cleaned or decommissioned identified and investigated for contamination level Risks: ➢ Holders of PCB-contaminated mineral oil from in-service equipment as well as related wastes are not willing to participate in the project ➢ Level of co-funding from the private sector not sufficient
Outcome 1 Identification process for PCB contamination in in-service and decommissioned transformers set up			
Output 1.1 *Identifying analytical laboratories for assessing PCB level in transformers*			
1.1.1 Drafting Terms of Reference	➢ Terms of Reference prepared ➢ Contractual arrangements prepared	➢ Terms of Reference reviewed ➢ Contracts signed with selected laboratories ➢ Monthly progress reports ➢ Evaluation reports	Assumptions: ➢ All laboratories routinely operating. ➢ The selected laboratories are willing to cooperate ➢ The trainers can help the trainees master the operating skills Risks: ➢ Certified laboratories not available in the country

Interventions	Objectively Verifiable Indicators	Sources of Verification	Assumptions and Risks
Output 1.2 *Establishment of Standard Method of Analysis for PCBs*			
1.2.1 Review of Moroccan analytical requirement based on PCB regulatory requirements 1.2.2 Review of International accepted PCB analytical methods 1.2.3 Harmonization and upgrading of Moroccan analytical standard methods	➢ Standard PCB analytical method adopted in Morocco	➢ PCB analytical method adopted by Morocco reviewed ➢ Evaluation reports ➢ Laboratory validation reports ➢ Technical training materials	Assumptions: ➢ The selected laboratories are active and willing to cooperate ➢ The trainers can help the trainees master the operating skills Risks: ➢ Laboratories are not willing to cooperate ➢ Not sufficient personnel in MEMEE laboratory
Output 1.3 *Samples collection and analysis*			
1.3.1 Sampling protocols for in-service and decommissioned transformers 1.3.2 Analysis of mineral oil-filled, in-service transformers 1.3.3 Analysis of mineral oil-filled surplus transformers and bulk storage mineral oil 1.3.4 Analysis of related waste coming from dismantled transformers before final disposal	➢ Standard Operating Procedures (SOPs) prepared for sample collection and analysis ➢ Skills of operators improved ➢ Overall management level improved ➢ Release of other pollutants within permitted limits ➢ Solid residues to landfill meeting the standards of safe disposal	➢ SOPs reviewed ➢ Monthly progress reports ➢ Evaluation reports ➢ Report of validation ➢ Technical training materials	Assumptions: ➢ The selected demonstration facilities are active and willing to cooperate ➢ The trainers can help the trainees master the operating skills ➢ Sufficient number of transformers to be cleaned or decommissioned identified and investigated for contamination level Risks: ➢ Potential transformers holders not willing to identify target transformers and therefore not participate.

Interventions	Objectively Verifiable Indicators	Sources of Verification	Assumptions and Risks
Outcome 2 Environmentally sound maintenance and treatment of in-service PCB contaminated mineral oil transformers in participating industries carried out			
Output 2.1 *Establishment of PCB contaminated mineral oil treatment facility*			
2.1.1 Drafting Terms of Reference 2.1.2 Preparation of Tendering Documents for technology providers 2.1.3 Assessment and selection of the most technically and economically viable option 2.1.4 Plant acquisition	➢ Terms of Reference prepared ➢ Tendering document prepared ➢ Contractual arrangements prepared ➢ Criteria for assessment and selection of alternatives agreed upon	➢ Terms of Reference reviewed ➢ Tendering document reviewed ➢ Contracts signed with selected facilities ➢ Monthly progress reports ➢ Evaluation reports	Assumptions: ➢ The selected facility is active and willing to cooperate ➢ The trainers can help the trainees master the operating skills Risks: ➢ Facilities are not willing to cooperate
Output 2.2 *Treatment of defined volume of PCB contaminated mineral oil and PCB contaminated metals*			
2.2.1 Collection and transportation of PCB contaminated mineral oil from participating industries sites to mineral oil decontamination facilities 2.2.2 Decontaminate at least 3,000 tons of PCB contaminated mineral oil	➢ Volume of decontaminated PCB containing oil ➢ Emission of VOCs and other pollutants meeting the limits ➢ Treated waste meeting standards for safe disposal to landfill	➢ Monthly progress reports ➢ Technical reports ➢ Evaluation reports	Assumptions: ➢ The de-chlorination facility is active and willing to cooperate ➢ The implementation is feasible ➢ The purchased equipment is reliable ➢ Modified facilities can meet the standards ➢ The trainers can help the trainees master the operating skills ➢ Routine operation for the dechlorination of contaminated oils and retrofilling of cleaned oil Risks: ➢ Potential transformers holders not willing to identify contaminated transformers ➢ Potential holders of PCB contaminated mineral oil not willing to treat their oil in dechlorination unit ➢ Electrical demand may not allow transformers containing PCB contaminated mineral oil to be available for treatment

Interventions	Objectively Verifiable Indicators	Sources of Verification	Assumptions and Risks
Outcome 3 Environmentally sound disposal of decommissioned PCB contaminated transformers and material recovery set up			
Output 3.1 *Establishment of PCB contaminated dismantling facility and PCB contaminated metal reclamation system*			
3.1.1 Drafting Terms of Reference 3.1.2 Preparation of Tendering Documents for technology providers 3.1.3 Assessment and selection of the most technically and economically viable option 3.1.4 Plant acquisition	➢ Terms of Reference prepared ➢ Tendering document prepared ➢ Contractual arrangements prepared ➢ Criteria for assessment and selection of alternatives agreed upon	➢ Terms of Reference reviewed ➢ Tendering document reviewed ➢ Contracts signed with selected facilities ➢ Monthly progress reports ➢ Evaluation reports	Assumptions: ➢ The selected facility is active and willing to cooperate ➢ The trainers can help the trainees master the operating skills Risks: ➢ Facilities are not willing to cooperate
Output 3.2 *Pilot project for the treatment of defined amountf PCB contaminated transformer carcasses*			
3.2.1 Dismantle decommissioned transformers 3.2.2 Metals recovery	➢ Number of dismantled decommissioned transformers ➢ Amount of metals recovered ➢ Emission of VOCs and other pollutants meeting the limits ➢ Treated waste meeting standards for safe disposal to landfill	➢ Monthly progress reports ➢ Technical reports ➢ Evaluation reports	Assumptions: ➢ The dismantling facility is active and willing to cooperate ➢ The implementation is feasible ➢ The purchased equipment is reliable ➢ Modified facilities can meet the standards ➢ The trainers can help the trainees master the operating ➢ There are enough PCB contaminated carcasses to operate the solid decontamination unit Risks: ➢ Temporary storage at decontamination site may be required until treatment facility for PCB contaminated transformer carcasses is built and becomes operational

Interventions	Objectively Verifiable Indicators	Sources of Verification	Assumptions and Risks
Outcome 4: Project management, monitoring and evaluation (M&E)			
Output 4.1 *Development and implementation of Project Monitoring management structure according to GEF M&E procedures*			
4.1.1 Establish the Project steering committee by relying on resources from related ministries or commissions at the national level and from local governmental agencies 4.1.2 Establish the Project management Team 4.1.3 Recruit a CTA, technical experts in PCB management, and evaluation and programming experts to form a Project Expert Team 4.1.4 Carry out training for the national/local project management staff 4.1.4 Designate a project focal point within UNIDO	➢ Project steering committee established ➢ National Project Management Team established with necessary office equipment procured ➢ National project expert team established ➢ Project management capabilities improved at national and local levels	➢ Working rules of the project steering committee ➢ TORs of the project management staff, including the project managers, coordinator, and technical support staff ➢ Expert recruitment notices and TORs for the CTA, technical experts in PCB management, and evaluation and programming experts ➢ Training materials on contractual management, project management tools, and basics of PCB management and disposal	Assumptions: ➢ Required resources from related ministries, commissions and local government agencies are available ➢ Various ministries agree on and support the project ➢ Coordination and cooperation can be achieved among various ministries ➢ Qualified project management staff can be recruited ➢ Qualified experts can be recruited ➢ The selected demonstration provinces have strong willingness for participation and cooperation Risks: ➢ Other government priorities may divert key resources necessary in the Project Project steering committee, which may require to include international expert to form part of the project expert team ➢ Delay in project implementation may cause delays in holding meetings and issuing required reports

Interventions	Objectively Verifiable Indicators	Sources of Verification	Assumptions and Risks
Output 4.2 Design and implement an M&E mechanism according to GEF M&E procedures			
4.2.1 Hold the Inception Workshop 4.2.2 Prepare the Inception Report 4.2.3 Measure impact indicators on an annual basis 4.2.4 Prepare Annual Project Reports and Project Implementation Reviews 4.2.5 Hold annual tripartite review meetings 4.2.6 Hold biannual Project steering committee meetings	➢ Inception Workshop held ➢ Detailed work plans prepared ➢ Data and information against indicators input into the MIS ➢ Non-compliances identified and corrected ➢ Technical and political guidance from the Project steering committee	➢ Inception workshop meeting minutes ➢ Inception Report ➢ Annual Project Reports and Project Implementation Reviews ➢ Biannual Project steering committee meeting minutes	Assumptions: ➢ The trained project management staff can well perform their jobs required in TORs ➢ Qualified external evaluation experts can be recruited ➢ No extreme weather conditions or other extreme events upon field visits Risk: ➢ Delay in project implementation
Output 4.3 External evaluation			
4.3.1 Carry out mid-term external review 4.3.2 Carry out final external evaluation 4.3.3 Complete the Terminal Report 4.3.4 Carry out annual project financial audits 4.3.5 Carry out biannual visits to selected field sites 4.3.6 Establish a project management information system (MIS), including a project website to disseminate information to various stakeholders	➢ Experience summarized and recommendations raised ➢ Problems identified and recommendations provided by field visits ➢ MIS established and made functional ➢ Project information, experience and lessons disseminated through website	➢ Mid-term and terminal external evaluation reports ➢ Terminal Report ➢ Annual project financial audit reports ➢ Field inspection reports ➢ MIS development documentations and reports generated by properly retrieving data and information from the MIS ➢ Project website development and maintenance documentations	Assumptions: ➢ Qualified IT service providers can be recruited to develop the MIS, including the project website ➢ A data and information collection mechanism among various stakeholders at different levels can be established to activate the MIS. Risk: ➢ Delay in project implementation as well as monitoring and evaluation

ANNEX B: TERM OF REFERENCES FOR INTERNATIONAL EXPERTS

Post: Chief Technical Advisor (CTA)

Duration: 3 work-months over a period of 3 years of which at least 1 work-month in Morocco. The number and duration of missions will be determined in the course of the project in accordance with the work plan.

Duty station: Morocco and home-based

Purpose:

i. Transfer international experience in PCB management and disposal and other local experts to the various stakeholders associated with PCB management. Provide technical advice for the planning of the PCB-dechlorination and decontamination facility, including sites for interim storage, packaging and transports of PCB-containing wastes;

ii. Assist MEMEE in overall technical support of other project activities, including institutional strengthening, the updating of the inventory of PCB-contaminated equipment, awareness raising among owners of PCB-contaminated electrical equipment, monitoring and evaluation, and inspection for enforcement and compliance;

iii. Review terms of references (TORs) for individual experts and implementation of project activities;

iv. Advise MEMEE on project monitoring, evaluation, including providing comments and finalizing the English version of progress reports on the ongoing activities, and annual action plan;

v. Troubleshoot technical and implementation issues that may emerge.

Scope of work:

The CTA in consultation with the UNIDO and the national project manager is expected to perform the following:

1	Assist MEMEE, together with national experts, to oversee all technical components of the Project. The Grant Agreement, Project Document, the Project Implementation Manual and the Annual Work Plan are the basic documents describing the project and guiding its implementation[5]. Through continuous project monitoring, the CTA will assist MEMEE to provide corrective countermeasures for accidental problem. The CTA will work together with the national project manager and a number of other individual technical experts at the highest technical level. The CTA will report directly to UNIDO Project Manager and MEMEE.
2	The CTA will provide overall technical assistance in the following aspects:
	- Support to workshops including participation in all important project workshops, introducing relevant international experience in the workshops, and reviewing and commenting all relevant deliverables of the workshops. This will include the following workshops: i. inception workshop ii. project implementation review meetings iii. monitoring and evaluation meetings

[5] The documents will be available soon after the inception workshop. Consultants interested in the position of the CTA are strongly encouraged to review the documents before considering the assignment.

	- **Support to project implementation including**: i. providing assistance in the planning of the PCB-dechlorination and decontamination facility, including sites for interim storage, packaging and transports of PCB-containing wastes; technology research and transfer, enforcement and compliance, and awareness raising. ii. providing assistance in developing, reviewing, and finalizing various project components such as institutional strengthening, the updating of the inventory of PCB-contaminated equipment, awareness raising among owners of PCB-contaminated electrical equipment, iii. guiding with the technology equipment vendors/suppliers, local experts of enterprise on technical issues concerning environmentally sound management and disposal of PCBs.
	- **Monitoring and Evaluation** for the whole process of the project**.** At this level the CTA will i. review and finalize the TORs for selection of experts and implementation of project activities in order to guarantee TORs are prepared in compliance with the requirement of the project and the principles of Stockholm Convention. ii. review and finalize all key project reports such as: ➢ drafts of the annual work plans of the project, ➢ quarterly progress reports on the ongoing activities, ➢ finalize the English version of all project reports and deliverables before dissemination to relevant stakeholders.
	- **Provide technical advice on the establishment of MIS.**
	- **Provide corrective countermeasures for accidental issues and provide advice on other project matters as requested by MEMEE.**

Qualifications:

- Extensive practical experience with the environmentally sound management and disposal of PCBs;
- PhD in a field directly related to PCB management and disposal;
- Experience with implementation of international projects; and
- Good communication and writing skills in English;

The following qualifications will be helpful: knowledge of the Stockholm Convention on POPs and working experience in Morocco.

Language: English, French

ANNEX C FEASIBILITY STUDY FOR THE USE OF COMBUSTION TECHNOLOGIES IN PCB DISPOSAL

Table of content

1) OBJECTIVE OF THIS STUDY

The objective of this report is to assess the feasibility to use thermal technologies for the final disposal of PCB oils and PCBs contaminated oils in Morocco**.**
The report was prepared on the basis of information collected during two missions in Morocco, in the framework of the preparatory work of a UNDP-UNIDO Full Size project to be implemented in Morocco. Meeting were held with representatives of companies, Industrial association, various government officials, especially of the Ministry of Territory Management, Water and Environment, GTZ and some laboratories.

Different types of thermal technologies (Incineration, gasification/pyrolysis, plasma arc, cement kiln co-incineration and metallurgical production of metals) are presented and discussed in this report. The main objective is not a detailed description of the processes, but the implication that their application can have in PCB final disposal, the environmental impact and the cost/effectiveness assessment. The current technical capability in Morocco for PCB management was evaluated too.

2. INTERNATIONAL REQUIREMENTS FOR PCBS-POPs ELIMINATION

Regulation on the management and disposal of hazardous waste, including POPs, are currently adopted by many countries. They do not cover only final disposal, but also transport and storage, concentration limits in raw material and emissions (air and residues), as well as criteria for operating any wastes treatment systems (mainly thermal processes)

The European Directive 2000/76/EC was introduced with the aim to prevent or reduce, as far as possible, air, water and soil pollution caused by the incineration or co-incineration of all kinds of wastes, as well as the resulting risk to human health. The Directive was intended to fill the gaps existing in the previous legislation (Directives 89/369/EEC and 89/429/EEC for new and existing municipal waste-incineration plants and Directives 94/67/EC for the incineration of hazardous waste).

Another important issue introduced by the Directive is the incorporation of the technical progress made on monitoring incineration-process emissions into the existing legislation, and to ensure that the international commitments arising from European protocols on pollution are respected, and more particularly those concerning limit values for the emissions of PCDD/PCDF, Mercury and dusts. An integrated approach was developed, and limits for discharges into water are added to the updated limits for emissions to atmosphere and additional requirement are provided for solid residues.

Unlike the past Directives, the new Directive applies not only to facilities intended for waste incineration ("dedicated incineration plants") but also to "co-incineration" plants (facilities whose main purpose is to produce energy or material products and which use waste as a regular or additional fuel, this waste being thermally treated for the purpose of disposal).

The Directive requires that all incineration or co-incineration plants must be authorised. Permits are issued by the competent authority and list the categories and quantities of hazardous and non-hazardous waste which may be treated, the incineration or co-incineration capacity and the sampling and measurement procedures which are to be used. Operators of incineration plants must have available information on the physical and chemical composition of hazardous waste, and information on the hazardous characteristics of the waste, before accepting hazardous waste,

In order to guarantee complete waste combustion, the Directive requires all plants to keep the incineration or co-incineration gases at a temperature of at least 850℃ for at least two seconds. If hazardous wastes with a content of more than 1 % of halogenated organic substances, expressed as chlorine, are incinerated, the temperature has to be raised to 1100℃ for at least two seconds.

Different limit values for the emissions to atmosphere are set out for normal incineration or co-incineration. The limit values for incineration are set out in Annex V to the Directive. The limit values for co-incineration plant emissions to atmosphere are set out in Annex II. They concern heavy metals, PCDD/PCDF, carbon monoxide (CO), dust, total organic carbon (TOC), hydrogen chloride (HCl), hydrogen fluoride (HF), sulphur dioxide (SO_2), nitrogen oxides (NO and NO_2). In addition, special provisions are set out as far as cement kilns, other industrial sectors and combustion plants which co-incinerate waste.

Similarly, all discharges of effluents caused by exhaust-gas clean up procedures must be authorized. This guarantees that the emission limit values set out in Annex IV to the Directive are not exceeded. The quantity and harmfulness of incineration residues must be reduced to a minimum and residues must be recycled. When dry residues are transported, precautions must be taken to prevent their dispersal in the environment. Tests must be carried out to establish the physical and chemical characteristics, and polluting potential, of residues.

The U.S.A. approved high efficiency incinerators to destroy PCBs with concentrations above 50 ppm. Wastes that contain 250 ppm or more of PCBs must be incinerated. Wastes that contain PCBs in the 50-250 ppm range can be incinerated, buried in a chemical waste landfill, or burned in a qualified industrial boiler.

EPA regulations 40 CFR 761.70 require performance testing of all PCB incinerators to ensure that they meet the requirements of 99.9999% PCB destruction and removal efficiency and 99.9% combustion efficiency. For liquid PCB incinerators, the regulations require a residence time of 2 seconds at 1200ºC ± 100ºC at 3% excess oxygen or 1.5 seconds at 1600ºC ± 100ºC at 2% excess oxygen. EPA regulations also require that PCB incinerators be tested for the following emissions: hydrogen chloride, particulate matter, oxygen, carbon monoxide and carbon dioxide.

A comprehensive list of national legislation containing provisions related to the management of wastes consisting of, containing or contaminated with POPs is reported hereafter.

Country	Legislation	Brief description
Austria	Soil Protection Acts	• Contains stringent limit values on PCBs, PCDDs and PCDFs in sewage sludge used as fertilizer.
Brazil	Norm ABNT/NBR, N° 8371/1997	• Procedures for handling, transport and storage of materials containing PCBs
Brazil	Resolution CETESB (São Paulo state), N° 007/1997	• Determines limits for PCDDs and PCDFs on emissions from medical waste incinerators with capacity > 200 kg/day
Brazil	Resolution CONAMA, N° 264/1999	• Procedures for environmental licensing on waste co-processing in cement kilns
Brazil	Resolution CONAMA, N° 313/2002	• Provides for an inventory of PCB stocks and industrial wastes
Brazil	Resolution CONAMA, N° 316/2002	• Procedures and criteria for operating thermal wastes treatment systems, provides limits on emissions of PCDDs and PCDFs
Brazil	Resolution CONAMA, N° 334/2003	• Procedures for environmental licensing for those establishments responsible for receiving pesticides package
Brazil	Decision CETESB (São Paulo state), N° 26/2003	• Sets limits for air emissions of PCDDs and PCDFs of cement kilns treating also waste
Brazil	Resolution CONAMA, N° 357/2005	• Provides maximum permitted levels for POPs in effluents discharged to water
Canada	Federal Mobile PCB Treatment and Destruction Regulations	• Contains emission standards for release of gases, liquids and solids contaminated with

Country	Legislation	Brief description
		PCBs, PCDDs and PCDFs.
European Community	Regulation (EC) No 850/2004 of the European Parliament and of the Council of 29 April 2004 on persistent organic pollutants and amending Directive 79/117/EEC, amended by Council Regulation (EC) No. 1195/2006 of 18 July 2006 amending Annex IV to Regulation (EC) No. 850/2004	• Article 7 contains provisions regarding the management of wastes containing, consisting of or contaminated with POPs.
European Community	Council Directive 96/59/EC of 16 September 1996 on the disposal of polychlorinated biphenyls and polychlorinated terphenyls (PCB/PCT)	• Contains regarding the disposal of PCBs and PCTs, inter alia on the decontamination and/or disposal of equipment and the PCBs therein.
European Community	86/280/EEC Council Directive of June 12 1986 on limit values and quality objectives for discharges of certain dangerous substances included in List I of the Annex to Directive 76/464/EEC and 88/347/EEC Council Directive of June 16 1988 amending Annex II to Directive 86/280/EEC on limit values and quality objectives for discharges of certain dangerous substances included in List I of the Annex to Directive 76/464/EEC	• Annex II contains emission limit values for discharge of aldrin, dieldrin, endrin and HCB-contaminated waste water produced during production.
European Community	Directive 2000/76/EC of the European Parliament and of the Council of 4 December 2000 on the incineration of waste	• Annex IV contains emission limit values for discharges of PCDD and PCDF contaminated waste water from the cleaning of exhaust gases. • Annex V contains air emission values for PCDDs and PCDFs
European Community	Council Decision 2003/33/EC of 19 December 2002 establishing criteria and procedures for the acceptance of waste at landfills pursuant to Article 16 of and Annex II to Directive 1999/31/EC	• Paragraph 2.1.2.2 of the Annex contains criteria for landfill of inert waste containing PCBs.
Finland	Council of State decision (1071/1989) on the restriction of the use of PCBs and PCTs	• Contains limit values for PCBs and PCTs
Finland	Council of State decision (101/1997) on oil waste management	• Contains limit values for PCBs in regenerated oil and in oil wastes destined for incineration
Finland	Council of State decision (711/1998) on the disuse of PCB appliances and the treatment of PCB waste	• Contains limit values for PCBs
Finland	Council of State decree (1129/2001) on a list of the most general wastes and hazardous wastes	• Contains limit values for PCBs
Germany	Federal Soil Protection and Contaminated Sites Ordinance	• Contains action levels regarding sites contaminated with aldrin, DDT, HCB, PCBs, PCDDs and PCDFs.
Germany	Ordinance on Landfills and Long-Term Storage Facilities	• Contains a limit for PCBs in soils used as recultivation layers of landfills. • Prohibits the landfilling of waste, which may harm public welfare due to its content of long-lived or bio-accumulable toxic substances.
Germany	Ordinance on Underground Waste Stowage	• Contains limits for use of waste contaminated with PCBs as stowage material.
Germany	Sewage Sludge Ordinance	• Contains limits for usage of sewage sludge contaminated with PCBs, PCDDs and PCDFs

Country	Legislation	Brief description
		as fertilizer.
Germany	Waste Wood Ordinance	• Contains limits for recycling of waste wood contaminated with PCBs.
Germany	Waste Oil Ordinance	• Contains limits for recycling of PCB contaminated oils.
Japan	Law Concerning Special Measures Against Dioxins	• Contains tolerable daily intake environmental standards for ambient air, water quality (including sediment) and soil, emission and residue standards for gas, effluent, ash and dust regarding PCDDs, PCDFs and co-planar PCBs.
Japan	Law Concerning Special Measures Against PCB Wastes	• Contains standards for the treatment of plastics and metals contaminated with PCBs.
Japan	Law Concerning Special Measures Against Soil Contamination	• Contains standards for the treatment of soil contaminated with PCBs.
Japan	Waste Management and Public Cleansing Law	• Contains criteria of hazardous wastes containing PCBs, PCDDs, PCDFs and co-planar PCBs.
Japan	Water Pollution Control Law	• Contains emission standards for effluent containing PCBs.
Mexico	Norm NOM-098 of 2004	• Contains emission and destruction efficiency standards for waste incinerators.
Mexico	Norm NOM-133 of 2001	• Contains regulations regarding handling of PCBs and a programme for the preparation of inventories.
Norway	Norwegian Product Regulation chapters 2 and 3 on regulated hazardous substances or a mix of substances and products containing hazardous substances	• Contains a ban on the production, use, import and export of PCBs, PCTs and products containing these substances, including PCB-containing capacitors.
Norway	Norwegian Waste Regulation chapter 14 on obsolete insulation windows that contain PCB	• Lays down requirements for the producers to collect and handle obsolete windows that contain PCBs.
Norway	Norwegian Pollution Regulation chapter 2 on clean-up of contaminated sites	• Contains limit values below which a soil is considered to be clean and suitable for use in sensitive areas.
Switzerland	Soil Burden Ordinance	• Contains actions levels regarding sites contaminated with PCBs, PCDDs and PCDFs.
United States of America	EPA 40 CFR 63 Subpart EEE National Emission Standards for Hazardous Air Pollutants from Hazardous Waste Combustors	• Contains standards for releases of PCDDs and PCDFs within air emissions.
United States of America	40 CFR 268.48 Universal Treatment Standards for Hazardous Wastes	• Contains standards for the treatment of hazardous waste prior to land disposal and aqueous waste prior to release. Covers all POPs except mirex.
United States of America	40 CFR 761.70 Standards for incineration of PCBs	• Contains standards for air emissions, when incinerating PCBs

The Stockholm Convention specifically targets very high concentration wastes for priority action (>10% or 100,000 mg/L PCBs), then “medium” and high concentration (500 ppm – 10% PCB) wastes, and finally low concentration (50 – 500 ppm PCB) wastes for phase-out. Since in most inventories the high concentration wastes accounts for more than 90% of the total mass of PCBs, (including also PCTs or PBBs), countries are encouraged to focus their initial efforts on the management and destruction of these wastes.

Another way to prioritize actions is to assess the risk of environmental exposure of certain types of wastes. The highest risk is associated with high-concentration liquid PCBs. Liquids have a higher risk to the environment than solids because, if spilled, they can contaminate the soil, water or sediment. Therefore all countries should ensure that liquid wastes are targeted for management and destruction as a first priority.

3. TECHNICAL REQUIREMENTS FOR PCBs-POPs ELIMINATION

The main aim of the Stockholm is the elimination of POPs and therefore recommends their complete destruction or irreversible transformation so that the substance is no longer a hazard after treatment and before the residue can be land-filled. The Basel Convention recommends treating all PCB, PCT (polychlorotriphenils) and PBB (polybromobyphenils) containing substances to the highest degree that is commercially available. This is referred to as the use of “best available techniques” (BAT). For a complete destruction many countries set as minimum requirement a rate of 99.9999% DRE (destruction and removal efficiency) or the achievement of a level of contaminant associated with the application of Best Available Techniques. Destruction technologies are often approved on the basis of this targets and levels of performance.

Notwithstanding, some consideration and criteria must be evaluated before selecting a thermal destruction technology for POPs waste. Firstly, it must be recognized that the number of types of PCBs wastes can be very high and not all the techniques are capable to process them.

The main waste groups are as follows:

Liquids From Products
- Very high-concentration oils (mainly askarel PCB, but also PCTs or PBBs) (>100,000 mg/L)
- High-concentration oils (10,000-100,000 mg/L)
- PCB contaminated mineral oil (<10,000 mg/L)
- Disposed paint or ink containing PCBs
- Disposed fire suppressants containing PBBs

Solids From Products
- Solid pure PBBs or PCTs
- Contaminated solid wastes (paper, metal products, absorbents and protective clothing used in handling wastes, glass, plastic, painted objects, auto shredder fluff, etc.)
- Contaminated solid equipment components including whole lamp ballasts

Wastes from Contaminated Sites
- In-situ contaminated soil and sediment
- In-situ contaminated groundwater
- Ex-situ contaminated water (pumped groundwater, process water, firefighting water, etc.)

Gases
- Contaminated air or gas from processes that treat or remove PCBs, PBBs or PCTs.

Secondly, the treatment capability of some types of waste contaminated with PCBs (soil, sediments and equipment solids as lamp ballasts) must be optimized by pre-treatment steps, aimed to reduce the volume of materials and to improve their physical quality. Some pre-treatment techniques attempt to separate the clean fraction of the material from others which can be relatively contaminated. Others separate water in the waste material from the solids. Separation techniques produce some residues that have to be further treated or disposed. The main goal is to minimize the amount of material to be disposed and to obtain reusable material. In many cases, separation technologies reduce the overall cost of the treatment.

The main categories of pre-treatment are:

- Dewatering;
- Size separation;
- Washing;
- Density separation;
- Equipment splitting;
- Wash water treatment.

Finally, although pre-treatment steps are correctly carried out, destruction technologies when treating lower concentration wastes are not expected to show a 99.9999% destruction efficiency in each case (because if the initial concentration of contaminant is low, it is very difficult to determine if the percentage of destruction was achieved using standard analytical techniques).

4. REVIEW OF PCBs-POPs THERMAL ELIMINATION TECHNOLOGIES

4.1 INCINERATION

Introduction

High-temperature hazardous-waste incinerators are the most common facilities used for the treatment by complete oxidation of wastes consisting of, containing or contaminated with any POPs, because they are very effective and because there are few alternatives with regulatory approval.
Incinerators can be designed to accept wastes in any concentration or any physical form, i.e., gases, liquids, solids, sludges and slurries, but homogeneity is preferred for optimal system operation, so blending and pre-processing measures may be necessary.

The main waste which can be incinerated are as follows:

- Solvents (e.g. gasoline, toluene, alcohol, or acetone);
- Halogenated and sulphur containing solvents (e.g. trichlorethylene, freon, carbon disulphide, mercaptans, PCB, etc);
- Mineral oils (e.g. lubricating oil, gas oil, or diesel oil, possibly mixed with water, soil, or gravel etc.);
- Organic pesticides, (e.g. Aldrin, Chlordane, Dieldrine, DDT, Endrin, Heptachlor, Hexachlorbenzene, Mirex, Toxaphene, POPs, empty pesticide containers etc.);
- Special waste (e.g. medicines, isocyanates); and
- Others (e.g. bitumen, amines, acetic acid, latex, glue, phenols synthetic oils, organic acids, paint).

In hazardous waste incineration plants, wastes with a PCB content as high as 60 - 100 % can be combusted. The same applies to special plants for the incineration of highly chlorinated hydrocarbons. UNEP Chemicals, in the document “Inventory of Worldwide PCB Destruction Capacity”, recognizes high-temperature incineration as the most widely used and proven technology for destroying PCBs, able to reach a PCB destruction removal efficiency of at least 99.9999 % if adequate temperatures (e.g. above 1200 °C) and proper operation are set. However, lower temperatures (e.g. 950 °C) together with appropriate conditions of turbulence and residence time have also been found to be effective for PCB incineration.

It must be pointed out that the Stockholm Convention in Annex C, Part II identifies waste incineration as a potential source of unintentionally produced POPs. Moreover, recent studies suggest that incinerators achieve destruction efficiencies that are lower than those achieved by certain non-combustion technologies. Therefore each incinerator must be assessed very carefully for its ability to destroy contaminants and its gaseous, liquid and solid emissions.

Description of the technology

An incineration plant basically consists of the following units:

- Furnace or kiln - Rotary kilns and stepped hearths are preferred since their configuration can treat liquid wastes in a better way. Stepped hearths are recognized to produce less fly ash in the gas stream exiting the furnace than other devices. Some kinds of fluidized bed kilns can also be used.
- Afterburning chamber;
- Heat recovery (or energy recovery) section and/or quencher
- Dry, wet and/or catalytic flue gas cleaning devices (including adsorption techniques);
- Particulate matter reduction devices (filters)
- Stack
- Waste-water treatment plant (in case wet systems are used for flue gas treatment).

Rotary kilns:

Rotary kilns are the most common kilns used for hazardous waste treatment because they are very robust and almost any waste can be incinerated. They consist of a cylindrical vessel slightly inclined on its horizontal axis. The vessel is usually located on rollers, allowing the kiln to rotate or oscillate around its axis (reciprocating motion). Solid waste, liquid waste, gaseous waste, and sludges can be incinerated in rotary kilns.

Solid materials are usually fed through a non-rotating hopper; liquid waste may be injected into the kiln through burner nozzles; pumpable waste and sludges may be injected into the kiln via a water cooled tube, especially where they have safety risks and require particular care to reduce operator exposure. The waste is conveyed through the kiln by gravity as it rotates. The residence time of the solid material in the kiln is determined by the horizontal angle of the vessel and the rotation speed: a residence time of between 30 to 90 minutes is normally sufficient to achieve good waste burnout.

Suitable temperatures and residence time must be assured for a complete oxidation of the waste and for the destruction of POPs. Therefore a proper operation of the primary chamber and of the secondary afterburning chamber is mandatory. In addition, a sufficiently strong turbulence is required to prevent cold spots in the burn chamber. This means to find the best balance between temperature and residence time that produces enough turbulence through the mixing of fuel and air. At a higher temperature a shorter residence time can be sufficient. The installation of automatic auxiliary burners to maintain optimal temperatures in the combustion chamber is suggested. Operating temperatures of rotary kilns used for wastes range from around 500 ℃ (as a gasifier) to 1450 ℃ (as a high temperature ash melting kiln). Higher temperatures are sometimes encountered, but usually in non-waste applications. When used for conventional oxidative combustion, the temperature is generally above 850 ℃. Temperatures in the range 900 - 1200 ℃ are typical when incinerating hazardous wastes.

Generally, and depending on the waste input, the higher the operating temperature, the greater the risk of fouling and thermal stress damage to the refractory kiln lining. Some kilns have a cooling jacket (using air or water) that helps to extend refractory life, and therefore the time between maintenance shut-downs.

Post-combustion chamber:

In order to increase the destruction of toxic compounds, a post-combustion chamber is usually added. Additional firing using liquid waste or additional fuel may be carried out to maintain the temperatures required to ensure the destruction of the waste being incinerated. The temperature can be above 1100 ℃ (at least 2 sec residence time)

The so called Modular Starved Air Incinerators consist of two stages. During the first stage (starved air section), the air-fuel ratio is kept low to promote drying and volatilization at temperatures of 800 - 900 ℃. In the second stage (secondary combustion chamb er) excess air is added and temperatures elevated to > 1000 ℃ by support burners to ensure complete gas phase combustion.

Heat recovery (or energy recovery) section and/or quencher;

Also after the burning chambers the operating temperature is a critical parameter. After the secondary chamber, it is necessary for the waste gas to pass as fast as possible the temperature range of 500-600 ℃ to 200℃ in order to avoid a de-novo synthes is for PCDD/PCDF. This can be realized through a fast cooling in the boiler, adding a spray tower or a quencher. These kinds of changes are not easy to carry out in existing plants, but are not expensive in new facilities. The main advantages are the recovery of energy in the boiler and the reduction of costs for the treatment of waste waters or boiler ashes that could be rich of PCDD/PCDF

Air pollution control Systems:

Process gases may require treatment to remove acids and particulate matter and to prevent the formation of and remove unintentionally produced POPs. This can be achieved through a combination of types of post-treatments, including cyclones and multi-cyclones, electrostatic filters, static bed filters, scrubbers, selective catalytic reduction, rapid quenching systems and carbon adsorption. Depending upon their characteristics, bottom and fly ashes may require disposal within a specially engineered landfill.

Dust collectors:

Cyclones and multicyclones are less efficient than bag filters and electrostatic precipitators in dust removal and should only be used in a pre-dedusting step to remove coarser particles from the flue gases and reduce dust loads on downstream treatment devices. Pre-separation of coarse particles will decrease the amount of fly ash contaminated with high loads of persistent organic pollutants.

Advantages of cyclones are their wide operational temperature range and robust construction. Erosion of cyclones can occur when the particulate matter concentration is very high and particularly where bed material escapes from fluidised bed plants

Electrostatic precipitators are also called electrostatic filters. They are mainly used in large plants. The efficiency of dust removal of electrostatic precipitators is mostly influenced by the electrical resistivity of the dust. The dust layer resistivity is influenced by waste composition. It may thus change rapidly with a changing waste composition, particularly in hazardous waste incineration.

Typical operational temperatures for electrostatic precipitators are 160 - 260 ℃. Operation at higher temperatures are generally avoided as this may increase the risk of PCDD/PCDF formation.

Wet electrostatic precipitators are based upon the same technological working principle as electrostatic precipitators. With this design, however, the precipitated dust on the collector plates is washed off using a liquid, usually water. This may be done continuously or periodically. This technique operates satisfactorily in cases where moist or cooler flue-gas enters the electrostatic precipitator. Wet electrostatic precipitators can capture very small particle sizes (< 1 mg/m^3) but require effluent treatment and are usually employed following dedusting.

Bag filters are more efficient than electrostatic precipitators (higher than 99%) and are generally coupled with a system for injection of active carbon. At temperatures higher than 200 ℃, if not frequently cleaned, a formation of active sites for PCDD/PCDF reformation can occur. Fabric filters are subject to water damage and corrosion and gas streams must be maintained above the dew point (130º–140º C) to prevent these effects. Some filter materials are more resistant to damage. Therefore an optimisation of operating procedure is recommended. Moreover, a bag leak detection system using should be considered for monitoring fabric filter performance.

Scrubbers:

Wet scrubbers are the most common devices used in hazardous waste incinerators.They are suitable for acid removal and reagent consumption is generally lower than semidry scrubber. Pre-dedusting of the gas stream may be necessary to prevent clogging of the scrubber, although scrubber capacity is sufficiently large.

The main disadvantage of Wet scrubbers is that they have a low PCDD/PCDF collection efficiency due to the low solubility of these compounds in aqueous media. Moreover, plastics materials that are widely used in the building of this kind of flue gas cleaning equipment due to their good corrosion resistance can show an adsorbing property for PCDD/PCDF. The typical operation temperature is 60-70 °C and at higher temperatures (90 °C if not well monitored) the adsorbed lower chlorinated PCDD/PCDF (the most toxic) could be desorbed to the gas phase with a desorption rate that increase with temperature. This can be avoided with the addition of activated coke to the scrubbing fluid or layers of polypropylene soaked with activated coke to the wall of the scrubber in order to improve the collection efficiency to a value of about 60-75%.

The main disadvantages are that Mercury can not be adsorbed, that their replacement in low scale incineration plant is not economically convenient (energy consumption for set-up of in and out temperatures) and that they produce high amount of waste water.

Semidry scrubbers use an alkaline reagent slurry (usually calcium hydroxide) which is introduced into the flue gases as a spray of fine droplets. The acid gases are absorbed into the aqueous phase on the surface of these droplets and neutralized to form a dry product, which is collected in an electrostatic precipitator or fabric filter, They operate with temperatures in the range 200-400 °C, depending on the boiler-quencher section, Moreover a reduction of gas temperature to 130-180 °C is advisable, suitable for next bag filter operation.

An addition of more injection nozzles for alkaline lime spraying to increase the acid reduction efficiency and a separately injection of activated carbon before semidry scrubber are usually suggested. It has been shown that a semidry flue-gas cleaning system with dosage of activated coke is the most cost-effective solution for pre-separation of mercury, PCDD/F and for dedusting. These scrubbers produce lesser residues than dry and wet scrubber, but they have be disposed of in secure dumping sites (contain PCDD/PCDF).

In dry scrubbers the absorption agent (usually lime or sodium bicarbonate) is fed into the reactor as a dry powder. The reaction products generated are solid and need to be deposited from the flue-gas as dust in a subsequent stage, normally a bag filter. They cannot reach the efficiency of wet or semi-dry (spray dry) scrubbers without significantly increasing the amount of reagent/sorbent and consequently the volume of fly ash produced.

Flow injection process and Spray absorbers:

In these process active carbon, mixed with an alkaline reagent in an amount of more than 80% to avoid risks of flames, is injected directly in the gas stream with a temperature of about 120°C so that the material is suspended in the flow homogeneously. The added material is transported to the next bag filter where it settles in a layer on the surface of the filter. In order to make better use of the adsorption material part of it may be re-circulated.

Flow injection processes are being used in Europe in a number of waste incineration plants for the collection of PCDD/PCDF, HCl, HF and SO_2. Due to the necessary high amounts of inert material the residual matter left from the process are considerable. With this process a PCDD/PCDF collection efficiency of 99% can be achieved.

Alternatively, active carbon, mixed with an alkaline reagent, is injected directly in the semidry scrubbers by using spray absorbers. The absorbent (lime slurry) is atomised in the spray tower. The gas is first absorbed by the liquid phase and then by the solid phase. Inlet temperature to the fabric filter in such combinations is important. A temperature drop below a lower limit (130º–140º C) are normally required to prevent condensation, clogging of the bag filter due to crystal water adhering to $CaCl_2$, and corrosion of the bags. PCDD/PCDF are adsorbed and discarded with the ashes collected by the following dust collector. This technique guarantees a level of efficiency of 60 % if followed by an electrostatic precipitator. By adding coke made from bituminous coal in a quantity of up to 500 mg/m^3 a much higher PCDD/PCDF collection efficiency of approx. 90% can be achieved.

An efficiency of removal of around 97% can be reached if a bag filter is installed as dust removal, because in this kind of device the residence time of waste gas is higher and adsorbing time too. With this configuration a good removal efficiency of Mercury has been detected.

Fluidized-bed process with adsorbent recycling:

With regard to process engineering, the fluidized-bed process lies between the flow injection process and the fixed-bed. The flue gas passes through the grate from the bottom and forms a fluid bed of coke with inert material with a temperature of about 120℃. As in the case of the flow injection proce ss limestone or lime can be used as inert material. However, the amount of coke can be higher than with the flow injection process. The adsorbent is separated from the flue gas in a dust collector (cyclone or bag filter) and returned to the fluid bed. Generally the adsorbent can be recycled several times so that it is feasible to collect other acid components such as HCl, HF and SO_2. While activated coke adsorbs mainly PCDD/PCDF and heavy metals, HCl, HF and SO_2 are removed by the lime-containing inert material.

The advantage of the fluidised-bed process lies in the high residence times of the adsorbent and in its better use. For this reason it can be assumed that the collection efficiency is higher than with the flow injection process

Fixed-bed or traveling-bed process:

It is a process with a very high efficiency in PCDD/PCDF and Mercury removal. In a fixed-bed or travelling-bed absorber granulated coke with different diameters are being used as adsorbent. Alternatively, zeolitic adsorbents have shown high efficiency, but they are used in a lesser extent.
In a fixed-bed waste gas pass through from bottom to top and in a travelling-bed the coke moves slowly quasi continuously or discontinuously from top to bottom while the waste gas flows in perpendicular or opposite direction to the direction in which the coke is moved. The exchange time period during a fixed-bed or travelling-bed processes can be 10 times longer than in flow injection or fluidised-bed processes.
The achievable PCDD/PCDF emission can be lower than 0.1 ng TEQ/Nm^3 if other devices such as activated coke injection systems are placed before and work properly. In order to minimise the disposal problems with the spent coke and to optimise the collection of various other pollutants, the fixed-bed or travelling-bed reactor is designed to consist of multiple beds. It must be reminded that a frequent disposal of the carbon layers in the furnace can lead to Mercury releases and PCDD/PCDF recirculation.

Catalytic decomposition by SCR:

SCR units generally used to reduce the concentration of Nitrogen Oxides have been proved to reduce also the concentration of PCDD/PCDF below 0.1 ng TEQ/Nm^3. This technique avoid the production of contaminated residues but requires an additional consumption of energy, since waste gases must be heated before entering the SCR unit, in order to reach the optimized working temperature for the catalyser. The removal efficiency for PCDD/PCDF can reach 85%. On the other hand, the catalyst has not the same capacity of removing many kinds of pollutants as the activated coke system. In order to prevent clogging of the catalyst with coarse fly ash particles as well as to avoid rapid wear and closing of the pores by ammonium sulphate the catalyst for the destruction of PCDD/PCDF is usually applied after all other cleaning stages This methodology can be applied to all incineration plants, but is suitable for medium-large facilities.

Electron irradiation processes:

PCDD/PCDF compounds in the flue gas of waste incineration plants can also be reduced by electron irradiation. A reduction of the PCDD/PCDF by 99% could be achieved. The decomposition products are simple organic acids; the pressure loss and the specific energy consumption of the process are low. Experimental plant TAMARA of the Nuclear Research Centre is located in Germany, but no large scale application of the process has become known to date.

A resume of the many secondary measures applied for reduction of PCDD/PCDF and Mercury are reported below.

Device	Release	Applicability	Other considerations
fabric filters	1-0.1 %	medium	use at temperatures < 260°c (depending on material) Specific techniques for Mercury removal are requested.
ceramic filters	low efficiency	higher	use at temperatures 800-1000°C, not common for waste incinerators
cyclones	low efficiency	medium	only efficient for larger particles
electrostatic precipitators	medium efficiency	medium	use at temperature of 450°C; Reformation of PCDD/F Low efficiency for fine particles, High NOx emissions,
catalytic oxidation SCR	high efficiency (98-99%) PCDD/F < 0.1 ng TEQ/m^3	high investment and low operating costs	only for gaseous streams after dust removal. no solid residues high space demand additional ammonia addition
fabric filters coated with catalyst	high efficiency (99%) < 0.1 ng TEQ/m^3	high investment	made from PTFE lower filter contamination Generally used in place of SCR and without activated carbons to avoid solid residues.
Adsorbent reburning			Applied with fixed bed adsorber and wet scrubber. Needs specific techniques for Mercury removal
Coke static bed	High efficiency < 0.1 ng/Nm^3		Residue are incinerated Good reduction for Mercury.
Addiction of activated carbon in gas stream	Efficiency can vary accordino to properties of activated carbons 60-75 % < 0.1 ng/Nm^3	Medium investment	Carbons are collected by the bag filter. Prevention of memory effect and consequent release of PCDD/PCDF
Wet scrubber	With addiction of carbon material reduction up to 70 %	Low investment	Without addction of carbon reduction negligible
Dry scrubber	Medium efficiency	Low-medium investment	Easy to use

Semidry scrubber	Reduction with adsorber and alcaline reagent	Low investment	-

A comparison of some combinations of different APCSs is presented hereafter

Collection process	Absorbent or adsorbent	Collection efficiency*)
Dust collector	dust collected in a filter	70%
Scrubber	bituminous coal coke	50%
Spray absorber plus electrostatic precipitator	lime slurry	60%
Spray absorber plus electrostatic precipitator	lime slurry plus bituminous coal coke in a quantity of approx. 500 mg/m^3	90%
Fluidised-bed process	zeolite	95%
Catalytic process	(NH_3 or H_2O_2)	95-99%
Spray absorber plus cloth filter	lime slurry plus bituminous coal coke in a quantity of approx. 500 mg/m^3	98%
Flow injection adsorption plus cloth filter	bituminous coal coke (200 mg/m^3)	99%
Fluidised-bed process	bituminous coal coke (80 mg/m^3)	99.9%
Fixed-bed or travelling-bed processes	anthracite coke	99.99%

Environmental impact of waste incinerators

Release to air:

Emissions to air have been for a long time the main problem for waste incineration plants. Significant advances in technologies for the cleaning of flue-gases in particular have lead to major reductions in the emissions to air. However, the control of emissions to air remains an important issue for the sector. A summary of the other main emissions to air from stack releases is shown below:

- particulate matter, –particulate matter - various particle sizes
- acid and other gases, including HCl, HF, HBr, HI, SO_2, NOx, NH_3
- some heavy metals (e.g. Pb, Cu, Cd, Cr, Ni, Hg)
- a variety of organic compounds, including PCDD/PCDFs, chlorobenzenes, chloroethylenes and polycyclic aromatic hydrocarbons (PAHs),
- odour, –from handling and storage of untreated waste
- green house gases –from decomposition of stored wastes e.g. methane, CO_2
- dusts, –from dry reagent handling and waste storage areas.

High levels of CO normally indicate that the combustion gases were not held at a sufficiently high temperature in the presence of oxygen for a long enough time to convert CO to CO_2, or that quenching has occurred. Because oxygen levels and air distributions vary among combustor types, CO levels also vary among combustor types. Carbon monoxide concentration is a good indicator of gas phase combustion efficiency, and is an important criterion for indicating instabilities and non-uniformities in the combustion process.

A review of the typical range of clean gas emissions to air from hazardous waste incineration plants is reported hereafter. (Source EU IPPC BREF on Waste incineration, 2006)

Parameter	Type of measurement	Daily averages (mg/Nm^3)		Thirty-minute Averages (mg/Nm^3)		Annual averages (mg/Nm^3)
	C: cont. N: non-cont.	Limits in 2000/76/EU	Typical range of values	Limits in 2000/76/EU	Typical range of values	Typical range of values
Dust	C	10	0.1 – 10	20	0.1 – 15	0.1 – 2
HCl	C	10	0.1 – 10	60	0.1 – 60	0.3 – 5
HF	C/N	1	0.04 – 1	4	0.1 – 2	0.05 – 1
SO_2	C	50	0.1 – 50	200	0.1 – 150	0.1 – 30
NO_X	C	200	40 – 200	400	50 – 400	70 – 180
TOC	C	10	0.1 – 10	20	0.1 – 20	0.01 – 5
CO	C	50	5 - 50	100	5 – 100	5 – 50
Hg	C/N	0.05	0.0003 – 0.03	n/a	0.0003- 1	0.0004 – 0.05
Cd +Tl	N	0.05	0.0005 – 0.05	n/a		0.0005 – 0.05
Σ other heavy metals	N	0.5	0.0013 – 0.5	n/a		0.004 – 0.4
PCDD/PCDF (ng TEQ/m³)	N	0.1	0.002 – 0.1	n/a		0.0003 – 0.08
1. Data is standardised at 11 % Oxygen, dry gas, 273K and 101.3kPa. 2. Other metals = Sb, As, Pb, Cr, Co, Cu, Mn, Ni, V						

Release to water

The main sources of releases to water are as follows:

- effluents from air pollution control devices, e.g. salts, heavy metals
- final effluent discharges from waste water treatment plants, e.g. salts, heavy metals
- boiler water - blowdown bleeds, e.g. salts
- cooling water - from wet cooling systems, e.g. salts, biocides
- road and other surface drainage, e.g. diluted waste leachates
- incoming waste storage, handling and transfer areas, e.g. diluted incoming wastes
- raw material storage areas, e.g. treatment chemicals
- residue handling, treatment and storage areas, e.g. salts, heavy metals, organics.

The wastewater produced at the installation can contain a wide range of potentially polluting substances depending upon its actual source. The actual release made will be highly dependent on the treatment and control systems applied.

A review of the typical annual average range of emissions to water after treatment from hazardous waste facilities in Europe is reported hereafter. (Source EU IPPC BREF on Waste incineration, 2006)

Parameter all mg/l (unless stated)	Yearly average	
	Minimum	Maximum
Suspended solids	3	60
COD	<50	<250
Cd	0.0008	0.02
T1	0.01	0.05
Hg	0.0004	0.009
Sb	0.005	0.85
As	0.0012	0.05
Pb	0.001	0.1
Cr	0.001	0.1
Co	<0.005	<0.05
Cu	0.01	0.21
Mn	0.02	0.2
Ni	0.004	0.11
V	<0.03	0.5
Sn	<0.02	<0.5
Zn	<0.02	0.3
Cl^-	3000	72000
SO_4^{2-}	300	1404
Dioxins (ng TEQ/l)	0.0002	<0.05
Flow of water (l/kg waste)	0.2	20

Solid waste and release to soil:

Residues produced from the flue-gas cleaning are an important source of waste production. The amount and nature of these varies, mainly according to the types of waste being incinerated and the technology that is employed. These residues contain concentrated amounts of pollutants (e.g. hazardous compounds and salts) and therefore normally are not considered appropriate for recycling purposes.

The following main waste streams are commonly produced during the incineration process:

- ashes and/or slag
- boiler ashes
- filter dust
- other residues from the flue-gas cleaning (e.g. calcium or sodium chlorides)
- sludge from waste water treatment.

In some cases, the above waste streams are segregated; in other cases, they are combined within or outside the process.

Some typical ranges of residue production are presented:

	Residue production (kg/t waste input)			(Tonnes)
	Minimum	Maximum	Average	Total annual amount (recorded)
Bottom ash	83	246	140	193372
Boiler ash + fly ash + solid flue-gas cleaning residue	32	177	74	79060
Filter cake from ETP	9	83	30	16896

Bottom ashes are generally produced in the largest quantities and depending on their characteristics can be sometimes used as for re-cycling as an aggregate replacement and construction materials. In modern well-operated plants the TOC (Total organic carbon) in bottom ashes can be below 1 wt %.

The mass and volume reduction of waste incineration causes an enrichment of a number of heavy metals in the bottom ashes compared to their concentration in the waste feed. It is important to note that the risks associated with bottom ash are not indicated only by the presence or absence of substances but by the fact that they can be possible emissions sources of pollutants to the environment.

Residues from dry and semi-wet flue-gas treatment are a mixture of calcium and/or sodium salts, mainly as chlorides and sulphites/sulphates. There are also some fluorides and unreacted reagent chemicals (e.g. lime or sodium carbonate). This mixture also includes some fly ash that has not been removed by any preceding dust removal step. It can, therefore, also include polluting heavy metals and PCDD/PCDF. The normal way of disposal is landfilling as hazardous waste, provided that tests of leachability are carried out.

The filter cake from the physico/chemical treatment of waste water from wet flue-gas treatment is characterised by a very high heavy metals content, but can also include salts of limited solubility, such as gypsum. The normal way of disposal is landfilling (as hazardous waste), after preatreatment because of the possible PCCD/PCDF content.

Residues from flue-gas polishing depend on the adsorbent used (activated carbon, cokes, lime, sodium bicarbonate, zeolite). The residue of activated carbon from fixed bed reactors is sometimes permitted to be incinerated in the waste incineration plant itself, if certain process conditions are fulfilled. The residue of entrained bed systems can also be incinerated, if the applied adsorbent is activated carbon or oven cokes only. If a mixture of other reagents and activated carbon is used, the residue is generally sent for external treatment or disposal, since there might be risks of corrosion. If zeolite is used, there are in principle possibilities to recover the mercury, but these techniques are not yet available in practice.

Emissions of POPs and other organic pollutants:

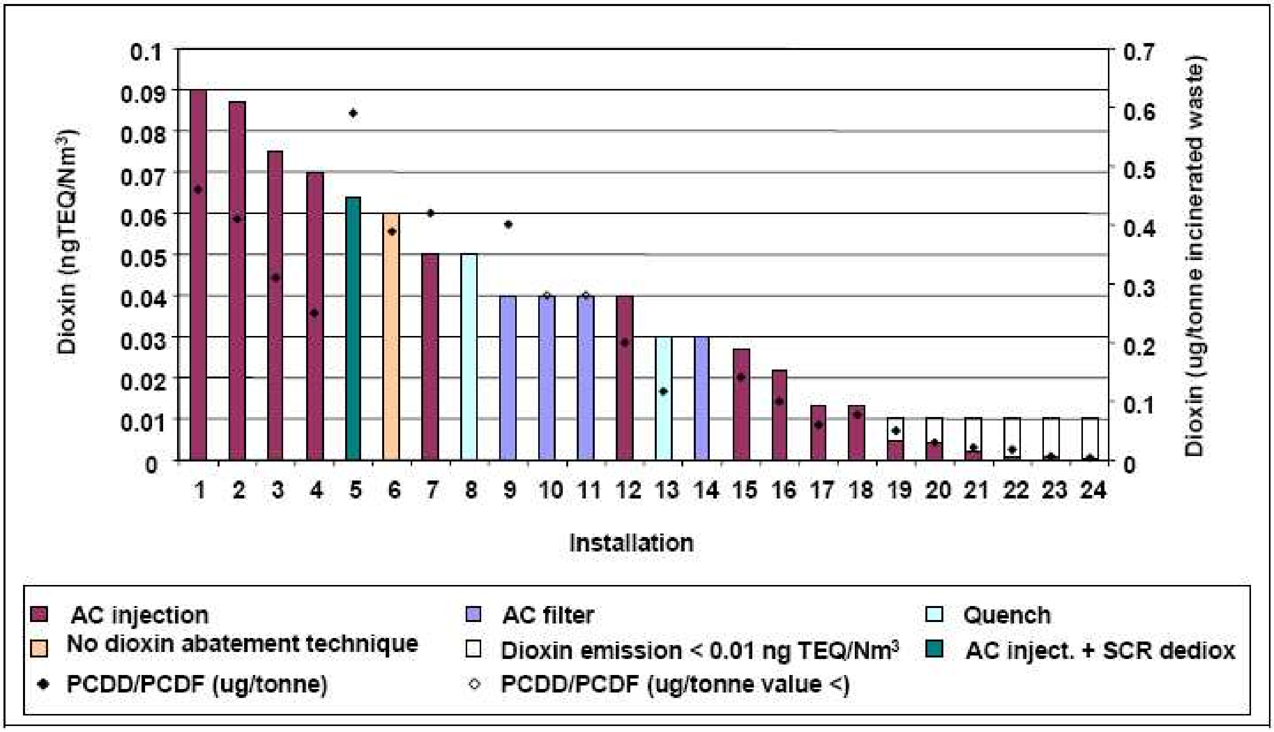
It is widely known that the emission of PCDD/PCDF from waste incineration is strongly affected by the operation, maintenance and use of abatement devices.

In the Dioxin Toolkit edited by UNEP four classes of emission factors for hazardous waste incinerators are defined. The high emissions of PCDD/PCDF from hazardous waste incineration are caused by the batch-type operations, which commonly lead to a long warming and cooling phase of the furnace resulting in pyrolytic conditions in the furnace over an extended period of time. Combined with the high heating value and high content of chlorine (as for PCBs) in the waste, the PCDD/PCDF formation potential can be quite high. The major release vectors of concern are air and residue.

Classification	Emission Factors - µg TEQ/t HW Burned	
	Air	Residue (Fly Ash Only)
1. Low technology combustion, no APCS	35,000	9,000
2. Controlled combustion, minimal APCS	350	900
3. Controlled combustion, good APCS	10	450
4. High technology combustion, sophisticated APCS	0.75	30

PCDD/PCDF can be found at levels of the order of ng/g in fly ashes or pg/g in other ashes, depending on the source of production. It must be pointed out that as pollution equipment becomes more effective in removing particulate matter, the toxicity of the any kind of ash increases. This has deep consequences in the method of disposal. Some ash is treated as hazardous waste, but sometimes, especially in developing countries, they are disposed of as ordinary waste in dumping sites.

A review of typical emission values reached by the implementation of different sequences of abatement devices is presented hereafter:



The emission of PCBs is not always monitored in hazardous waste incineration plants. The available data show values mostly less than detection limit and ranging from <1 µg/Nm³ to <2 ng/Nm³.

The emission of Poly-Aromatic-Hydrocarbons (PAHs) is also not always monitored. The available data show values range from <1 µg/Nm³ to <0.1 µg/Nm³..

Typical concentrations of organic compounds in the various solid residues in some modern facilities are compiled in the table shown below. (Source: EU IPPC BREF on waste incineration, 2006)

Parameter	Bottom ash	Boiler ash	Filter ash
PCDD/F (I-TEQ)	<0.001 – 0.01	0.02 – 0.5	0.2 – 10
PCB	<5 – 50	4 – 50	10 – 250
PCBz	<2 – 20	200 – 1000	100 – 4000
PCPh	<2 – 50	20 – 500	50 – 10000
PAH	<5 – 10	10 – 300	50 – 2000
All values in ng/g			

Residue	Average value in ng/kg I-TEQ	Max value in ng/kg I-TEQ	Number of samples	Total amount in 2003/tonnes
Bottom ash	46	46	1	1100000
Fly ash	2946	16900*	34	82200
Boiler ash	42	86	3	2900
Wet FGC salts	636	5400	16	25500
Filter cake	17412	66000*	30	8300
* This is a relatively old installation with modern FGT-equipment that prevents dioxin emissions to air. The residue is land filled on a hazardous waste landfill site.				

Destruction efficiency:

Properly managed incinerators have reported Destruction and Removal Efficiency (DRE) for POPs waste higher than 99.9999. However, the DRE only accounts for the emission at the stack and not the emission in the residues. A better measurement of destruction is the "Destruction Efficiency (DE)" which is defined as DE= Mi -Mo/Mi x 100, where Mi is the mass of a chemical fed into the destruction system during a known period of time and Mo is the mass of that same chemical released in stack gases, fly ash, scrubber water, bottom ash and any other incinerator residue. DEs higher than 99.999 have been reported for aldrin, chlordane and DDT, while DEs between 83.15 and 99.88 per cent have been reported for PCBs.

Energy requirements:

The amount of combustion fuel required will depend upon the composition and calorific value of the waste, but generally high energy requirement are needed.

Material requirements:

The main requirement come from the use of fuel for primary chamber and gypsum, lime or active carbon for the pollution abatement devices.

Portability:

Hazardous waste incinerators are available in both portable and fixed units.

Health and safety:

Health and safety hazards for workers include those associated with high operating temperatures. Some risk to environment and human health come from air emissions and incomplete combustion., especially as far as concern POPs, acid and heavy metals emission when high flow rates are considered (large facilities).

Capacity:

Hazardous-waste incinerators can treat between 30,000 and 100,000 tons per year.

State of commercialization:

There is a long history of experience with hazardous waste incineration.

Vendors:

A number of existing hazardous-waste incineration facilities are identified within the inventory of worldwide PCB destruction capacity.

Costs

The main costs affecting the building and operation of a waste disposal plant can be separated in different streams and in two main components: an initial capital investment, followed by annual operating and maintenance costs. Moreover, savings, avoided costs and revenues must be considered to calculate the annual costs.
It must be reminded that incineration costs are strongly dependent on the size and treatment capacity of the plant, due to the high investment needed for flue gas cleaning devices and operating costs.

Some examples are given hereafter.

Hazardous-waste incineration (for an incinerator treating 70,000 tons per year)

	Investment costs (millions of euros)	
	2004[a]	1999[b]
Construction time	3	6.5
Electrical works	10	20
Infrastructure works	6	12.5
Machine parts	16	32.5
Other components	14	27.5
Planning/approval	3	6
Total investment costs	**52**	**105**
	Operational costs (million of euros)	
Administration	0.3	0.5
Capital financing costs	5	10.5
Maintenance	4	4
Operating resources/energy	1.3	2.5
Other	0.3	0.5
Personnel	3	5.5
Waste disposal	0.8	1.5
Total operational costs	**14.7**	**25**
Per ton incineration costs (without revenues)	*200–300*	*350*

Gate fees at hazardous waste incinerators within Europe have been reported to range between €50 and €1,500 (Source: European Commission 2004).

[a] Source for figures in first column: European Commission 2004.
[b] Source for figures in second column: Mean values of the specific costs of incineration for municipal and hazardous wastes (1999), VDI 3460: Emission Control Thermal treatment of waste, Germany, March 2002

Specific costs for PCB treatment (UNEP report on destruction capacity, 2004)

Technology	type of PCB treated	Eur/ton of waste
rotary kiln + afterburning	bulk liquid, oils bulk packed material	50-500 750
high temp incineration	liquids, paper, wood capacitors	400-900 800-1500
pretreatment +incineration+ efficient apcds	solid PCB liquid PCB capacitors	600-1500 250-1500 depend on size

Specific costs for pollution control systems. Source: EU Bref On Waste Incineration, 2006

Electrostatic precipitator:

Parameter	Unit	Throughput per line		
		75000 t/yr	100000 t/yr	150000 t/yr
Consumption of electricity				
Specific consumption	kWh/t	12	12	12
Specific costs of energy consumption	EUR/t	0.29	0.29	0.29
Disposal costs				
Specific amount of accumulated waste	kg/t	27.50	27.50	27.50
Specific costs for waste disposal	EUR/t	4.13	4.13	4.13
Maintenance and wear				
Share of investment costs	%	2	2	2
Specific costs of maintenance	EUR/t	0.27	0.24	0.21
Investment costs	EUR	1000000	1200000	1600000
Specific investment costs	EUR/t	1.37	1.24	1.10
Rated specific overall costs	**EUR/t**	**6.06**	**5.89**	**5.73**

Dry flue-gas cleaning with fabric filter

Parameter	Units	Throughput		
		75000 t/yr	100000 t/yr	150000 t/yr
Consumption of electricity				
Specific consumption	kWh/t	9	9	9
Specific costs of energy consumption	EUR/t	0.22	0.22	0.22
CaO-consumption incl. waste disposal				
Specific consumption	kg/t	0.00	0.00	0.00
Stoichiometric factor		3	3	3
Specific costs for adsorption	EUR/t	0.00	0.00	0.00
Activated coke consumption				
Specific consumption	kg/t	1.00	1.00	1.00
Specific costs of activated coke	EUR/t	0.30	0.30	0.30
Disposal costs				
Specific amount of accumulated waste	kg/t	28.50	28.50	28.50
Specific costs for waste disposal	EUR/t	4.28	4.28	4.28
Maintenance and wear				
Share of investment costs	%	1	1	1
Specific costs of maintenance	EUR/t	0.15	0.15	0.13
Specific costs of filter wear	EUR/t	0.78	0.78	0.78
Investment costs	EUR	1150000	1450000	2000000
Specific investment costs	EUR/t	1.58	1.49	1.37
Rated specific overall costs	**EUR/t**	**7.30**	**7.21**	**7.08**

Dry flue-gas cleaning with adsorption

Parameter	Units	Throughput per line		
		75000 t/yr	100000 t/yr	150000 t/yr
Consumption of electricity				
Specific consumption	kWh/t	13	13	13
Specific costs of energy consumption	EUR/t	0.33	0.33	0.33
CaO-consumption incl. waste disposal				
Specific consumption	kg/t	14.44	14.44	14.44
Stoichiometric factor		1.50	1.50	1.50
Specific costs for adsorption	EUR/t	4.50	4.50	4.50
Activated coke consumption				
Specific consumption	kg/t	1.00	1.00	1.00
Specific costs of activated coke	EUR/t	0.30	0.30	0.30
Disposal costs				
Specific amount of accumulated waste	kg/t	28.50	28.50	28.50
Specific costs for waste disposal	EUR/t	4.28	4.28	4.28
Maintenance and wear				
Share of investment costs	%	1	1	1
Specific costs of maintenance	EUR/t	0.23	0.22	0.20
Specific costs of filter wear	EUR/t	0.78	0.78	0.78
Investment costs	EUR	1725000	2175000	3000000
Specific investment costs	EUR/t	2.37	2.24	2.06
Rated specific overall costs	**EUR/t**	**12.78**	**12.63**	**12.44**

Gypsum semidry scrubber

Parameter	Units	Throughput per line		
		75000 t/yr	100000 t/yr	150000 t/yr
Consumption of electricity				
Specific consumption	kWh/t	19	19	19
Specific costs of energy consumption	EUR/t	0.48	0.48	0.48
Reheating				
Temperature increase	°C	30	30	30
Heat demand	kWh/t	0.06	0.06	0.06
Specific costs	EUR/t	0.39	0.39	0.39
$CaCO_3$ consumption				
Specific consumption	kg/t	11.42	11.42	11.42
CaO-consumption				
Specific consumption	kg/t	1.89	1.89	1.89
Costs of neutralising agent	EUR/t	0.47	0.47	0.47
Disposal costs				
Specific amount of accumulated gypsum	kg/t	14.78	14.78	14.78
Specific amount of filter cake	kg/t	1.00	1.00	1.00
Specific costs	EUR/t	0.45	0.45	0.45
Maintenance and wear				
Share of investment costs	%	2	2	2
Specific costs	EUR/t	0.67	0.60	0.53
Investment costs	EUR	2500000	3000000	4000000
Specific investment costs	EUR/t	3.43	3.09	2.75
Rated specific overall costs	**EUR/t**	**5.89**	**5.48**	**5.07**

NaOH wet scrubber

Parameter	Units	Throughput per line		
		75000 t/yr	100000 t/yr	150000 t/yr
Consumption of electricity				
Specific consumption	kWh/t	19	19	19
Specific costs of energy consumption	EUR/t	0.48	0.48	0.48
Reheating				
Temperature increase	°C	30	30	30
Heat demand	MWh/t	0.06	0.06	0.06
Specific costs	EUR/t	0.39	0.39	0.39
NaOH- consumption				
Specific consumption	kg/t	6.88	6.88	6.88
CaO-consumption				
Specific consumption	kg/t	4.71	4.71	4.71
Costs for neutralising agent	EUR/t	3.77	3.77	3.77
Disposal costs				
Specific amount of accumulated gypsum	kg/t	0.00	1.00	2.00
Specific amount of filter cake	kg/t	25.64	25.64	25.64
Specific costs	EUR/t	3.85	3.91	3.97
Maintenance and wear				
Share of investment costs	%	1.5	1.5	1.5
Specific costs	EUR/t	0.36	0.33	0.30
Investment costs	EUR	1800000	2200000	3000000
Specific investment costs	EUR/t	2.47	2.27	2.06
Rated specific overall costs	**EUR/t**	**11.31**	**11.14**	**10.96**

Catalytic reaction (SCR)

Parameter	Units	Throughput per line		
		75000 t/yr	100000 t/yr	150000 t/yr
Consumption of electricity				
Specific consumption	kWh/t	8	8	8
Specific costs of energy consumption	EUR/t	0.20	0.20	0.20
Reheating				
Temperature increase	°C	30	30	30
Heat demand	MWh/t	0.06	0.06	0.06
Specific costs	EUR/t	0.64	0.64	0.64
NH_4OH consumption (as NH_3 solution 25 %)				
Specific consumption	kg/t	2.44	2.44	2.44
Specific costs	EUR/t	0.37	0.37	0.37
Maintenance and wear				
Share of investment costs	%	1	1	1
Specific	EUR/t	0.16	0.15	0.13
Average life cycle	a	10.00	10.00	10.00
Specific costs catalyst wear	EUR/t	0.30	0.30	0.30
Investment costs	EUR	1200000	1500000	2000000
Specific investment costs	EUR/t	1.65	1.54	1.37
Rated specific overall costs	**EUR/t**	**3.32**	**3.20**	**3.02**

In conclusion, the main advantages and drawbacks of incineration process can be resumed as follows:

Main advantages	Main drawbacks
stable combustion	monitoring and stabilisation of process parameters needed
Total destruction of organic wastes	Possible reformation of unintentional POPs
sensitive volume reduction (up to 85%)	suitable pollution control devices for PCDD/PCDF and metals
energy recovery	fly ashes must be treated and/or landfilled
reduced use of open or controlled landfills	complex configuration, require highly skilled personnel
available in both portable And fixed units	Public perception of incineration is becoming increasingly negative
Costs can vary depending on capacity	Retrofitting costs for emission control devices can be very high

4.2 PYROLYSIS-GASIFICATION

Introduction:

In general these methods have been applied to selected waste streams and on a smaller scale than incineration. In addition to municipal wastes and sewage sludge, gasification can be used for some hazardous waste, while pyrolysis for contaminated soils.
Their scope is to separate the components of the reactions that occur in conventional waste incineration plants by controlling process temperatures and pressures in specially designed reactors.
As well as specifically developed pyrolysis/gasification technologies, standard incineration technologies (i.e. grates, fluidized beds, rotary kilns, etc) may be adapted to be operated under pyrolytic or gasifing conditions i.e. with reduced oxygen levels (sub-stoichiometric), or at lower temperatures.
The aim of gasification and pyrolysis processes are to convert certain fractions of the waste into process gas (called syngas, which can be used as feedstock for other processes) and reduce gas cleaning requirements by reducing flue-gas volumes. The reduced oxygen content implies a lower formation of PCDD/PCDFs.
The process is suitable for a large variety of organic waste in different physical forms, i.e., solids, liquids, sludge and slurry containing or contaminated with POPs. Wastes containing or contaminated with PCBs (up to 500 mg/kg waste) and PCDDs/PCDFs (up to 50.000 ng TEQ/kg) may be treated. The chlorine levels in the hazardous waste can reach up to 6 wt. % (fluids) and 10 wt. % (solids).
Some pre-treatment steps are required. For solid wastes, size reduction must be carried out for bulky solid waste along with the removal of ferrous and non ferrous metals. In the case of liquid and pasty waste, sludge, solids and water must be separated by sedimentation and density separation. The pre-purified oil is distilled in order to reach water content of < 1%. There is no water content restriction for slurry products to be fed into the entrained flow gasifier.

Process description:

Gasification is a partial combustion operating at high temperatures (1300℃–2000℃) and high pressure (about 25 bar) using steam and pure oxygen in a reducing atmosphere to produce gases that can be used as feedstock, or as a fuel. All hydrocarbon molecules in the waste are irreversibly broken into small gaseous molecules such as hydrogen, and carbon monoxide, methane and carbon dioxide. Short-chain hydrocarbons such as ethane, propane, butane and other compounds are produced in small amounts (< 1 vol. %). Persistent organic pollutants including PCBs contained in the waste are effectively destroyed. The resulting raw gas is subsequently converted in a multistage process to pure synthesis gas for the production of highest-grade methanol.

There are several different gasification processes available or being developed which are in principle suited for certain hazardous wastes. It is important that the characteristics of the waste keep within certain predefined limits.

The special features of the gasification process are:

- smaller gas volume compared to the flue-gas volume in incineration (by up to a factor of 10 by using pure oxygen)
- predominant formation of CO rather than CO_2
- high operating pressures (in some processes)
- accumulation of solid residues as slag (in high temperature slagging gasifiers)
- small and compact aggregates (especially in pressure gasification)
- material and energetic utilisation of the synthesis gas
- smaller waste water flows from synthesis gas cleaning.

The following gasification reactors are used:

- fluidised bed gasifier
- current flow gasifier
- cyclone gasifier
- packed bed gasifier.

For utilisation in entrained flow, fluidised bed or cyclone gasifiers, the feeding material must be finely granulated. Therefore, pre-treatment is necessary, especially for some hazardous wastes.
Hazardous wastes, on the other hand, may be gasified directly if they are liquid, pasty or finely granulated.

Pyrolysis is the degassing of wastes in the absence of oxygen, during which pyrolysis gas and a solid coke are formed. In a broader sense, “pyrolysis” is a generic term including a number of different technology combinations that constitute, in general, the following technological steps:

- smouldering process: Formation of gas from volatile waste particles at temperatures between 400 and 600 ℃
- pyrolysis: Thermal decomposition of the organic molecules of the waste between 500 and 800 ℃ resulting in formation of gas and a solid fracti on
- gasification: Conversion of the carbon share remaining in the pyrolysis coke at 800 to 1000 ℃ with the help of a gasification substance (e.g. air or steam) in a process gas
- incineration: Depending on the technology combination, the gas and pyrolysis coke are combusted in a incineration chamber.

Pyrolysis processes can be used for decontamination of soil, treatment of synthetic waste and used tyres, treatment of cable tails as well as metal and plastic compound materials for substance recovery.

It is common for the pyrolysis, gasification and a combustion based process to be combined, often on the same site as part of an integrated process. The installation is, in total, generally recovering the energy value rather than the chemical value of the waste, as would a normal incinerator.
The following systems have been developed:

Pyrolysis - incineration systems

- Pyrolysis in a rotary kiln - coke and inorganic matter separation – incineration of pyrolysis gas
- Pyrolysis in a rotary kiln - separation of inert materials - combustion of the solid carbon rich fraction and the pyrolysis gas
- Pyrolysis in a rotary kiln - condensation of pyrolysis gas components - incineration of gas, oil and coke
- Pyrolysis on a grate - directly connected incineration
- Pyrolysis on a grate (with subsequent melting furnace for low metal content, molten bottom ash production) - circulating fluidised bed (burnout of particles and gas).

Gasification systems:

- Fixed bed gasifier - pretreatment drying required for lumpy material
- Slag bath gasifier - as fixed bed but with molten bottom ash discharge

- Entrained flow gasifier - for liquid, pasty and fine granular material that may be injected to the reactor by nozzles
- Fluidised bed gasifier - circulating fluid bed gasifier for pretreated municipal waste, dehydrated sewage sludge and some hazardous wastes
- Bubbling bed gasifier - similar to bubbling fluidised bed combustors, but operated at a lower temperature and as a gasifier.

Pyrolysis - gasification systems:

- Conversion process - pyrolysis in a rotary kiln - withdrawal and treatment of solid phase - condensation of gas phase - subsequent entrained flow gasifier for pyrolysis gas, oil and coke
- Combined gasification-pyrolysis and melting - partial pyrolysis in a push furnace with directly connected gasification in packed bed reactor with oxygen addition (e.g. Thermoselect).

Environmental impact:

Basically the same pollutants already described for incineration can be emitted from gasification/pyrolysis plants. Since reduced atmosphere is used and high temperature can be reached (in gasification process), the possibility of the formation of PCDDs and PCDFs is limited. DEs of 99.974 % have been reported for PCDDs and PCDFs.

In general for co-processing of PCB the same Air Pollution Control Systems (APCS) needed for reducing emissions and already described for the incineration process are used

Energy requirements:

The waste is treated with a gasification mixture containing at least 15 wt. % coals in order to ensure stable process conditions. No additional energy in the form of electricity or steam is necessary. Pyrolysis and gasification processes may export some of the energetic value of the incoming waste with the substances they export e.g. syngas, chars, oils, etc. In many cases these products are either directly or subsequently burned as fuels to utilise their energy value, although they may also be used for their chemical value as a raw material, after pretreatment if required

Material requirements:

There is a need for a gasification agent (steam and oxygen) for the gasification technologies used. Other material requirements include calcium carbonate (limestone) to influence viscosity of slag.

Portability:

The gasification technology is available only in fixed configurations.

Health and safety:

The process effectively destroys POPs in a closed loop system without endangering human health or the environment. Use of hydrogen gas under pressure requires suitable controls and safeguards to ensure that explosive air-hydrogen mixtures are not formed. Operating experience gained from 1992 to date has indicated that the process can be undertaken safely.

General costs:

Gasification and pyrolysis are not as widely applied for wastes as conventional incineration. Cost data provided may therefore be subject to more variation than that provided for incineration installations
For small plants (3000-4000 t/year) the investment costs can range from 250,000 and 1 million US$ depending on applied APCDs and energy/chemical recovery.
Some other data on costs are reported hereafter

Approximate costs of pyrolytic incinerators (Europe, 1996)

Incinerator equipment	Investment costs (in 1000 US$) for capacities (tonnes/day) of				
	0.4	1	2	4	8
Without energy recovery or gas cleaning	50	100	120	150	230
With energy recovery but without gas cleaning	100	180	230	340	570
With energy recovery and gas cleaning	300	400	480	600	780

The main advantages and drawback of these process are reported below.

Main advantages	Main drawbacks
Reduced flue-gas volumes Lower temperatures in primary chamber	Used only for some hazardous wastes (contaminated soils)
Reduced Flue gas treatment capital costs	Need suitable APCDs for emission control of dioxins and metals
Chemical value/energy recovery	Accumulation of solid residues as slag
Suitable for smaller plants	Starts and stops can be frequent
	High operating-maintenance costs

4.3 MOLTEN SALT OXIDATION

The molten salt process has been used on a small scale since many years. According to the UNEP survey on PCB disposal techniques, it is however not commonly used for these kind of POPs

Process description:

Molten salt oxidation is a thermal method for completely oxidizing the organic fraction of wastes in a bed of alkaline molten salt, usually sodium carbonate or a eutectic of alkali carbonates., operating at a temperature of 900 to 1000℃. Oxidant air is added with the waste stream into the salt bath, and the reaction takes place within the salt bath virtually eliminating the fugitive emissions found in incineration. The organic components of the waste react with oxygen to produce CO_2, N_2, and water. Inorganics like halogens, sulphur, and phosphorus are converted to acid gases, which are then “scrubbed” and entrapped in the salt in forms such as NaCl and Na_2SO_4. Other incombustible inorganic constituents such as heavy metals, are entrapped in the salt, as either metals or oxides, and are easily separated for disposal

Waste preparation:

The materials to be processed are normally conveyed into the oxidizing chambers using pneumatic feed systems. Solid waste have must be shredded for pneumatic conveying, while liquid wastes are injected using commercial oil gun systems. The process cannot treat soils and other materials with a high content of inert material

Environmental impact:

The reaction product gases contain nitrogen, carbon dioxide, oxygen, and steam, along with reaction salts, depending on the wastes.

Gaseous emissions and release of vaporised heavy metals may require the same Flue gas treatment facilities of incineration plants, such as filtering due to the entrainment of very fine salt particles, and the total salt requiring disposal may be several times the weight of the wastes destroyed.
No data are available as far as concern the PCDD/PCDF and other POPs emissions in process residues, but the destruction efficiency should be reasonably very high.

Efficiency:

With bench and pilot scale systems, liquid 1,2,4-trichlorobenzene (58.6 weight percent chlorine) was destroyed in molten sodium carbonate/sodium chloride with efficiencies of 99.9999970 and 99.9999932 percent at bed temperatures of 900℃ and 1000℃ respectively. With chlordane, the pilot scale system achieved DREs of 99.99983 percent when samples were taken before filtering systems and >99.9999988 percent when sampled after the bag filter

Energy requirements:

These treatment processes use very substantial amounts of energy. Typically, approx. 700 - 1200 kWh/t is used of treated residue to reach and maintain the elevated temperatures, but up to approx. 8000 kWh/t has been reported.
Energy consumption and operation varies with furnace type and plant design.

General costs:

As far as concern the disposal of FGT residues, the technique is expensive compared to other treatment options. Treatment costs are reported to be in the order of EUR 100 - 600/t of residue. Investment costs can be about EUR 10 - 20 million for a plant with a capacity of 1 – 2 t/hr.
Depending on chlorine content as well as the capacity of the facility, the cost (in Australian dollars) of treating organochlorine wastes vary from $1200 to $2000 per ton. The residuals from the process are not useful, and must be disposed of properly in a secure landfill. For a feed rate of 1000 kg/h, the cost is in the order of $1150/tonne. The above costs do not include effluent treatment costs, residuals and waste shipping costs handling and transport costs, analytical costs, and site restoration costs.

Applicability of the technique:

Thermal treatment including melting and vitrification is widely used, mostly in Japan and the US, for treatment of bottom ashes as well as combinations of bottom ash and FGT residues. In Japan it is estimated that about 30 - 40 plants are operated, however examples in Europe can also be found.

Health and safety:

One hazard of the process is potential superheated-vapor explosions when liquid wastes are introduced

4.4 PLASMA TECHNOLOGY

Plasma technology can be ascribed to a combustion/pyrolysis technique, but show some characteristics that make it an alternative option to incineration. This technique is still under development but it used for industrial waste disposal (destruction of ozone depletion CFC and PCBs)

Process description:

Plasma energy is heat energy produced when electric current flows through a gas, which undergoes a rapid ionization. Resistance of the ionized gas to the flow of electrical current creates extremely high temperatures. Gases such as helium argon, nitrogen or air can be ionized to become the conductor. Plasma arc torches can be adapted for many applications in industry. There are two types of torches typically produced, transferred arc and non-transferred arc. The non-transferred arc torch produces a more dispersed heat and is used for annealing and drying processes. As far as pyrolysis is concerned, the instantaneous arc high temperatures of converts all organic material into basic atoms that recombine into simple gases. The waste is not burned or combusted, but is pyrolyzed at high temperatures. Combustion does not occur and ash does not form in the pyrolysis process. The combination of high temperature in the absence of air and a controlled input of steam convert organic and solid materials into a vitreous substance and a hydrogen-rich, clean gas.

Pre-treatment is not required for most liquids. Solids such as contaminated soils, capacitors and transformers can be pre-treated using thermal desorption or solvent extraction.

Advantages and Drawbacks:

Plasma pyrolysis process has many advantages over conventional incineration of hazardous waste, such as:

- Plasma-arc torches produce the lowest-mass sustainable heating source available at the highest controlled sustainable temperatures known.
- The solid volume reduction can be up to 200.1.
- Fuel gas produced in the process may be used as feedstock in boilers, chillers or fuel cells or may be used in various applications including production of methanol.
- Because it is not a combustion process, the volume of gases produced can be ten times lower than the volume of gases produced by an incinerator.
- Capacity range is very broad (from hundreds kg/h to several T/h)
- conversion of organic and solid materials into a vitreous substance and a hydrogen-rich clean gas
- By-products (glassy slags) are recyclable since toxicity tests indicate that the vitrification process encapsulates cadmium, lead, Mercury, chromium, therefore reducing dumping site requirements.

The main drawbacks are as follows:

- Plasma show a complex configuration
- It is still a developing technique
- It has generally high cost, strongly depending on the size

Various plasma reactors have been developed for the thermal destruction of hazardous waste, mainly in Australia (Pact, Parcon, Plascon, Startech), Japan and Italy (CSM, Material Development Centre).

Emissions and residues:

Since total air emission volumes of plasma furnaces are less than for conventional combustion processes, the potential impact of emissions is expected to be lower.

DREs for organic compounds can be higher than 99.99%. However, volatile metals and products of incomplete combustion (PIC) can be generated and may need to be removed by an appropriate scrubber

Treated soils and other materials from this process are generally converted into vitrified ash. Typical PCDD/PCDF emissions from different kinds of plasma technique are reported hereafter:

type of technique	PCDD/PCDF emissions ng/Nm3
argon plasma (Australia)	0.006
inductively coupled radio frequency plasma	0.012
CO_2 plasma arc	0.013
microwave plasma (Japan)	0.0011 (TEQ)
nitrogen plasma arc (Australia	0.044 (TEQ)

PCDD/F levels in the treated ash are reduced. The following PCDD/F inputs and emissions are reported for the plasma destruction of MSW incinerator fly ash. Fly ash output arises from the baghouse used to treat process off-gas:

Ash input: 50 ngTEQ/g
Slag output: <0.001 ngTEQ/g
Fly ash output: <0.005 ngTEQ/g
Flue-gas output: <0.05 ngTEQ/m3

Energy requirements:

Very high energy consumption is reported: 0.7 – 2 kWh./kg of ash treated

Power requirements are typically:
AC submerged arc furnace 650 – 1000 kWh/t-ash;
DC plasma furnace 600 – 800 kWh/t-ash.

Costs:

Capital cost can vary in a large extent depending upon the configuration and upon factors such as:
- Waste feed – molecular structure, weight and concentration;
- Electricity costs;
- Argon and oxygen costs;
- Geographic location and site specific issues;
- Caustic costs; and
- Required emission limits.

Compared to other techniques, external thermal treatment costs are reported to be high.

Vitrification costs are highly sensitive to the unit cost of electricity. Treatment costs for residues are reported to be in the range EUR 100 to 600/t of ash. Investment costs can be up to EUR 20 million for a plant of capacity 1 – 1.5 t/hr, but can be lower for mobile units and a reasonable range for capital costs is 500,000 - 1 million US$.

The operating costs for PCB disposal also vary according to the kind of waste and process. The PACT system was reported to have relatively high capital cost as well as high operating cost ($4000 - $8000 per ton), while in the Plascon system the latter were estimated to be under $3000/ton.

In the UNEP inventory of PCB destruction capacity, 2004, the cost to dispose contaminated transformers by plasma arc is reported to be 140 US$/Ton, whereas for liquid PCB is 470-1600 US$/Ton

4.5 CEMENT KILNS

Introduction:

Cement kiln can be used for the co-incineration of hazardous waste during the clinker production in large and long rotary kilns.

A wide range of other fuels can be used other than coal, including petroleum coke, natural gas and oil and it is not uncommon for kilns to be capable of multi-fuelling and for fuels to be changed based on the prevailing costs of different fuels. In addition to conventional fuels, the cement industry uses various types of waste as a fuel, including hazardous waste, thus contributing to their destruction. This may be done at the request of national governments or in response to local demand. This co-processing can only be done if certain requirements with respect to input control (for example of heavy metal content, heating value, ash content, chlorine content), process control and emission control are met.

In a well-controlled facility high destruction efficiency of organic compounds present in such wastes can be achieved. However, it must be pointed out that this activity is distinct from fuel or raw material substitution in the process. Cement kilns are primarily production processes for clinker, and not all operating conditions ideal for the destruction of wastes may be suitable. For example, destruction of organic wastes by incineration requires not only high temperature and long residence time, but also an excess content of oxygen, whereas cement kilns tend to operate at lower exhaust oxygen levels and more elevated carbon monoxide levels.

Waste pre-treatment:

Cement kilns are capable of treating both liquid and solid wastes, provided that a suitable preparation of the raw material is carried out. This is generally done by specialized companies in dedicated facilities.

Usual pre-treatment steps consist in the homogenization of solid and liquid wastes through drying, shredding, mixing and grinding. For dry and semi-dry kiln systems, the raw material components are ground and dried to a fine powder, making use mainly of the kiln exhaust gases and/or cooler exhaust air. For raw materials with a relatively high moisture content, and for start up procedures, an auxiliary furnace may be needed to provide additional heat. Wet grinding is used only in combination with a wet or semi-wet kiln system. The raw material components are ground with added water to form a slurry. The wet process is normally preferred whenever the raw material has a moisture content of more than 20% by weight.

Liquid wastes can be then injected into the hot end of the kiln. Solid wastes may be introduced into the calcining zone at some facilities. For long kilns, this means that the solid waste is introduced mid-kiln, and for preheater/precalciner kilns it is introduced onto the feed shelf in the high-temperature section.

Process description:

The main processes employed in making cement clinker can be classified as "wet" or "dry" depending on the method used to prepare the kiln feed. In the wet process the feed material is slurried and fed directly into the kiln. In the dry process the kiln exhaust gases are used to dry the raw meal in a pre-heater – pre-calciner section while it is being milled.

The waste treatment process in a cement kiln is principle the same as in a dedicated incineration plant. The big difference lies in the pre-treatment part and in the flue gas cleaning part. Cement kilns typically consist of a long cylinder of 50–150 meters, inclined slightly from the horizontal (3 per cent to 4 per cent gradient), which is rotated at about 1-4 revolutions per minute.

The raw materials (a fine powder containing strictly controlled proportions of limestone, to provide calcium carbonate, and clay, to provide silica, alumina and iron oxides) are fed into the upper or cold end of the rotary kiln. The slope and rotation cause the materials to move toward the lower or hot end of the kiln. The kiln is fired at the lower end of the kiln, where temperatures reach 1,400℃–1,500℃. When the powder is homogenized and heated in the kiln, the lime molecules combine with all the silica, alumina and iron oxide molecules to form clinker. The raw materials are transformed into clinker in several stages:

- up to 550℃ the mixture is dried and the clay dehy drates;
- from 550℃ to 900℃ pre-heating and decarbonisatio n takes place (calcining);
- from 900℃ to 1,300℃ the di-calcium silicates, al uminates and ferroaluminates are formed;
- from 1,300℃ to 1,450℃ the formation of tri-calci um silicate takes place.

After reaching this temperature, the clinker is rapidly cooled. The clinker is finely grounded, 3% to 5% gypsum is added to control the setting rate and other additives (slag, fly-ash, limestone filler, etc.) may be introduced to form the final product

Cement kilns treating wastes may require modifications to the rotary kiln. Potential feed points for supplying fuel to the kiln system are:

- The main burner at the rotary kiln outlet end;
- A feed chute at the transition chamber at the rotary kiln inlet end (for lump fuel);
- Secondary burners to the riser duct;
- Precalciner burners to the precalciner;
- A feed chute to the precalciner/preheater (for lump fuel);
- A mid-kiln valve in the case of long wet and dry kilns (for lump fuel).

Operating conditions within the kiln are maintained and controlled by monitoring numerous plant operating parameters throughout the system. These include feed material composition, gas temperatures and gas flow rates. These parameters are used for control of feed flow rates into the unit (for raw meal and fuel) and for controlling discharge gas flows from the unit.

The main features of cement kilns regarding waste co-incineration are as follows:

- Very high temperature reached (in precalciner and preheater section up to 800℃, in the kiln up to 1500-2000℃) are suitable for organic waste d estruction.
- Good oxygen level, mixing conditions and residence time can be reached
- Alkaline environment suitable for acid emission prevention (chlorine and sulphur are neutralized in the form of chlorides and sulphates) and control chlorinated pollutant reformation.
- PCB contaminated waste (with limited concentration) can be added to hazardous waste which provide additional energy value as a substitute fuel
- Liquid wastes or low ash wastes are relatively easy to burn in a cement kiln
- Soils and bulk material need specific pretreatment
- Capacity of co-incineration of hazardous waste is up thousand tons/year
- The quantities of the inorganic and mineral elements added in treating scheduled wastes are usually limited (and in general will be a small proportion of the large feed requirements of a commercial kiln), and should not adversely affect the quality of the clinker product
- Chlorides have an impact on the quality of the cement and so have to be limited. Chlorine can be found in all the raw materials used in cement manufacture, so the chlorine levels in the hazardous waste can be critical.

Environmental impact:

Co-incineration of hazardous wastes should only be performed if the cement kiln operates according to the best available techniques. If certain provisions for waste quality and waste feeding are met the co-processing of waste will not change the emissions from a cement kiln stack significantly.

In general for co-processing of PCB in cement kilns the use of the same pollution control devices already described for the incineration process (filters, scrubbers, carbon injection, carbon towers) is strongly recommended.

Dust is the main emission to control. Rotary kilns are generally equipped with electrostatic precipitators, on account of the relatively high exhaust gas temperatures. Fabric filters are also used, particularly on pre-heater kilns, where exhaust gas temperatures are lower. The emission level associated with these best available techniques is 20–30 mg dust/m^3 on a daily average basis

Recovered cement kiln dusts should be re-circulated into the kilns as much as possible. However, changing from no recirculation of cement kiln dust to full recirculation will change its chemical composition over time, increasing the alkali content and in semi-volatile and volatile heavy metals, thus leading to operating problems; therefore a certain fraction of the collected dust must be disposed of in engineered landfills.

Depending on the composition of raw material, quality of emissions can vary and includes nitrogen oxides, carbon monoxide, sulphur dioxide and other oxides of sulphur, metals and their compounds, hydrogen chloride, hydrogen fluoride, ammonia.

Unintentional POPs emissions:

Among micro pollutants, PCDD/PCDFs, benzene, toluene, xylene, polycyclic aromatic hydrocarbons, chlorobenzenes and PCBs can be emitted. It should be noted, however, that cement kilns can comply with PCDD and PCDF air emission levels below 0.1 ng TEQ/Nm.

Many Dioxins, PCB and some HCB measurements were carried out from wet and dry cement kilns with and without the co-processing of alternative fuel and raw materials (See UNEP-Thailand Dioxin monitoring project). Generally low emission (under limit) were found (higher emissions from wet kilns rather than dry process).

A comprehensive survey of PCDD/PCDF emissions from cement kilns in developed and developing countries is given in the table in the next page. The data represents more than 2200 measurements in kilns with and without the firing of a wide range of waste materials and covering the period from early 1990’s until recently.

Another survey was carried out by Cembureau, in 110 cement kilns in 10 European countries . The average concentration, taking into account all of the data in this dataset, was 0.016 ng I-TEQ/m^3. The range between the lowest and highest concentrations measured was < 0.001 to 0.163 ng I-TEQ/m^3.

Data from several kilns in the United States show average PCDD/PCDF emissions of 1.76 ng I-TEQ/m3 when operating their air pollution control devices in the range of 200°–230°. Tests in the United States also indicated higher emissions for some kilns where hazardous wastes were fired. Moreover, many studies indicate that, provided combustion is good, the main controlling factor for the PCDD/PCDF emissions is the operating temperature of the dust collection device in the gas cleaning system. Plants equipped with electrostatic precipitators operating at lower temperatures (200 °C or less) appear to have low emission concentrations whether or not they use waste (UNEP 2003).

The possible effect of feeding different wastes to the lower-temperature preheater/precalciner was investigated by Lafarge. It resulted that wastes injected at mid or feed-end locations do not experience the same elevated temperatures and long residence times as wastes introduced at the hot end and therefore the observed PCDD/PCDF air emissions were quite low.

Data for stack emissions from cement kilns indicate that well-designed, well-operated facilities can achieve very low exhaust gas concentrations of PCDD/PCDF, it can also be expected that such facilities will have low levels in cement kiln dust recovered from the air pollution control system.
The two main solid materials produced in cement production are the cement clinker from the cooler and the particulate matter collected in the air pollution control devices.

Data on solid residues have been gathered from cement companies participating in the Cement Sustainability Initiative (CSI). Eight CSI companies reported in 2005 an average PCDD/PCDF concentration in 57 cement clinker dust as 1.24 ng I-TEQ/kg. The clinker samples came from wet and dry suspension preheater kilns.

Hexachlorobenzene (HCB) and PCB have not been the subject of regulatory monitoring in cement plants to date. Most measurements that have taken place have not detected HCB emissions. As regards PCB emissions, 40 measurements carried out in 13 kilns in Germany in 2001 revealed a maximum concentration in air emissions of 0.4 µg PCB /Nm^{3}.

Country or company	Use of alternative fuel and raw materials?	Concentration, in ng I-TEQ/m^3, of PCDD/PCDF[a]	Number of measurements	Emission factor µg I-TEQ/ton cement[a]
Australia	Yes	0.001–0.07	55	0.0032–0.216
Belgium	Yes	< 0.1	23	
Canada	Yes	0.0054–0.057	30	
Chile	Yes	0.0030–0.0194	5	
Colombia	Yes	0.00023–0.0031	3	
Denmark	Yes	< 0.0006–0.0027	?	
Egypt	Yes	< 0.001	3	
Europe	Yes	< 0.001–0.163	230	< 0.001–5
Germany 1989–1996	Yes	0.02	> 150	
Germany 2001	Yes	< 0.065	106	
Holcim 2001	Yes	0.0001–0.2395	71	0.104 (clinker)
Holcim 2002	Yes	0.0001–0.292	82	0.073 (clinker)
Holcim 2003	Yes	0.0003–0.169	91	0.058 (clinker)
Heidelberg	Yes	0.0003–0.44	> 170	
Japan	Yes	0–0.126	164	
Lafarge	Yes	0.003–0.231	64	
Mexico	Yes	0.0005–0.024	3	
Norway	Yes	0.02–0.13	> 20	0.04–0.40
Philippines	Yes	0.0059–0.013	5	
Poland	Yes	0.009–0.0819	7	
Portugal		0.0006–0.0009	4	
RMC	Yes	0.0014–0.0688	13	
Siam Cement Co.	Yes	0.0006–0.022	4	
South Africa	(Yes)	0.00053–0.001	2	
Spain	Yes	0.00695	89	0.014464
Spain Cemex	Yes	0.0013–0.016	5	
Spain Cimpor	Yes	0.00039–0.039	8	
Taiheiyo	Yes	0.011	67	
Thailand	Yes	0.0001–0.018	12	0.00024–0.0045
UK	Yes	0.012–0.423	14	< 0.025–1.2
Uniland		0.002–0.006	2	0.005–0.011
USA[b]	Yes	0.004– ~ 50	~ 750	< 0.216–16.7
Venezuela	Yes	0.0001–0.007	5	
Vietnam		0.0095–0.014	3	

Source: Advanced Guidelines on BAT/BEp UNEP December 2006

Efficiency:

Testing of cement kiln emissions for the presence of organic chemicals during the burning of hazardous materials has been undertaken since the 1970s, when the practice of combusting wastes in cement kilns was first considered. The destruction and removal efficiency for chemicals such as methylene chloride, carbon tetrachloride, trichlorobenzene, trichloroethane and PCB has typically been measured at 99.995% and better.

The potential use of cement kilns to incinerate wastes containing PCB has been investigated in many countries. The destruction and removal efficiencies determined from several trial burns indicate that well-designed and operated cement kilns are effective at destroying PCB.

Energy requirement:

New kiln systems with five cyclone preheater stages and precalciner will require an average of 2,900–3,200 MJ to produce 1 Mg of clinker.

Capacity:

Cement kilns co-incinerating wastes as a fuel are normally limited to a maximum of 40 per cent of the heat requirement in the form of hazardous waste. It has been noted, however, that cement kilns with high throughput can potentially treat significant quantities of waste.

Costs:

The capital investment can be maintained parallel with the hazardous waste incineration. The main additional costs mainly come from retrofitting with APCD systems (dedusting or scrubbers). Generally costs are strongly dependent on pretreatment and kind of wastes.

Specific cost for chlorinated and PCB co-incineration: from 1000 US$/Ton up to 5000 US$/Ton.

Advantages and drawbacks:

Main advantages	Main drawbacks
Stable combustion	Hazardous waste needs pre-treatment
Very high temperature and long residence times	Monitoring and stabilisation of process parameters
Most cement kilns can meet dioxin emission limit of 0.1 ng TEQ/nm^3	Dust reduction devices needed to reduce Dioxin emissions
Recirculation of ashes	Quality of clinker could be affected with time
Reduction of acid emissions	High presence of heavy metals

4.6 THERMAL AND METALLURGICAL PRODUCTION OF METALS

Process description:

The metallurgical production of metals is primarily designed for the recovery of iron and non-ferrous metals (e.g. aluminium, copper, zinc, lead and nickel) from ore concentrates and from secondary raw materials. However, this type of the processes with certain types of blast furnaces, shaft furnaces or hearth furnaces can also be used in some cases for the destruction of the POP content of appropriate wastes.

All these processes operate under reducing atmospheres at high temperatures (1,200℃–1,450℃). The high temperature and the reducing atmosphere destroy POPs and avoid the De novo synthesis.

The blast furnace and the shaft furnace processes use coke and small amounts of other reducing agents to reduce the iron-containing input to cast iron. There are no direct emissions of process gas as it is used as a secondary fuel. Iron-containing materials recycled by the conventional blast furnace process require pre-treatment in an agglomeration plant

In the hearth furnace process, the iron-containing material is fed in a multi-hearth furnace together with coal. The iron oxide is directly reduced to solid iron. In a second step the reduced iron is melted in an electric arc furnace to produce cast iron. Generally no pre-treatment is necessary for the multi-hearth furnace process, although under in some special cases the fine solids may have to be pelletized. This involves only the addition of water and the formation of pellets in a drum. Special pre-treatment of materials contaminated with POPs is not usually necessary.

Other processes which can be used for the destruction of the POP content in wastes are the Waelz rotary kiln process and bath melting processes using vertical or horizontal furnaces. These processes are reductive, reach temperatures of 1,200℃ and us e rapid quenching for to avoid PCDD/PCDF reformation

In the Waelz process zinc-containing steel mill dusts, sludges, filter cakes, etc. are pelletized and smelted together with a reductant. At temperatures of 1,200℃, the zinc volatizes and is oxidized to “Waelz Oxide”, which is collected in a filter unit.

Emissions and residues:

PCDDs and PCDFs may be formed within the process or downstream in the flue gas treatment system. Application of BAT should prevent or at least minimize the emissions to air emissions below 0.1 ng TEQ/Nm^3. Data on DE or DRE are not available.

Slags are in many cases used for construction purposes. For iron metals, emissions can occur from pre-treatment in an agglomeration plant and also in the raw gases from the melting furnace. Residues from de-dusting systems are mainly re-used in metallurgic industry.

Raw gases from the multi-hearth furnace are de-dusted by a cyclone, then generally are burned in a post-combustion chamber, followed by a quenching process. The main pollution abatement procedures consist in the addition of adsorbent and the final dedusting by a electrofilters or bag filter. Raw gases from the melting furnace are burned in a post-combustion chamber and cooled by a quencher, then are mixed up with the raw gases of the multi-hearth furnace for the joint adsorbance step.

Residues include filter dusts and sludges from waste water treatment.

Energy requirements:

Production processes for iron and non ferrous metals are energy-intensive with significant differences between different metals. The treatment of the POP content in wastes within these processes requires little additional energy.

Waste types:

The above processes are specific to the treatment of the residues such as dusts and sludges from gas treatment, , that may be contaminated with unintentional produced POPs, or contaminated soils added to the raw material. There is no information on the treatment of pure PCB or contaminated oils from transformers or capacitors.

Material requirements:

For production of metals, raw materials (ores, concentrates or secondary material) are used as well as additives (e.g., sand, limestone), reductants (coal and coke) and fuels (oil and gas). Temperature control to avoid de novo synthesis of PCDDs and PCDFs requires additional water for quenching.

Portability:

Metal smelters are large and fixed installations.

Health and safety:

The treatment of wastes within thermal processes can be regarded as safe if properly designed and operated.

Capacity:

Metal smelters described above have feedstock capacities above 100,000 tonnes per year. Current experience with the addition of wastes contaminated with POPs to the feedstock involves much smaller quantities.

State of commercialization:

All the types of furnaces are in operation and used worldwide with appropriate BAT/BEP implemented.

Vendors:

As the primary use of plants operating these processes is not the destruction of the POP content in wastes there are no vendors of plants dedicated to this purpose.

5. COMPARATIVE EVALUATION OF THE REVIEWED POPs ELIMINATION TECHNOLOGIES

The technical/environmental comparative assessment of the reviewed elimination technologies presented in the previous chapters can be carried out on the base of the following parameters:

- Type of waste treated
- Capacity
- Materials and Energy consumption
- Emissions and residues
- Elimination efficiency
- Management and maintenance
- Availability and portability
- Health considerations
- Costs

A rank, from 1 (the best) to 6 (the worst) will be given to each technology, according to the comparison of each parameter, as far as concern the disposal of hazardous waste, including PCB oils or contaminated materials.

Type of waste treated

Almost all the techniques require pretreatment steps before destroying waste. Incineration and cement kilns have the capability to accept a broad range of wastes, while pyrolysis, plasma and metallurgical process usually are more used for the disposal of contaminated soils and solid residue (fly ashes) coming from abatement devices. Plasma has also been used to dispose PCB contaminated oils. The use of metallurgical process or molten salt is not very common.

Technique	Incineration	Pyrolysis/ gasification	Molten salt oxidation	Plasma	Cement kiln	Thermal and metallurgical production metals
Type of waste treated	Solvents Halogenated and sulphur containing solvents Mineral oils Organic pesticides Special waste Others	Solids, liquids, sludge and slurry. Commonly used for contaminated soils	Pretreatment is needed for solids. The process cannot treat soils and other materials with a high content of inert material	Pre-treatment is not required for most liquids. Solids such as contaminated soils, capacitors and transformers can be pre-treated using thermal desorption or solvent extraction.	Liquid and solid wastes, provided that a suitable preparation of the raw material is carried out.	Contaminated soils, dust residues from abatement devices
Overall assessment	**1**	**4**	**6**	**3**	**2**	**5**

Capacity:

Incineration and cement kilns have the highest capacity for treating hazardous waste with a part of highly chlorinated waste. Plasma and pyrolysis plants are usually small sized plants with minor capacity. Other techniques can vary in a large extent depending on the scope of the process.

Technique	Incineration	Pyrolysis/ gasification	Molten salt oxidation	Plasma	Cement kiln	Thermal and metallurgical production metals
Capacity	Hazardous-waste incinerators can treat between 30,000 and 100,000 T/a.	Capacity can vary in a broad range depending on the specific use Typical range: 100-200 T/a up to 3000-4000 T/a	Capacity range is very broad Typical figures are 1-2 T/h	Capacity range is very broad From hundreds kg/h to several T/h	co-incinerating wastes as a fuel limited to max 40 % of the heat requirement	Metal smelters have capacities above 100,000 T/a. The addition of POP wastes involves much smaller quantities.
Overall assessment	**1**	**3**	**5**	**4**	**2**	**6**

Materials and Energy consumption:

Cement kiln and metallurgical production of metals are characterised by a high consumption of energy and need a huge amount of raw material as far as concern their primary scope, but need slight more energy to co-process little amount of hazardous waste. In the cement kilns, the heat value of wastes can be used by the process itself, but at the same time other operations (like pre-treatment) may hardly be influenced by the burning of mixed chemical waste. Molten salt oxidation use very substantial amounts of energy, but the consumption and operation varies with furnace type and plant design.

In incineration and pyrolysis process, the amount of fuel is strongly dependent on the size of the plant and type of burned waste. However, it must be pointed out that large facilities can recover more heat and calorific value from wastes than low size facilities, which can be reused.

Technique	Incineration	Pyrolysis/ gasification	Molten salt oxidation	Plasma	Cement kiln	Thermal and metallurgical production metals
Materials and Energy consumption	The amount of combustion fuel required depends upon the composition and calorific value of the waste, but generally high energy requirement are needed. gypsum, lime or active carbon for the pollution abatement devices are requested	Gasification agent (steam and oxygen) Syngas, chars, oils, produced in the process are burned as fuels to utilize their energy value, or may be used as a raw material, for their chemical value	High consumption of energy, depending on the waste treated	High consumption of energy, depending on the waste treated	Reduced energy consumption when burning wastes, due to the utilisation of the heat value. Other operations at the cement plant may hardly be influenced by the burning of mixed chemical waste	Metal Production processes are energy-intensive. Treatment of the POP contaminated wastes requires little additional energy.
Overall assessment	**3**	**4**	**6**	**5**	**1**	**2**

Emissions, residues and elimination efficiency :

As described in the previous chapter, the list of pollutants emitted during all types thermal process is very long. The use of dedicated abatement devices can reduce the emission of the main macropollutants (dusts, NOx, SOx and CO) under legislative limits. The main problem concerning incineration and pyrolysis (especially for small plants) is the emission of organic micropollutants (such as PAHs, PCDD/PCDF, PCBs) and heavy metals. Sometimes the costs to reduce these emission is very high and the effectiveness not sufficient to respect the limits. Large facilities adopting suitable BAT/BEP can reach good results, but in this case the main concern is the high flow rate of emission gases or solid residues, so that the total mass emission can have a sensible impact.

Plasma facilities and molten salt oxidation show lower emissions of POPs and a huge reduction of emission volumes, but it must be reminded that generally this technique is used for small facilities. Solid residues produced are generally recyclable, thus avoiding other treatment steps.
DREs are generally very high (higher that 99.99%) but if the DEs lower values are taken in account, it appears that the main problem can be the high levels of POPs in the solid residues, especially in fly ashes, than must be further disposed of.

Cement kilns can show very low POPs emissions with respect to incineration plants, due to the use of coal as primary fuel (with sulphur as inhibiting agent), very high temperatures reached in the main combustion process and the use of suitable abatement devices. It is noted that it is rather difficult to document the environmental performance of cement kilns as substances and decomposition products originating from hazardous waste destruction are diluted in emissions and residues originating from raw materials. It is a fact that many countries set a limit to the amount of chorine content in the waste to be burned, so that low amount of hazardous waste can be generally disposed of with this process. As for the other process, the huge flow emission volumes must be considered when considering the total mass POPs emission.

In the thermal production of metals the main concern is with the uncontrolled fugitive emissions and with the fact the usually this kind of facilities are not equipped with dedicated abatement devices for PCDD/PCDF emission reduction.

Molten salt oxidation is foreseen a promising technology, but very few data are available on PCDD/PCDF emissions.

Technique	Incineration	Pyrolysis/ gasification	Molten salt oxidation	Plasma	Cement kiln	Thermal and metallurgical production metals
Emission and residues	In addition to macropollutants Mercury PCDD/PCDFs, chlorobenzenes, chloroethylenes PAHs are emitted. Heavy metals and POPs in solid residues Suitable BAT are needed	In addition to macropollutants Mercury PCDD/PCDFs, chlorobenzenes , chloroethylenes PAHs are emitted. Heavy metals and POPs in solid residues Suitable BAT are needed Particular attention must be paid in process optimization in small plants	Gaseous emissions and release of vaporised heavy metals The same Flue gas treatment facilities of incineration plants are required Organic compounds, are almost completely destroyed	Heavy metals and products of incomplete combustion (PIC) Typical PCDD/PCDF emissions under 0.1 ng/Nm^3	Dust is the main emission to control. Depending on the composition of raw material, emissions includes NOx, CO, SOx, HCl, HF, NH3. POPs emission very low	Particulate matter and SOx main emission. PCDD/ PCDFs may be formed Only the application of BAT can minimize the emissions to air emissions below 0.1 ng TEQ/Nm^3 Organic pollutants can be found in fugitive emissions
Overall assessment	**3**	**5**	**4**	**1**	**2**	**6**

Techniques	Incineration	Pyrolysis/ gasification	Molten salt oxidation	Plasma	Cement kiln	Thermal and metallurgical production metals
Elimination efficiency	Properly managed incinerators have reported DREs for POPs waste higher than 99.9999. DEs higher than 99.999% reported for pesticides, while DEs between 83.15 and 99.88 % for PCBs.	DEs of 99.974 % have been reported for PCDDs and PCDFs.	DRE of 99.999 % for Chlorinated solvents and pesticides	DREs for organic compounds can be higher than 99.99%.	DRE: 99.995%	Not available
Overall assessment	**3**	**5**	**4**	**1**	**2**	**6**

Management and Maintenance:

Small incineration or pyrolysis plants need a particular attention in the optimization of combustion parameters and in the management of abatement devices, due to the possible reformation of POPs in the process. On the other hand, large facilities, such as cement kilns or incinerators, have high volumes of raw material to be processed and huge amount of residues (ashes and wastewaters) to be treated. In the case of hazardous waste co-processing, pre-treatment represents a critical step.
Facilities with moving parts are most expensive. In this perspective cement kilns results in low maintenance.In plasma and molten salt oxidation a particular attention must be paid for the energy requirements of the process

Technique	Incineration	Pyrolysis/ gasification	Molten salt oxidation	Plasma	Cement kiln	Thermal and metallurgical production metals
Management and Maintenance	Optimization of combustion parameters and abatement devices required Contaminated residues must be sent to landfill or burned. Wash water to be treated.	Continuous optimization of combustion parameters and abatement devices required due to lower size Contaminated residues must be sent to landfill or burned. Wash water to be treated.	Optimization of energy supply	Complex configuration needs continuous optimization	Attention must be paid for waste pretreatment section. Steady process with few moving parts	Attention to the process and control of fugitive emissions
Overall assessment	**3**	**5**	**2**	**4**	**1**	**6**

Availability and Portability:

Technique	Incineration	Pyrolysis/ gasification	Molten salt oxidation	Plasma	Cement kiln	Thermal and metallurgical production metals
Availability and Portability	Common equipment available in many countries. in both portable and fixed units. Transportable: may take 3-6 months to set up.	The gasification technology is available only in fixed configurations. Pyrolysis usually adopted in small plants	Thermal treatment of solid residues including melting and vitrification is widely used. Not common in developing countries	Plasma is quite a established commercial technology, however the process can be very complex, expensive and operator intensive. Small and portable facilities are available but their commercialization is not common	Equipment largely used in many countries. Fixed large facilities	Metal smelters are large and fixed installations. Common in industrialized countries
Overall assessment	**1**	**3**	**5**	**6**	**2**	**4**

Health consideration:

As discussed above, the main risks related to incineration or pyrolysis plants is the potential emissions of heavy metals and POPs, if proper process management and BATs implementation are not carried out.

Plasma generally show lower health risks, but it must be reminded that it is not a common technique. The main concern with cement kilns and production of metals is the great load of emission volumes generated. Thermal production of metals is recognised to be a huge source of fugitive emissions

Technique	Incineration	Pyrolysis/ gasification	Molten salt oxidation	Plasma	Cement kiln	Thermal and metallurgical production metals
Health consideration	Risk to environment and human health come from air emissions and incomplete combustion,	Same risks of incineration (higher for small facilities) Use of hydrogen gas under pressure	Potential superheated-vapor explosions when liquid wastes are introduced	Lower emission volumes than incineration. heavy metals and PICs entrapped in slags reduce	The high flow rates can cause the emission of huge loads/year of the main pollutants	The high flow rates can cause the emission of huge loads/year of the main pollutants and their deposition in nearby areas.

	(POPs, acids and heavy metals) when high flow rates are considered (large facilities).	requires suitable controls		risk	and their deposition in nearby areas. POPs emissions very low	Non dedicated technology is a risk for POPs emissions
Overall assessment	**4**	**5**	**2**	**1**	**3**	**6**

Costs:

Apart investment and operating costs, which strongly depend on the size of facilities, specific costs for POP contaminated waste disposal also can vary depending on the type of wastes and process. Generally dedicated plants (as incinerators) show lower costs than cement kilns, which are not focused on waste disposal and have some limitation. Some not common techniques as molten salt and plasma can show higher figures.

Tecnique	Incineration	Pyrolysis/ gasification	Molten salt oxidation	Plasma	Cement kiln	Thermal and metallurgical production metals
Costs	Investment cost very high for large facilities (up to hundred MEur) Specific costs for PCB treatment vary with type of waste in the range 500-2000 Eur/T	Capital cost can vary in a large extent, typically in the range 250,000 -1 million US$.	Very wide range of costs For FGT residues disposal , is expensive compared to other treatment options. Disposal costs up to 2000 $/T	lower capital and maintenance costs than incineration Capital cost can vary in the range 500,000 -1 million US$. Disposal costs for PCB contaminated vary with waste. For transformers 140 US$/T, for liquid PCB: 470-1600 US$/T	Specific cost for chlorinated and PCB co-incineration: from 1000 US$ up to 5000 US$/T.	Not available
Overall assessment	**2**	**3**	**5**	**1**	**4**	**6**

Overall assessment:

Technique	Incineration	Pyrolysis/ gasification	Molten salt oxidation	Plasma	Cement kiln	Thermal and metallurgical production metals
Type of waste treated	1	4	6	3	2	5
Capacity	1	3	5	4	2	6
Materials and energy consumption	3	4	6	5	1	2
Emission and residues	3	5	4	1	2	6
Elimination efficiency	3	5	4	1	2	6
Management and Maintenance	3	5	2	6	1	4
Availability and Portability	1	3	5	6	2	4
Health consideration	4	5	2	1	3	6
Costs	2	3	5	1	4	6
Total mean	2.3	4.1	4.3	2.9	2.1	5.2

6. Conclusion:

From the above evaluation it appears that Incineration plants and cement kilns represent comparable techniques to dispose of POP wastes, including PCBs. Plasma show very good figures as far as concern the environmental impact, but suffer from the complexity of the process and the limited commercialization and diffusion. Small facilities like pyrolysis plants or molten salt oxidation are valid alternatives, but a particular attention should be paid with the optimization of the process. Thermal production of metals is definitely not a dedicated solution and can present problems with uncontrolled emissions, although some application (i.e. disposal of contaminated soils) can be used.

The current situation of Morocco was investigated with the aim to evaluate the applicability of one or more thermal technologies for the final disposal of pure PCB oils or PCB contaminated equipment.

In Morocco updated and environmentally sound hazardous waste incinerators are not currently present, or those existing are very old, low sized and poorly equipped.

Small facilities would present very high costs to be retrofitted with suitable BAT, and the disposal of PCBs in these facilities (either PCB pure oils or contaminated mineral oils) would be too expensive.

To better explain this issue, a list of examples of incremental cost assessment carried out in medical waste incinerators in New Zealand is presented. Medical waste incinerators can be compared with small and medium sized facilities for the disposal of hazardous waste, because they show similar levels of PCDD/PCDF emissions and because they use similar dedicated pollution abatement devices-The aim is to compare the costs related to the adoption of BAT/BEP for the reduction of PCDD/PCDF and the cost associated with retrofit options.
Source:
The Cost-Effectiveness of Reductions in Dioxin Emissions to Air from Selected Sources. Report prepared for the Ministry for the Environment of New Zealand. August 2001 - http://www.mfe.govt.nz

Small incinerators:

Typical process characteristics:

- Capacity 50–100 kg/hr
- baseline emission of 200 mg TEQ/year for 3,000 hours of operation in an uncontrolled process
- exhaust gas concentration of approximately 40 ng TEQ/Nm^3.

Selected technology options	Reported emissions (ng TEQ/Sm^3)	Likely performance		Emission standard achieved (ng TEQ/Sm^3)	Costs (NZ$'000s)			
					Existing (retrofit)		New	
		% reductions	mg TEQ/year		Total installed	Operating	Total installed	Operating
Good combustion practice (GCP)[a]	0.5–10[b]	75–98.8	2.5–50	10	70	10	Zero	Zero
GCP + rapid cooling or quench (Q)[c]	0.5–5[d]	87.5–98.8	2.5–25	5	130	40	50	30
GCP + Q + fabric filter (FF)	0.1–2[e]	95–99.8	0.5–10	2	220	120	120	110
GCP + Q + carbon injection (C) + FF	0.005–0.07[f]	99.8–99.99	0.02–0.35	Not a realistic option				
GCP + Q + C + FF + reheat + catalyst[g]	0.001–0.049[h]	99.88–99.998	0.005–0.25	Not a realistic option				

Medium incinerators:

Typical process characteristics:

- capacity of 300–500 kg/hr
- baseline emission of 200 mg TEQ/year for 3,000 hours of operation of a unit with good combustion practice
- exhaust gas concentration of approximately 10 ng TEQ/Nm3.

Selected technology options	**Reported emissions** (ng TEQ/Sm³)	**Likely performance**		**Emission standard achieved** (ng TEQ/Sm³)	**Costs** (NZ$'000s)			
					Existing (retrofit)		**New**	
		% reductions	mg TEQ/year		**Total installed**	**Operating**	**Total installed**	**Operating**
Good combustion practice (GCP)[a] (baseline)	0.5–10[b]	0	200	10	Zero	Zero	Zero	Zero
GCP + rapid cooling or quench (Q)[c]	0.5–5[d]	50–95	10–100	5	100	60	90	60
GCP + Q + fabric filter (FF)	0.1–2[e]	80–99	2–40	2	520	160	410	160
GCP + Q + carbon injection (C) + FF	0.005–0.07[f]	99.3–99.95	0.1–1.4	0.1	610	180	490	180
GCP + Q + C + FF + reheat + catalyst[g]	0.001–0.049[h]	99.5–99.99	0.02–0.98	0.05	1,300	210	1,100	210

Large incinerators:

Typical process characteristics:

- capacity of 1000 kg/hr
- baseline emission of 400 mg TEQ/year for 3,000 hours of operation of a unit with good combustion practice
- exhaust gas concentration of approximately 10 ng TEQ/Nm3.

Selected technology options	**Reported emissions** (ng TEQ/Sm³)	**Likely performance**		**Emission standard achieved** (ng TEQ/Sm³)	**Costs** (NZ$'000s)			
					Existing (retrofit)		**New**	
		% reductions	mg TEQ/year		**Total installed**	**Operating**	**Total installed**	**Operating**
Good combustion practice (GCP)[a] (baseline)	0.5–10[b]	0	400	–	Zero	Zero	Zero	Zero
GCP + rapid cooling or quench (Q)[c]	0.5–5[d]	50–95	20–200	5	140	80	120	80
GCP + Q + fabric filter (FF)	0.1–2[e]	80–99	4–80	2	570	190	450	190
GCP + Q + carbon injection (C) + FF	0.005–0.07[f]	99.3–99.95	0.2–2.8	0.1	690	220	550	220
GCP + Q + C + FF + reheat + catalyst[g]	0.001–0.049[h]	99.5–99.99	0.04–2	0.05	1,800	260	1,400	260

As can be seen in the tables, for low size incinerators the achievement of BAT/BEP performance levels (i.e 0.1 ng/Nm^3) is a not realistic option, both in the case of new facilities and retrofit situations, whereas a large facility can meet the standards only applying a fabric filter or a combination of carbon injection/fabric filter.

A central treatment and disposal facility project (CNEDS- Centre National d'Elimination de Déchets Spéciaux or National Centre for Disposal of Special Hazardous Waste) is in preparation, with the support of GTZ, the German Corporation for Technical Cooperation. In the PDF-B stage was reported that this process would have been completed in 2006 and that the expected first phase of the CNEDS would have been the establishing by the 2007-2008 of the facilities for physical-chemical treatment, oil-recycling, medical waste treatment and a special engineered landfill for hazardous waste. The estimated cost was reported to be US$10 million and its capacity was expected to be 100,000 T/a for industrial hazardous waste and 7,500 T/a for medical hazardous waste. The financial partner is the German Development Bank, KfW, Entwicklungsbank.

It must be pointed out that the preparatory PDF-B documents states that no PCB equipment will be treated in this facility. Latest information report that this project so far is still at the first stage (feasibility study), strongly delayed with respect the expectation, and will be reasonably ready only by 2011-2012. Therefore it can not be included as an option in the framework of the GEF project. Reasonably, some kind of cooperation could be set up in a later moment, especially as far as concern the pretreatment steps of wastes before final disposal.

The same discussion can be carried out with the implementation of low size pyrolysis-gasification facilities. The building of a facility would require too much time with respect the timeline of the project.
It must be also reminded that due to the limited amount of pure PCB oils (as reported in all the inventories carried out in the last years) and their continuing decrease, the Morocco Government has already decided to co-finance the shipping and final disposal abroad of this kind of waste, in the framework of the GEF project.

The use of cement kilns to treat the related waste coming from the dismantling process of decommissioned transformers was also evaluated during the two missions of the international experts in Morocco.

In Morocco there are currently 4 major international groups operating in the cement industry, with about 24 plants. Only 5 plants are equipped with BAT to co-burn alternative fuels or some kinds of wastes (like tyres and some industrial wastes, plastics and used oils).

As agreed between the Ministry of Environment and the local Cement association, there are some rules covering the acceptance ands management of these kinds of wastes, along with the PCDD/PCDF monitoring from the stacks of the involved facilities. Although by the technical point of view the disposal of PCB contaminated oils in cement kilns could be possible, provided some retrofitting operation to be carried out in the pretreatment steps and in the abatement devices for PCDD/PCDF control, some limitations consist in the absence of a suitable regulation that permit the co-incineration of PCB waste with a concentration higher than 50 ppm. This task will be performed during the activities of the project.

With this perspective, the additional investment costs should be evaluated with respect two different scenarios. This issue was discussed during different meeting with representatives of the cement companies.

The first scenario is the treatment of the total amount of PCB contaminated oils, where the PCB concentration could be not a limitation by the technical point of view, provided suitable analytical assessment. Moreover, currently two of the cement companies are planning to set up pretreatment (blending) units and one facility in Fez was told to be ready to accept PCB wastes.

The second scenario deals with the disposal of a very low amount of contaminated material, coming from the dismantling of decommissioned transformers or capacitors. In this case the investment cost would be too high in proportion to the waste to be treated and the companies excluded a possible involvement in this case.

Plasma technology shows some characteristics, which may be evaluated for its implementation in PCB disposal. As discussed above, it presents some advantages, such as the reduced emissions, although the investment cost are higher if compared with other existing technologies.

The main concern is with the fact that it is still a not widely commercialised technology and requires high skilled personnel. Moreover, it would be used only for particular wastes.

Other disposal technologies such as molten salt or the use of dedicated facilities for metal production are considered as ancillary technologies. Metal production facilities could be used only in some case, as the disposal of contaminated soils in absence of alternative and dedicated solution.

ANNEX D FEASIBILITY STUDY FOR THE USE OF NON- COMBUSTION TECHNOLOGIES IN PCB DISPOSAL AND/OR DECONTAMINATION OF PCB-CONTAMINATED MATERIALS

1. Introduction

This project document "Management of PCB-contaminated transformers in Morocco" outlines UNIDO's proposal for the provision of technical assistance to public and private sector actors to increase the in-country capacity for overcoming identified barriers for safe and sustainable management of PCB-contaminated transformers at all stages of their life cycle.

It is estimated that up to 20 - 30% or about 30,000 electrical transformers in used in Morocco may be contaminated with PCBs above the threshold level of 50 mg/kg or ppm. Based on the inventory of transformers in the generating, transmission and distribution electrical system, including the industrial sector, it is estimated that the 30% of contamination level represents near 13,000 metric tons of PCB contaminated mineral oil.

The existence of PCB contaminated mineral oil transformers in any given jurisdiction is a complex problem due the number of transformers involved and the locations they installed. Larger power transformers can be found in electrical generating stations and transmission stations, medium size transformers are usually found in distribution stations and industrial sites, heavy users of electricity such mining, steel and manufacturing facilities, while small distributions transformers are installed in the electrical distributions network covering the whole country.

Because of the logistic and tremendous efforts required to analyze all electrical transformers, in most countries owners of transformers and government officials have establish programs where mediun and large size transformers are analyzed and depending of the PCB level found, measure to properly manage the units are implemented. Small sizes transformers on the other hand, are left in-service until their useful life expired. Once these transformers are to be replaced, the oil in the transformers are tested for PCB content and managed appropriable.

An environmentally friendly manner to manage and re-classify large and medium size PCB contaminated mineral oil transformers is using a retrofilling method. This method of managing low level PCB contaminated mineral oil from in-service electrical systems is widely used by the industry to convert PCB-contaminated equipment into non-PCB units. The retro-filling solution for high level PCB transformer was commercially available in North America in the early 1990's, but it has been discontinued.

Retro-filling is an economical and simple solution for the removal from in-service of PCB contaminated mineral oil. Depending of the original PCB level in the mineral oil in the contaminated transformer, retro-filling may have to be repeated to achieve the usually less than 50 ppm target level. Based on industry experience, transformers with PCB in the liquid that contain between 50 and 700 ppm, will require just one retro-filling process to achieve a final PCB concentration of less than 50 ppm, transformers that contain between 700 and 2000 ppm will require two retro-fillings to achieve the less than 50 ppm target. However, transformers than contain between 2000 and 10000 pm will require retro-filling to be applied 3 times to achieve the less than 50 ppm.

Because most of the mineral oil electrical transformers contaminated with PCBs contain less than 700 ppm, then it is expected that one retro-filling will be required to convert most of the PCB-contaminated transformers into PCB-free units. Retro-filling when applied to PCB contaminated mineral oil transformers is a sound and economical solution for the elimination of PCBs from electrical systems.

In order to economically apply the retro-filling solution to mineral oil PCB contaminated transformer, it is necessary to have access to a dechlorination unit that can treat the mineral oil and selectively destroy the PCBs. The dechlorination system however has to be able to yield a mineral oil that can be suitable for re-use in the electrical transformer.

Distribution of the PCB in transformers shows that most of the PCBs are in the dielectric fluid and the absorbed by the porous componens of transformers, namely insulating paper and wood spacers. A very small fraction of all PCBs in a transformer are contained in the metallic components. Specifically, PCBs or oil-containing PCBs are held on the surface of the inert metallic (steel) and imbedded in the varnish that may be coating the conductor (copper wiring). Degreassing solvents have been used to dissolve the PCBs from the metallic surfaces, rendering a PCB-contaminated solvent and a PCB-free metal.

Aggressive solvents such as perchloroethylene and other chlorinated materials are being used to decontaminate porous materials and metals from PCB contaminated transformers. Technologies based on solvent extraction require a method to reclaimed the solvent. Because of the significant difference of the boiling point between the chosen solvent and the PCBs, Distillation has been commonly used for this purpose.

In the context of the proposed PCB project in Morocco however where a smaller number of PCB contaminated transformers will require metal cleaning, it is conceived that rather than using the normal degreasing solvent such as Perchloroethylene, hot mineral oil be used as PCB dissolvent agent. The hot oil will be able to dissolve the PCBs from the metallic surfaces and lowering the contamination level to lower than 50 mg/kg or other acceptable standard. The PCB contaminated oil recovered from the metal cleaning activity will then be treated in the dechlorination unit, destroying selectively the PCBs and rendering a dielectric fluid suitable for re-use in transformers or for cleaning additional transformer's metallic components.

The vast extent of the PCB contamination problem in Morocco represents a significant economical and environmental challenge for the Moroccan government and PCB users to meet the commitments made under the Stockholm Convention.

The proposed UNIDO's project aims at establishing decontamination/treatment facilities for the environmentally sound dechlorination and reclamation of PCB contaminated mineral oil as well as at the decontamination, reclamation and recycling of copper and steel recovered from PCB contaminated mineral oil transformers, specifically:

- Establishment of facility to drain, dismantle and decontaminate metal components from PCB transformers. In this facility, pure PCBs drained from transformers and porous material such as insulating paper and wood from pure PCB transformers will re-packaged and shipped abroad for incineration.
- Establishment of a dechlorination plant to reclaim PCB contaminated mineral oil. This plant could be made fixed or mobile and would be used to clean PCB contaminated mineral oil from in-service transformers, as well as to clean the mineral oil used to clean the metallic components of surplus PCB contaminated transformers.

In order to assist countries like Morocco to deal with the disposal of obsolete POPs, including PCBs, the Global Environmental Facilities, concurrent with its mandate to support innovative and environmentally sound approaches and technologies, will support the demonstration and replication of innovative and cost-effective practices and technologies, in particular non-combustion technologies. Based on waste streams, some of these non-combustion technologies have proven to be superior to incineration, not only economically, but also from the environmental and social points of view.

It is believe that the establishment of these two facilities will provide Morocco with:

- Within the country, long-term, best economical solution for dealing with PCB disposal problem. Decontamination of PCB mineral oil using dechlorination methods is less expensive than shipping and incinerating the waste in European incinerators. In addition, the mineral oil in dechlorination systems is reclaimed and reused in transformers, unlike incineration where it is totally destroyed and has to be replaced by new oil to fill the empty transformers, if incinerated.

- Best environmental solution as only the small fraction of PCB within the waste matrix is selectively destroyed without the need to destroy the whole matrix as incineration would do. This approach not only reduces the potential generation of carbon dioxide, but allows the recovery and recycle of valuable commodities such as transformer mineral oil, copper and steel.
- Best social solution, as sustainable jobs are created within Morocco to maintain the facilities and the PCB services being offered.

2. Non-Combustion Technologies

There is a number of non-combustion technologies that have developed and used for the treatment and destruction of PCB contaminated materials. In order to have a complete view of these technologies and their application for the destruction and/or decontamination POP contaminated materials the Scientific and Technical Advisory Panel (STAP) held a workshop in Washington D.C from 1-3 October, 2003.

The STAP Workshop was attended by experts from developed and developing countries, academia, research, international and government agencies, as well as representatives of the GEF Secretariat and the Implementing Agencies. The workshop was also attended by representatives from the Stockholm and Basel Convention Secretariats, and by UNIDO and FAO.

In addition to the STAP Workshop, a document prepared for the first meeting of the Technical Advisory Group of the UNIDO/UNDP/GEF Project: *Demonstration of Viability and Removal of Barriers that Impede Adoption and Effective Implementation of Available, Non-combustion Technologies for Destroying Persistent Organic Pollutant* also contains relevant information on non-combustion technologies.

Rather than repeating ourselves and provide information already available in the public domain, this reports summarizes those technologies that are suitable for use in the proposed PCB project in Morocco. When available, additional information is presented for those technologies already identified.

Based on the above-mentioned criteria, the following technologies meet are considered suitable for use in the UNIDO's PCB Management Project for Morocco:

- Based Catalysed Dechlorination
- Sodium Reduction Processes
- Solvated Electron Process.

The following proposed criteria was applied to the PCB destruction/dechlorination technologies considered for this project:

A. Complete destruction of the PCB contaminant without destruction of the mineral oil.
B. Commercially available and proven track record
C. Prevent the formation of dioxins, furans and other by-product POPs.
D. Not generate any wastes with POPs characteristics.

Based Catalysed Dechlorination

The process is based on the pioneer work carried out General Electric on the reaction between Potassium or Sodium Hydroxide and the Polychlorinated Biphenyls in the presence of an organic catalyst. The technology was developed by a group of Scientist at USEPA laboratories in Cincinnati, USA.

Based the Vendor's web page www.bcdinternational.com/ "In the typical BCD application for treating pure or high level liquid PCB (Askarels or Aroclors), the PCB material is pumped into a heated reactor containing hydrocarbon oil, sodium hydroxide and a suitable BCD catalyst. The reaction is immediate, rapid and capable of treating to a final PCB residual concentration of < 0.2-PPM.

There are various sized liquid BCD treatment units for PCB remediation. The smallest is a continuous flow BCD reactor for placing on line to remediate transformer or other low-level PCB fluids of <100 PPM PCB. (EBARA Corp., Japan)

The next size liquid BCD treatment systems are in the 200-500 gallon size range. These units are sized from 1,000 to 2,500 gallon capacities. This size reactor is well suited for both treatment of materials desorbed from BCD solids reactors and routine small scale liquids treatment.

The commercial large scale liquid BCD reactors for PCB destruction are typically sized from 1,000 to 2,000 gallons capacity.

The operational parameters for these units vary due to size, heating/cooling and other design characteristics. Small unit initial heat-up can vary from 2 to 4 hours as can cool down to discharge temperatures. Reaction times are typically in the 10 minute to one/two hour range depending on PCB introduction rate and the reactor temperature. In a large batch reactor if the PCB liquid is fed into the system at operating temperature the rate of reaction is extremely fast, on the order of minutes. This results in completion of PCB destruction of 100,000 to 350,000 PPM of PCB within a sixty to ninety minute time range. Thus small and large BCD liquid treatment units can be operated to treat two to four batches of PCB waste per day.

Destruction Efficiencies for this technology, according to Vendor's claim is in liquid treatment >99.99% depending on the initial PCB concentration fed into the reactor. US federal laws regarding residual PCB in used liquids (typically oils) require <2 PPM total PCB residual in treated oils. The Japanese laws state that the residual must be <0.2 PPM total PCB in treated oils. All of these requirements have been either met or exceeded by the BCD processes.

The BCD technology is available for licensing from BCD Group Inc., Cincinnati, OH 45208, USA, kornel_a@bcdinternational.com Website: www.bcdinternational.com

Sodium Reduction Processes

The sodium-based reaction for the destruction of PCBs and other toxic chlorinated materials has been used for a number of companies to develop efficient and economical means to manage PCB wastes. Most of the applications have been for the selectively destruction of PCBs from mineral oil, rendering a PCB-free dielectric fluid suitable for re-use in electrical transformers. Some uses however, have also been applied for the destruction of pure PCBs. Most noticeable of all, is the Toyota City PCB destruction plant commissioned and operated by the government of Japan for the destruction of pure PCBs.

The sodium based reaction for the dechlorination of electrical insulating oils contaminated with low levels of polychlorinated biphenyls (PCBs) is dependent on the reaction of active sodium with the chlorine in the PCB molecules, under carefully controlled conditions, to form sodium chlorine and hydrocarbon residues.

The principle reaction in the process is the direct removal of the chlorine atoms from the PCB molecule by sodium;

i.e.: $RCl_x + Na^+ \text{-------}> NaCl + R^+_{x-1}$

Where RCl is a PCB molecule containing x number of chlorine atoms (x =1 to 10), Na^+ is a reactive sodium atom, and R^+_{x-1} is a PCB molecule with 1 chlorine atom removed.

R^{+}_{x-1} is reactive free-radical from the biphenyl structure and combines with H^{+} ,formed by the reaction of sodium with water or donated by the mineral oil, to form a neutral RH molecule. If RH contains additional chlorine, it is again attacked by sodium and the process is repeated until all chlorine atoms have been replaced by hydrogen atoms. At this point, the PCB molecule has been converted to a biphenyl molecule and all chlorine atoms have combined with sodium to form sodium chloride or table salt.

Important side reactions which can occur during the dechlorination process include the reaction of sodium with trace water or with acidic organic oxidation products formed while the oils were in service. These side reactions render undesirable acidic oil components insoluble and therefore assist in their removal in subsequent centrifuging and filtering stages.

While the principal organic product formed in the dechlorination reaction is biphenyl, a small amount of an insoluble residue known as Polyphenyls is also produced as a result of biphenyl polymerization. The yield of Polyphenyls increases relative to that of biphenyl as the PCB concentration of the input oil increases. As with neutralized oil acids, this material is removed from the oil in subsequent treatment stages.

Complete dechlorination reaction occurs in both highly concentrated PCB liquid waste (i.e. pure) or low concentration PCB contaminated mineral oil.

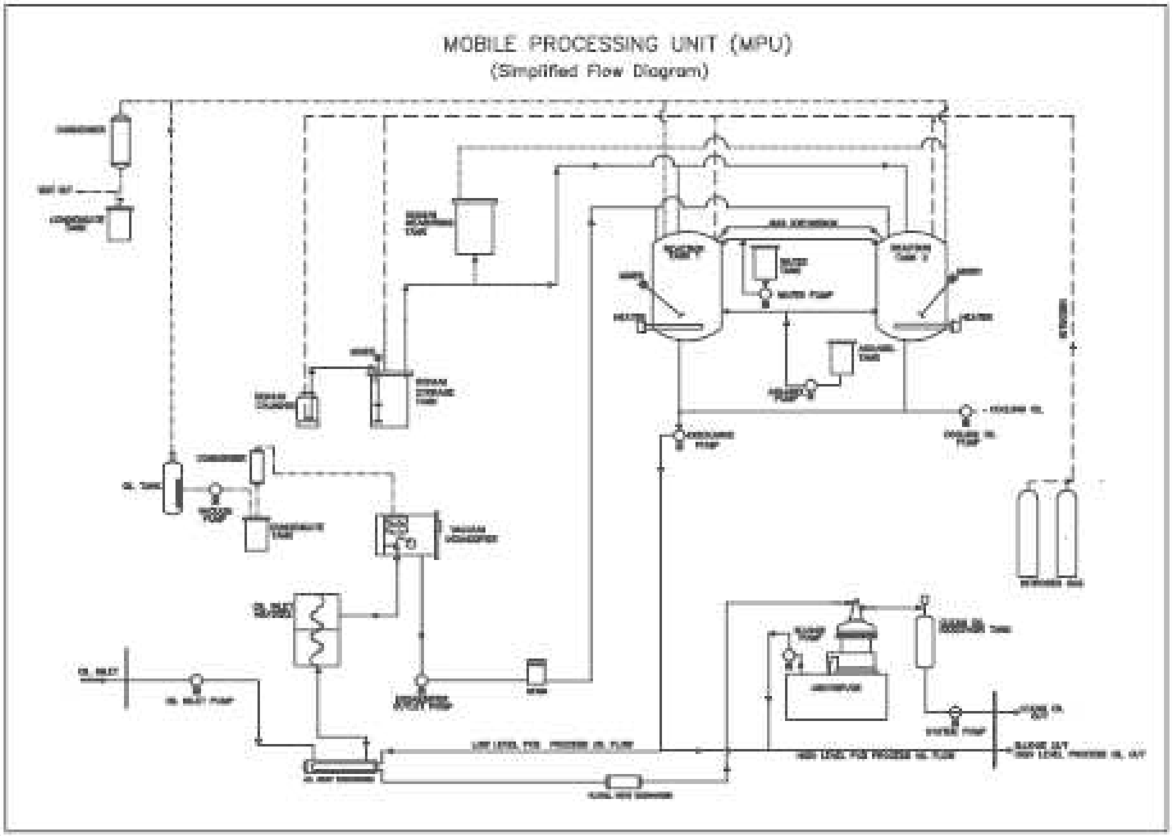
The sodium based reaction for the dechlorination of PCB contaminated mineral oil can be designed as a batch or or a continuous process. Although as a batch process this mode of operation may reduce the throughput capacity of a similar size system when operated on a continuous mode, there are several practical advantages of the batch process, namely:

- Better emission control. In a batch process the reaction vessel remain close until batch analytical data confirms all PCBs in the reactor has been destroyed. Once the PCB destruction has been confirmed, the reaction vessel is purged with nitrogen during the neutralization of the excess sodium used in the reaction. Obviously, the same level of control cannot achieve on a continuous process.
- The batch operation mode avoid cross contamination of already cleaned oil. As every batch of oil is analyzed prior to evacuation of the reaction vessel, in the batch process everything in the reaction vessel is analyzed. In a continuous processing mode, samples are taken at the different times and if there is fault in the operating conditions, this fault, translated in poor destruction reaction, could be detected only after it has already cross contaminated the already cleaned oil.

- The sodium-based reaction as most PCB destruction reaction, it is an exothermic process. The heat of reaction is quite significant and depending on PCB concentration, could generate enough heat to increase the temperature of the reaction mixture well over the mineral oil flash point. This is even more important when destroying high level PCB liquid waste.

A typical diagram describing a sodium-based PCB destruction unit is given in Figure 1

Figure 1 Simplified diagram of a sodium-based PCB destruction system



As shown in Figure 1, a typical sodium-based PCB destruction system would have two reaction vessels. At the start of a daily operation, both reaction vessels will be empty. One reaction vessel will be first filled with PCB contaminated mineral oil, while the second one remains empty. At the completion of the first batch, the reaction vessel is emptied. As the first reaction vessel is emptied, the second vessel is simultaneously loaded with PCB contaminated oil. Heat from the completed reaction (warm oil) is used to warm up the second batch being loaded. The batch process continues until the work load for the day is completed.

To start the process operation for decontaminating PCB contaminated mineral oil, the PCB level in the oil to be treated is first determined. The presence of other chlorinated contaminants such as tri and tetra-chlorobenzenes, dioxins and furans, water or acids is further investigated or determined.

Once the PCB level in the oil to be treated is known (in addition to other chlorinated material), waste oil is fed into the processing unit. After passing through a heat exchanger and a heater, the oil goes into a degassifier where water and other volatile components are removed. The contaminated oil is further heated to about 80-85 ^{o}C before reaching the selected reaction vessel.

Once the reaction vessel is loaded with the pre-determined PCB contaminated oil volume and the oil temperature is at the desired level, the sodium dispersion reagent is added. After adding the sodium reagent, the PCB destruction reaction is allowed to complete for 15 to 30 minutes. The occurrence of the reaction is evidenced by a slightly increase in the mixture's temperature. The amount of heat evolved and therefore the oil's temperature increase will depend on the PCB and other chlorinated material concentration.

As the PCB destruction reaction is a free-radical type of reactions, it usually goes to completion very quickly. After the reaction period has elapsed, a sample of the reacting mixture is taken and promptly analyzed. If the analytical results confirmed that the reaction has been completed, then the gas in the reaction vessel is purged with nitrogen and the excess of sodium reagent in the vessel is neutralized with water.

The amount and composition of the sludge by-product will depend on the initial PCB concentration in the treated batch and the amount of sodium reagent added. The higher the PCB level in the original oil, the sludge would have relatively higher concentration of Polyphenyls and Sodium Chloride and lower concentration of Sodium Hydroxide. As the PCB in the original waste oil increases, the sodium-chlorine ratio required to effectively complete the PCB destruction reaction is reduced, thereby relatively reducing the amount of excess sodium left in reaction vessel that needs neutralization.

For batches of contaminated oil with low PCB concentrations (i.e. less than 2,000 ppm), the sludge by-product can be separated from the oil in the system's centrifuge. However, the sludge is quickly settle and separated from the oil in high PCB level waste oil.

Once the sludge is separated from the cleaned oil, the sludge can be further treated with an acidic water solution to convert of Sodium Hydroxide into water and the corresponding salt and to separate the petroleum-based Polyphenyls fraction. This clean Polyphenyls fraction composed of Carbon and Hydrogen can be used as fuel in industrial furnaces.

The Sodium-based process is an efficient chemical process for the destruction of PCBs and other halogenated materials, including all persistent organic pollutants included in the United Nations Stockholm Convention.

Analytical results from different, independent laboratories have confirmed the consistency and completeness of the PCB destruction reaction. Operated as a batch process and a close system, all PCBs are totally destroyed before the reaction before is re-open and the cleaned oil/by-product removed from the reactor. The final concentration of PCBs from the treatment of low level PCB contaminated mineral oil or the destruction of pure PCBs is essential the same, non-detection of PCBs in liquid phase, solid (sludge) or in the air emission streams.

United Nations Industrial Development Organization request for Proposal No. 16001337/ZP requires that the proposed non-combustion technology must meet a Destruction Efficiency of not less than 99.9999 (six nines) for PCBs and other POPs of concern. The Destruction Efficiency is defined as:

Equation 1:

$$DE(\%) = \{(totalPCBin) - (totaPCBout)/(totalPCBin)\} * 100$$

Because of the best available analytical technique, High Resolution Mass Spectroscopy, has a minimum detection level of 1 to 4 ug/kg for PCBs in oil and 0.036 ug/kg of PCBs in sludge, the minimum DE of 99.9999% cannot be demonstrated when any PCB destruction technology is used to treat PCB contaminated mineral oil.

The six nines PCB destruction efficiency can only be demonstrated when destroying pure PCBs. The data included in the experimental program carried out by Kinectrics Inc. (one of the Vendors for this technology) to demonstrate its sodium-based PCB destruction process meets Japanese Regulatory requirements can be used to confirm the minimum 99.9999% Destruction Efficiency for this technology.

The demonstration program for the Japanese government included five PCB destruction runs, namely two runs using PCB contaminated mineral oil (~ 100 ppm) and three runs using pure or high level PCB wastes (Table 5, page III-19). Runs 3-1 and 3-2 were carried out using a blend of pure Aroclor 1242 (Delor 103) and transformer Askarel containing Aroclor 1260 (Delor 106) and tri- and tetra-chlorobenzenes. Table 5 in the Japanese report (page III-50) provides an explanation of the numbering system used throughout this report. Thus the results for runs 3-1 and 3-2 are referred in Maxxam Laboratories report as runs 2-1 and 2-2 respectively.

The results for residual PCB concentration in the oil phase (liquid) are given in pages III-102 and III 103. It is observed that the residual PCB content in the oil phase is below the minimum detection level for all congeners analyzed. Table 1 summarizes the results for the residual PCBs (isomer groups) for the liquid phase.

The results for residual PCB concentration in the sludge (solid phase) are given in pages III 183 and III-184 of the report. For the solid phase, it is also observed that the residual PCB concentration is below the minimum detection level for the analytical technique. These results have also been incorporated into Table 1 below.

Table 1. Analytical results for oil (liquid) and sludge (solid) phases for high level PCB destruction experiments

ISOMER	**Liquid MDL**	**Sludge MDL**
	µg/kg	µg/kg
Monochlorobiphenyl	1	0.036
Dichlorobiphenyls	1	0.036
Trichlorobiphenyl	1	0.036
Tetrachlorobiphenyl	4	0.036
Pentachlorobiphenyl	1	0.036
Hexachlorobiphenyl	1	0.036
Heptachlorobiphenyl	1	0.036
Octachlorbiphenyl	1	0.036
Nonachlorobiphenyl	1	0.036
decachlorobiphenyl	1	0.036
SUMM	**13**	**0.36**

Air PCB emissions were also determined during the PCB destruction experiments. Table “PCB Congeners in air (pages III-173 and III-174) shows that the PCB emissions, after the air pollution control system, in the destruction unit (Maxxam ID 141044 and 141046) for runs 3-1 and 3-2 were below the detection level of 30 nanograms for the analytical technique. With 10 possible isomer groups, the total PCB emission from these experiments was < 300 nanograms.

Table 2. Summary of PCB injection and final PCB concentration for High Level PCB destruction experiments

RUN #	Aroclor 1242	Aroclor 1260	Total PCBs	Chlorobenzenes	Total Chlorine	Final PCB in Liquid	Final PCB in Sludge	Mass of Oil	Mass of Sludge	Total PCB air emission
	(kg)	(kg)	(kg)	(kg)	(kg)	µg/kg	µg/kg	kg	kg	ηg
						All Isomers	All Isomers			all isomers
3-1	14.8500	1.1220	15.9720	0.53	7.23	<13	<0.36	766.044	398.16	<300
3-2	14.8500	1.1220	15.9720	0.53	7.23	<13	<0.36	766.044	398.16	<300

The analytical results and the mass of oil and sludge allow the quantification of the total PCB residual in each byproduct stream. Table 3 summarizes the amount of residual PCBs in the sludge, oil and air streams.

Table 3. Residual PCBs in the sludge, oil and air streams for PCB destruction experiments 3-1 and 3-2.

Run #	Residual PCBs in sludge	Residual PCBs in Oil	PCBs air emission	Total un-reacted PCBs
	µg	µg	µg	µg
3-1	143.3376	9958.5200	0.3000	10102.16
3-2	143.3376	9958.5200	0.3000	10102.16

With the data in Table 3 and using equation 1, the Destruction Efficiency for Kinectrics' Sodium-based PCB destruction technology can be calculated. The results are summarized in Table 4.

Table 4. Destruction Efficiency for Kinectrics' Sodium-based PCB Destruction Process

Total Initial PCBs	Total Initial PCBs	Mass of Residual PCBs	PCBs Destroyed	Total Destruction Efficiency
kg	µg	µg	µg	%
		Less than	Greater than	Greater than
15.9720	15972000000	10102.16	15971989898	99.99993675
15.9720	15972000000	10102.16	15971989898	99.99993675

As summarized in Table 4, Kinectrics sodium-based PCB destruction is able not only able to meet, exceeds the 99.9999% Destruction Efficiency required for the UNIDO's PCB Project in Slovakia. This destruction efficiency is being met for every batch of high level PCB waste being destroyed using this technology.

As previously indicated, there are several Vendors for the sodium-based technology, namely:
Kinectrics Inc. and Powertech of Canada, Fluidex of South Africa, SD Myers and Clean Harbors of the USA, Sumitomo Corporation of Japan.

Solvated Electron Process

Commodore Solution Technologies, Inc. has developed an innovative total systems approach to environmental remediation, which utilizes a patented (Abel, 1992) chemistry called Solvated Electron Technology (SET ™). Solvated electron solutions are some of the most powerful reducing agents known. Formed by dissolving alkali and alkaline-earth metals in anhydrous liquid ammonia to produce a solution of metal cations and free electrons, solvated electron solutions are capable of providing unique reductants of great activity. They provide a highly useful mechanism for the reductive destruction of many organic molecules and are extremely effective in the dehalogenation of halogenated organic compounds. Commodore has received a nationwide EPA operating permit for the non-thermal destruction of PCBs in soils, oils, surfaces and solid materials using this process. The permit further allows for the recycle of treated PCB containing oils. The SoLV™ process is a total solution that incorporates pre- and post- treatments, where necessary, for environmental clean up. It is applicable to a broad range of substrates including liquids, solids, soils, personnel protective equipment and job materials. Commodore has successfully commercialized this technology. Equipment capable of treating 10 tons a day is currently in the field. This paper provides an overview of the technology and process. Individual case studies are available for specific examples where the process has been utilized.

Functional organic compounds have proven to be some of the most difficult and expensive remediation challenges to face the environmental clean up industry. As a class, they represent some of the most toxic, environmentally persistent, and difficult-to-destroy compounds known. In the environment, materials such as pesticides, PCBs, dioxins, furans, PAHs, BTXs, explosives, chemical warfare agents, chlorofluorocarbons, and chlorinated solvents are deemed to pose a hazard to health and the environment, even when present in relatively small quantities. To meet today's stringent cleanup standards, vast quantities of materials such as soil, job equipment, adsorbents, process liquids, and building materials must be treated to remove contaminants that may be present in quantities measurable only in parts-per-million.

Other than landfill, commercially available remediation technology options are limited principally to thermal processes such as incineration; plasma arc, catalytic extraction, gas phase chemical reduction, and thermal desorption. These are undesirable due to generation of off gases such as dioxins. There is a need for a total system and cost effective remediation approach that can destroy contaminants while rendering the soil or other matrix materials non-hazardous.

The SoLV™ process utilizes solvated electron solutions to destroy hazardous contaminants. In the process, contaminants are destroyed by a chemical reduction mechanism, whereby the functional organic compounds are converted to petroleum hydrocarbons and metal salts. In the case of a PCB molecule, the halogen atoms are stripped from the halogenated organic compound and converted to sodium chloride and the carbon skeleton is converted to high molecular weight hydrocarbons. The resultant remediated soil can be returned to its original location.

The application of this versatile chemistry to environmental matrices has been proven by Commodore to be a cost-effective approach for addressing environmental remediation issues. Further, the chemistry has been validated by an independent research group.

Although the discovery was made in 1865 that sodium metal dissolves in liquid anhydrous ammonia to form a dark blue solution with some rather unusual properties, solvated electron solutions still remain an under utilized phenomenon to most chemists. Yet, solvated electron solutions are one of the more powerful reducing agents known. Solvated electron solutions, also referred to as dissolving metal solutions, are formed by dissolving alkali or alkaline-earth metals, including sodium, calcium, lithium, and potassium, in anhydrous liquid ammonia.

Formation of the solvated electron is believed to occur as illustrated in the following

Equation:

$$Na^{O} \xrightarrow{NH3} Na^{+} + e^{-}$$

The solutions, which form rapidly when the metal enters the ammonia, are characterized by a deep blue coloration and an electrical conductivity approaching that of liquid metals. For convenience, the solvated electron systems are frequently regarded as solutions of the metallic cation and electrons, a concept supported by the results of a number of physical measurements.

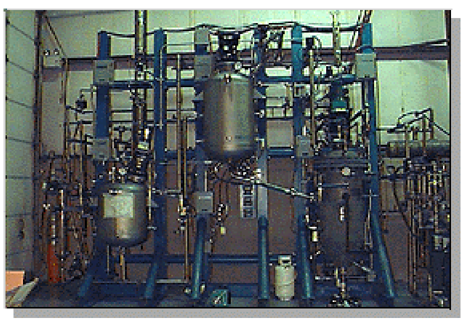
Halogens can be split from organic halides by solvated electron solutions, yielding quantitative amounts of the halogen anion. In fact, this procedure was employed as early as 1914 for the analytical determination of organic halogens. By properly controlling reaction parameters, it is possible, in the case of the alkyl and aryl halides, to direct the reaction pathway so that the fully substituted parent hydrocarbon and the metal-halide are the sole reaction products. For the case of aromatic material, the parent hydrocarbon can react further to produce high molecular weight oligomers.

In addition to halogens, many other organic molecules are reactive towards solvated electrons. Several review articles have appeared that addresses the broad application of the chemistry. Organic phosphorous and sulfur compounds such as pesticides and chemical warfare agents are known to be reactive to solvated electrons. It is also well understood that aromatic materials such as benzene and poly aromatic hydrocarbons are chemically reduced by the Birch reaction using solvated electrons.

Process Description

The SoLV™ process is modular in nature. Commodore has developed several process variations depending on the nature of the material being remediated. The various modules are designed to be tailored to each particular remediation site in a manner such that the most cost-effective sequence is utilized. The SET™ treatment module is the centerpiece of the process and is a critical component of each process. All equipment is mobile and able to be placed at the site, which eliminates the expense of transporting hazardous materials. Space does not allow the description of all the possible combinations of these modules. However, they generally include front-end modules that can remove water or extract the contaminants of interest. Next, the SET™ treatment module is required to destroy the contaminants. Back end modules are available to recycle ammonia, pH adjust, concentrate or fix the reaction products depending on the specific needs of the client.

Commodore's commercial L1200 liquid unit is shown in Figure I.



This system consists of a sodium transfer station, which warms sodium cast in shipping drums to a liquid state, and then pumps the liquid to the solvator tank. This tank is filled with anhydrous ammonia from an ammonia storage tank. The sodium dissolves in the ammonia creating a solvated solution. This solution is discharged to a reactor vessel, where a volume of approximately 65 gallons of the solvated solution is maintained.

Contaminated liquid is pumped to the reactor vessel where organics are instantly destroyed. The conductivity of the solution in the reactor vessel is continuously monitored, and when it drops to 200 Mhos feed is stopped. The destruction reaction is very fast and is essentially diffusion controlled. Removing ammonia vapor controls the temperature and pressure of the vessel. This results in lowering the temperature of the vessel. The feed rate for this system is approximately 1,600 pounds of material per day.

Oils such as contaminated transformer and cutting fluids can be readily detoxified using SET™ in Commodore's L-1200 system. This is a liquid unit, which requires the ability to pump the material to be treated. Oils containing over 20,000 ppm of PCB have been detoxified to below 0.5 ppm PCB. Table I lists data for destruction of PCBs in oils.

Table I Destruction of PCBs in Oils		
Material	**Pre-Treatment (ppm)**	**Post-treatment (ppm)**
Used Motor oil	23,339	<1.0
Transformer oil	509,000	20*
Mineral Oil	5000	<0.5
Hexane	100,000	0.5
*Sodium feed was deficient. Can be improved by using additional sodium.		

Based on the Vendor's the above data demonstrates the effectiveness of the SoLV™ process in destroying hazardous organic materials. The SoLV™ process is very versatile and adaptable to a broad range of remediation situations.

The process is non-thermal. Most reactions are conducted at 40 degrees F or below. These low temperatures protect against volatile emissions. The destruction process is carried out in a totally closed system. Even the ammonia that is vented when reactors are opened is captured by a scrubber and returned to the reactor during the pH adjustment. During this process, the ammonia is released for reuse. Minor amounts of hydrogen generated from catalytic sodium degeneration are vented through the scrubber system. Volatile hydrocarbons, that may be formed, are condensed and available for fuel use.

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One distinguishing feature of the SoLV™ process is that no portion of the original molecule is discharged to the atmosphere or to water. The process is reductive in nature and therefore not capable of forming dioxins or furans and similar wastes, which can be found in oxidizing technologies. This is especially beneficial, because communities are becoming increasingly watchful of waste facilities as concerns mount over particulate material that is released to the atmosphere and surrounding water.

The end products from the SoLV™ process are principally metal salts such as sodium chloride and hydrocarbons. The product streams are not classified as RCRA hazardous and they pass all of the hazard criteria identified in USA 40 CFR 261.21 through 40 CFR 261.24.

The only raw materials needed for the process are ammonia, sodium, and a neutralizing acid such as sulfuric acid. All of these reactants are commodity chemicals.

When considered in light of other process available, the hardware required implementing the SoLV™ process is simple and compact. All process equipment is off the shelf and engineered to be mobile. Destruction can take place at the site without the cost associated with transporting hazardous cargo.

The Solvated Electron Technology can be licensed from Commodore Applied Technologies Inc. from the USA.

Other non-combustion technologies such as Gas Phase Chemical Reduction (GPCR) and Plasma Arc Technologies were not included in this study, as when applied to PCB contaminated mineral oil, both of these processes destroy the mineral oil matrix as well.

3. Conclusions

UNIDO's proposal for the provision of technical assistance to public and private sector by establishing a transformer dismantling facility and a PCB contaminated mineral oil dechlorination plant in Morocco is an environmentally and economically sound options for the disposal of PCB wastes in the country. This option provides a long-term PCB management solution to Moroccan PCB needs, creating local disposal alternatives with the creation of local jobs and the recovery of precious commodities such as mineral oil and copper and steel from PCB contaminated transformers.

The technologies outlined in this study, namely the Based Catalyzed Dechlorination, Sodium-Based Processes and the Solvated Electron Technology represent sound, proven dechlorination alternatives that can be adopted and implemented in Morocco.

The existence of nearly 13,000 metric tons of PCB contaminated mineral oil in Morocco and this GEF co-financed project represent a significant market opportunity for technology vendors to be interested in bringing their technology to Morocco. This market can be complemented by the potential excursion of the technology vendors to neighbouring countries.

ANNEX E ETUDE DE FAISABILITE DE L'ELIMINATION DES PCBS ET LEUR DECHETS AU MAROC

Table of content

0 Liste des abréviations

POP	: Polluant organique persistant
DE	: Département de l'Environnement
CS	: Convention de Stockholm
MTD	: Meilleures techniques disponibles
MPE	: Meilleures pratiques environnementales
ONE	: Office national d'électricité
PCB	: Polychlorobiphényles
RTM	: Radiotélévision marocaine
PNUD	: Programme des nations unies pour le développement
DGCL	: Direction Générale des Collectivités Locales
PNM	: Plan National de Mise en œuvre
CPG	: Chromatographie en phase gazeuse
ONEP	: Office national de l'eau potable
UATRS	: Unité d'appui technique à la recherche scientifique

1 Contexte de l'étude

Les PCBs, dont le danger a été démontré par les scientifiques, sont des substances toxiques persistants dans l'environnement. Ils ont la particularité de résister aux dégradations biologiques classiques, de s'accumuler dans les tissus vivants et de se déplacer sur de longues distances.

Pour cerner leur problématique, la communauté internationale élaboré deux traités internationaux que sont La Convention de Stockholm et le Protocole d'Aarhus. Ces traités visent la réglementation et la gestion écologiquement durable de l'élimination, la production et l'utilisation des POPs. Parmi les POPs existants, une liste de 12 familles/classes/catégories de produits chimiques reconnus comme les plus dangereux, a fait l'objet de ces traités. Elle est composée de huit pesticides chlorés, deux familles de produits chimiques industriels dont les polychlorobiphényles (PCBs) et de dioxine/furanes chlorés, sous-produits générés lors des processus de combustion et d'incinération.

Le Royaume du Maroc fait partie des pays signataires de la convention de Stockholm et vient de la ratifier très récemment courant mai 2004. Pour respecter les dispositions de cette convention, il se doit de mettre en place des moyens de prévention et de gestion écologique des POPs.

Le respect des dispositions de la convention de Stockholm réside aussi dans l'aptitude de des institutions et leurs cadres à suivre et appliquer le PNM. Dans ce cadre, s'inscrit la présente étude qui vise deux parties distinctes : la faisabilité d'élimination des PCBs et leurs déchets ainsi que le traitement des sols contaminés par les POPs.

2 Approche suivie pour l'élaboration de l'étude

La réalisation de cette étude a été accomplie conjointement avec des missions d'experts internationaux. Durant leurs missions, l'expert national s'est attelé a collecté les informations nécessaires à la réalisation de sa mission et la facilitation des contacts pour les besoins des experts internationaux. Ainsi, le cheminement des travaux a suivi les étapes ci-après :

- Visites de certains sites
- Visites d'opérateurs en lien avec les PCB
- Suivi, facilitation pour les analyses d'huiles minérales
- Elaboration de l'étude de faisabilité
  - Circuit et inventaire des PCBs, sols et déchets
  - Technologies disponibles
  - Meilleures technologies pour le Maroc
  - Analyse des coûts
- Références consultées
- Personnes contactées

Le contenu et le détail de chaque rubrique, sont donnés ci-après.

3 Généralités sur les PCB[6]

Les PCB sont des composés ayant une structure biphényle, c'est-à-dire deux noyaux benzéniques liés entre eux, qui sont chlorés à un degré variable. Il existe théoriquement 209 congénères.

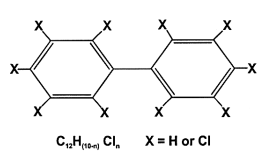

Figure 1: structure générale des PCB

[6] Renforcement des capacités nationales pour la gestion de POP au Maroc, MATEE-PNUD, EDIC-2004

La stabilité chimique de ces produits constitue leur principale qualité sur le plan commercial, cette stabilité a néanmoins généré un réel problème environnemental à cause de leur extrême rémanence dès le moment où les PCB sont émis dans l'environnement. En fait, les PCB sont parmi les polluants les plus largement répandus, ayant été détectés dans pratiquement tous les milieux environnementaux et ceci pratiquement à l'échelle planétaire.

La production industrielle des PCB a été arrêtée, depuis 1983, dans la plupart des pays. On admet qu'on a produit dans le monde entier entre 1,5 et 2 millions de tonnes de PCB.

Les diélectriques chlorés contiennent généralement de 40 à 60 % de PCB et 40 à 60 % de TCB (Trichlorobenzène qui est le solvant du PCB).

Les PCB continuent à être largement utilisés et couvrent divers domaines d'application. Le tableau suivant présente les systèmes contenant les PCB selon que leur présence se situe dans des systèmes fermés, partiellement fermés ou ouverts. Ces désignations se réfèrent à la facilité avec laquelle les PCB contenus dans un produit peuvent contaminer l'environnement.

4 Les PCB au Maroc

Selon les données disponibles, depuis près d'une décennie, les PCB se trouvent au Maroc dans les appareils électriques, notamment les transformateurs, les condensateurs ou sous la forme de déchets (analyses, chiffons, etc.).

Les besoins en appoint des huiles de transformateurs, fait que de nombreux stocks ont été mis en évidence comme à Tanger et chez la Cotef à Fès.

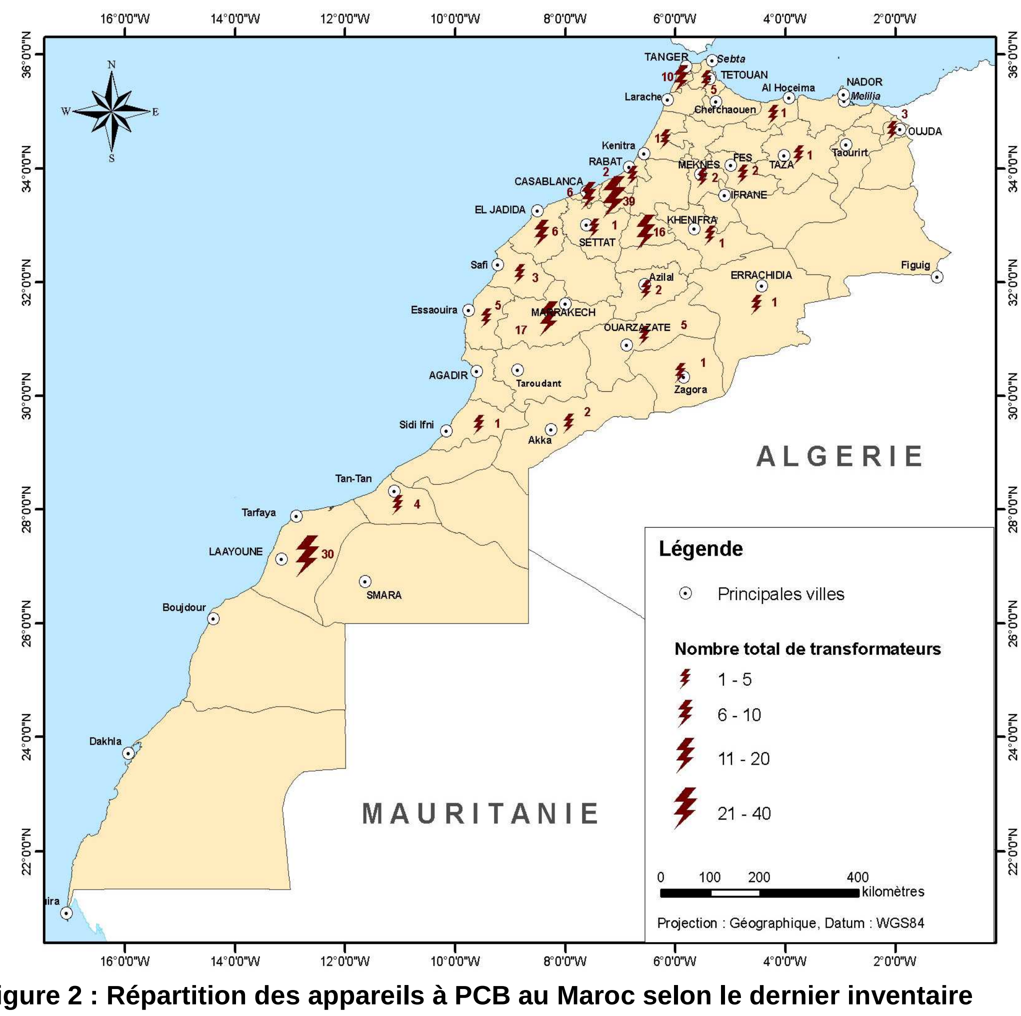

Figure 2 : Répartition des appareils à PCB au Maroc selon le dernier inventaire

A part ce circuit, bien connu, les PCB se sont disséminés dans l'environnement national par les mécanismes et vecteurs classiques, à savoir l'eau, les sédiments, l'air et la chaîne trophique. La carte ci-après[7] illustre la densité en appareils électriques contenant des PCB, telle que cela émane des différents inventaires réalisés.

Il apparaît que la plupart de ces appareils contenant des PCB sont situés dans la partie nord du Royaume, avec une forte densité, bien nette dans la région du Grand Casablanca. Cette densité s'explique par la densité de l'activité industrielle dans cette zone.

5 Toxicité des PCB

Les effets toxiques des PCB sur l'être humain augmentent avec le taux de chloration et les produits d'oxydation, qui peuvent être beaucoup plus toxiques que les PCB eux-mêmes. Les intoxications par contact cutané et par ingestion peuvent avoir des effets très graves, en particulier sur le foie et le système enzymatique. En cas d'intoxication chronique, les symptômes habituels sont les suivants: nausées, vomissements, perte de poids, oedèmes et douleurs dans le bas-ventre.

Ainsi, les PCB sont bien résorbés par les voies digestives, mais également par la peau et les poumons, ils se répartissent rapidement dans le corps et s'enrichissent dans les tissus adipeux. L'absorption de grandes quantités, conduit à des maladies aiguës de la peau (acné chlorée, pigmentations de la peau et ongles, perte de cheveux), causent des dommages au foie, à la rate et aux reins et affaiblissent le système immunitaire.

6 Visites de sites contenant des appareils à PCB

Afin d'appréhender les différents volets de la faisabilité de décontamination des sites pollués et ceux contenant des PCBs, une mission a été menée conjointement avec des experts internationaux, dans le cadre de cette étude. Les institutions et les sites visités sont déclinés dans le tableau suivant.

Tableau 1 : Visites réalisées dans le cadre de l'étude

Institution/site[8]	Objectif de la visite
Site de l'ex voix de l'Amérique	Prospection du site et des déchets contaminés par les PCB
Sites des ferrailleurs de Tit Mellil	Appréhender l'ampleur des contaminations
Décharge de Mediouna	Localisation des récupérateurs de produits potentiellement contaminés
Holcim/écoval	Discussions avec les responsables de ces unités industrielles sur la possibilité d'élimination des sols contaminés
Oksa Maroc	Informations sur le niveau de contamination observé
Ateliers marocains-Bouskoura	Capacités d'intervention dans le démantèlement des transformateurs
Altair Maroc	idem
Univers électrique	idem
Nitham	Idem
ONE	Disponibilité à réaliser des analyses des huiles minérales

[7] Inventaire des PCB au Maroc, DSPR, 2007
[8] sont répertoriés uniquement les visites auxquelles l'expert national a assisté

De ces visites, il a été possible de palper le niveau de sensibilité des différents maillons de la chaîne de gestion des PCB au Maroc, ce qui permet d'anticiper sur les chances de réussite des actions préconisées dans la suite de cette étude de faisabilité.

7 Campagne d'analyse des transformateurs à huile minérale

L'étude de faisabilité pour l'élimination des PCB de l'environnement national a besoin, pour plus de pertinence d'une analyse représentative des appareils théoriquement saints sur l'ensemble du territoire. Ceci permet de planifier les moyens de transport et d'analyse de ces appareils et analyser les coûts de leur décontamination.

Pour y aboutir, nous avons planifié une campagne d'analyse pour 125 appareils électriques choisis arbitrairement. Ces analyses sont confiées à SD Myers, assisté par l'expert national dans la mobilisation des détenteurs et l'explication de la finalité de ces analyses.

A la finalisation de la présente étude, la campagne d'analyses n'est toujours pas achevée. On se contentera donc des informations fournies par Oksa Maroc sur le taux de contamination en se basant sur des appareils que ce Laboratoire a analysés de manière aléatoire au grès des demandes des clients. Le taux de contamination annoncé est de l'ordre de 16-22%.

Les détenteurs visés par les analyses dans le cadre de la campagne généralisée sont donnés ci-après. Les échantillons pris sont donnés en annexe.

Casablanca et environs (70[9])

Mohammadia

- ONE – centrale thermique (5)
- Lydec (10)
- Lessieur Ain Harrouda (2)
- Samir (2)
- SNEP (2)

Mediouna

- Lydec (5)

Bouskoura

- Ateliers (1)
- ST Microelectronics (2)

Berrechid

- ONE (10)
- Settat
- ONE (10)
- Settavex (2)
- Roca (2)
- Cristal Strass (2)
- ONEP forages (3)

[9] nombre de transformateurs

Casablanca

- BIMO (2)
- Cosumar (2)
- Coats (1)
- Colorado (2)
- Prodec (1)
- Leader Food (2)
- Lessieur Roches noires (2)
- Rabat et ses environs (10)
- Atlantic de Nimes Bouknadel (1)
- Atlantic confection Takkadoum (1)
- Ateliers de lingerie Takkadoum (1)
- Top Wash (Salé) (1)
- Base aérienne de Salé (4)
- Mocary (salé) (1)
- Legler (Skhirat) (1)
- Kénitra (5)
- Base aérienne de kénitra (5)
- Rak (3)
- Centrale thermique (2)

Tanger , Tétouan et leurs environs (20)

- Amendis (10)
- Société Lukus-Larache (2)
- Jacob de Lafont (2)
- Fromagerie (zone industrielle Moghogha) (1)
- Colainord – Mdiq (1)
- CIF-Tanger (1)
- Daher –Tanger free zone (1)
- Aéroport boukhalef (2)

Marrakech et ses environs (20)

- Conserveries Carrier-Saada-Marrakech (1)
- Radeema (10)
- Forages ONEP et champs captant de la région de Marrakech (2)
- Aéroport de Marrakech (2)
- ONE et environs de Marrakech (5)

Les détenteurs ont été choisis de sorte à représenter la densité des appareils à PCB, telle qu'elle est identifiée lors des précédents inventaires (2001, 2004 et 2007).

8 Faisabilité de l'élimination des PCBs du Maroc

L'étude de faisabilité développée dans le présent document cherche à répondre aux questions suivantes :

- Sous quelles formes existent les PCBs au Maroc ?,
- Où sont ils concentrés ?
- Comment évaluer leurs gisements ?
- Quelles technologies sont elles disponibles ?
- Quelles sont les meilleures technologies pour le Maroc ?
- Quelle capacité nationale pour l'élimination ?
- Quel est le coût d'élimination ?
- Quels risques et impacts présentent l(a)es variante(s) choisie(s) ?

Formes identifiées, des PCBs au Maroc : Circuit et inventaire des PCBs, sols et déchets

PCBs dits purs : Les PCBs ont fait l'objet de trois inventaires, en 2000-2001, 2004 et 2007. Ces trois inventaires ont montré successivement une diminution des appareils à PCB au Maroc, du fait de leur élimination par les détenteurs. Les plus actifs d'entre eux, ont été l'OCP, l'ONEP, la Lyedc, les ports et certains opérateurs industriels. Il n'en reste pas moins que de nombreux sites de détenteurs dont l'armée de l'air et le site de l'ex voix de l'Amérique reste truffés d'appareils électriques contenant des PCB purs dont les plus importants sont le pyralène et l'Askarele.

Comme données de base pour la réalisation de l'étude de faisabilité, nous avons repris les données actualisés et disponibles au niveau de la DSPR[10]. Ainsi le gisement des appareils et déchets contenant des PCBs en forte concentration, sont :

- Transformateurs : 371 (dont 224 t de PCB) et 447 t de déchets solides (ferraille, bois, céramiques, etc.)
- Condensateurs : 394 unités (dont 2,5 t de PCB)
- Autres équipements à PCB : 129 tonnes (49 t PCB)
- PCB en vrac : 5,6 tonnes

La répartition de ce gisement (graphique ci-après) montre que le secteur industriel domine en termes de nombres de détenteurs, suivi par les administrations.

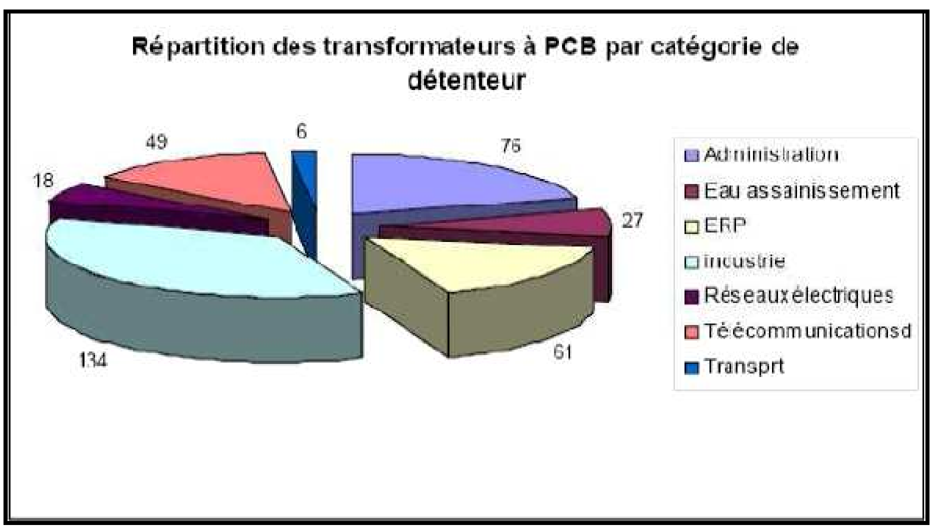

Figure 3 : Répartition des appareils à PCB selon le type de détenteurs

[10] DSPR : Direction de la Surveillance et de la Prévention des Risques, MEMEE

La répartition des appareils électriques identifiés lors du premier inventaire montre que le gisement des PCBs purs est concentré dans un rayon de 100-150 km autour de la région du Grand Casablanca. Environ un cinquième des appareils se trouve entre Kénitra et Tanger et près de 10% dans les villes de Sidi Slimane, Fès et Meknès.

Suite aux dernières vagues d'élimination des PCB, on peut affirmer que les zones qui demeurent les plus truffées en appareils sont Kénitra-Sidi Slimane-Meknès et Tanger. Ce sont l'armée de l'air et la RTM qui seraient les plus importants détenteurs au Maroc.

Huiles et déchets contaminés par les PCBs

La manipulation, sans précaution des transformateurs saints, finit par les contaminer. Deux inventaires (2001 et 2004) ont estimé le potentiel en huiles minérales qui seraient contaminées par les PCB. Le premier inventaire, réalisé par la DSPR[11] dans le cadre de la coopération Suisse a estimé le taux de contamination des appareils à PCBs à 20-25%[12]. Cette information a été confirmée dans le cadre du second inventaire.

Ce taux a été confirmé lors des investigations dans le cadre de la présente étude de faisabilité. Le laboratoire Oksa Maroc nous informé d'un taux de contamination de 16-22%, sur la base des analyses qu'il a réalisé de manière aléatoire, sur un échantillon de près de 200 appareils.

L'inventaire réalisé en 2004, a mentionné un potentiel de 3000 tonnes d'huiles sur la base d'un taux de contamination de 20%. Le dernier inventaire en date (2006-7) a confirmé ce potentiel et a conforté la possibilité d'un gisement plus conséquent de 15 000 t en raison des données sur le degré de contamination de certains parcs de transformateurs comme celui de l'armée de l'air et dans els régions lointaines (en montagne par exemple). En effet, lors des séminaires de sensibilisation aux nuisances des PCB, SD Myers avait rapporté un taux de contamination de près de 50% dans un lot d'appareils analysés à Layoune et Tan Tan.

L'étude de faisabilité, dans la suite du document, se focalise sur le potentiel de 3000 t, consolidé par les deux derniers inventaires et que nous considérons comme tranche prioritaire.

Déchets et sols contaminés par les PCB

La mauvaise gestion des appareils à PCB et la mauvaise maintenance de ces équipements, génèrent des déchets contaminés.

Tous les inventaires réalisés sur les PCBs ont mis en évidence des déchets contaminés, dans certains sites, comme celui de Tanger (RTM) ou à la COTEF à Fès. Ces déchets sont en général des chiffons ayant servi à la maintenance ou des emballages contaminés par les PCB. Ainsi, le site de Tanger abrite du bois, des carcasses de transformateurs et de la ferraille contaminée. Le sol du même site et ceux d'autres détenteurs de transformateurs sont contaminés par les pertes en huile-PCB. Ceci provient dans la plupart des cas de l'absence de bacs de rétention protégeant le sol.

En conclusion, le gisement disponible, qui fera l'objet de l'étude de faisabilité comprendra :

- Des appareils à PCB pur et leurs déchets
- Des huiles contaminées

L'élimination de chaque type de PCB sera étudiée à part, l'interaction entre les deux parties sera étudiée dans le but de réduire les coûts d'élimination.

Analyse des contraintes et la fiabilité du gisement, objet de l'étude

Le gisement des appareils à PCBs et leurs déchets est relativement bien cerné, eu égard aux différents inventaires et estimations réalisés. Les déchets et les sites contaminés ne sont pas encore connus dans leur majorité, mais ils ne font pas l'objet de la présente étude.

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[11] réalisé par EIT et Dr Zakarya
[12] information obtenue auprès de Oksa Maroc

La concentration de la plupart des détenteurs dans la partie nord du Royaume est plutôt un facteur favorable à la décontamination à moindre coût. Cependant, la décontamination à moyen et long termes, concernera l'ensemble du territoire, en raison de l'électrification généralisée. On doit donc s'attendre à analyser des transformateurs dans différentes localités plus ou moins faciles à d'accès comme les zones montagneuses.

Comme autre facteur favorable à la décontamination, il y a le fait qu'à part les grandes villes du Royaume dont les opérateurs de l'électricité sont des régies ou des sociétés privées, le reste du territoire est géré par l'office national d'électricité (ONE). Il constitue le seul interlocuteur des opérateurs dans le cadre du projet d'élimination.

Analyse comparée des MTD[13] et MPE[14] et faisabilité pour le Maroc

L'élimination des PCBs du territoire national passe par leur identification, leur collecte, transport et suivi de leur élimination. Sans la maîtrise de chacune de ces tâches, le projet sera handicapé dans sa globalité et ne mènera pas aux objectifs escomptés, notamment l'impact environnemental positif.

Analyse du degré de contamination des appareils saints

Les taux de contamination actuellement disponibles permettent d'appréhender le gisement en huiles contaminées. Cependant, lors de la mise en œuvre du projet de décontamination, on aura besoin d'analyser systématiquement tous les appareils existants, soit près de 80 000 unités[15]. Le coût estimatif pour l'analyse de ce parc d'appareils avoisinerait les 24-48 Millions de Dhs[16].

Une enveloppe budgétaire de 24-48 Millions de Dhs est à prévoir pour les analyses

Cette enveloppe budgétaire peut être revue à la baisse si les analyses sont réalisées au Maroc.

Prestataires d'analyse, privés

Les capacités nationales en matière d'analyse des PCBs ne posent pas de problèmes au Maroc. Il existe des Laboratoires spécialisés dans de telles analyses mais leur nombre demeure limité. On a identifié uniquement :

- Oksa Maroc et
- SD Myers
- Apave

Les trois opérateurs sont des représentations de sociétés étrangères, ils se contentent en général du prélèvement des échantillons. Les analyses sont réalisées à l'étranger (en France pour l'Apave et Oksa Maroc et au Canada et USA pour SD Myers).

L'inconvénient que cette situation représente est un coût d'analyse élevé par rapport à des analyses de pesticides par exemple, considérés similaires du point de vue moyens analytiques.

Laboratoires publics

Il existe au Maroc des laboratoires nationaux dont les capacités d'analyse ont été mises à niveau dans le cadre des actions précédemment menées pour la gestion des PCB. Il s'agit de :

- L'institut d'hygiène
- Le Laboratoire National de l'Environnement
- Le Laboratoire de la Gendarmerie Royale (LARATES)

Selon notre appréciation, les trois laboratoires sont capables et prêts à participer aux analyses prévisibles dans le cadre de la décontamination des huiles minérales.

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[13] MTD : meilleures techniques disponibles
[14] MPE : Meilleures pratiques environnementales
[15] Source : inventaire des PCB au Maroc, DSPR, 2007
[16] Source : Oksa Maroc et SD Myers, coût variant de 300-600 Dhs/échantillon

Précision des analyses

Jusqu'à présent le niveau de contamination a été analysé sur la base du seuil des 50 ppm requis dans le cadre de la convention de Stockholm.

Pour la faisabilité de l'élimination des PCBs au Maroc, l'analyse devra être quantitative. En effet selon la concentration en PCBs dans les huiles minérales, plusieurs techniques de décontamination sont disponibles.

La campagne d'analyse en cours permettra de fournir cette réponse pour le gisement des appareils contaminés au Maroc. Nous supposons, pour l'état actuel que le niveau de contamination est légèrement supérieur à 50 ppm.

Méthodes d'analyse

Plusieurs techniques d'analyse existent et sont éprouvées. Celle qui devra être utilisée pour l'estimation des huiles contaminées devra être basée sur le principe de la chromatographie, en raison de sa spécificité aux congénères des PCBs. La méthode basée sur la déchloration du PCB par le sodium est rapide et moins coûteuse, mais présente l'inconvénient d'être qualitative et peut être faussée en cas de présence de dérivés chlorés (pentachlorophénol).

$$R\text{-}Cl + Na \rightarrow NaCl + R$$ [17]

Déchets des analyses

Les analyses des huiles contaminées génèrent des déchets, minimes mais certainement importants en nombre et en degré de contamination.

A titre d'exemple, l'analyse des 80 000[18] appareils électriques au niveau national, génèrera 80 000 échantillons qui deviennent des déchets solides à éliminer par la suite pour ceux déclarés contaminés, soit environ 16000 échantillons. Si le poids de chacun est de 50 g (huile résiduelle + emballage). On doit s'attendre à une quantité de déchets d'environ 800 kg.

Collecte et transport des appareils à PCBs

Le démantèlement, la collecte et le transport des PCBs purs devront suivre des pratiques propres de la part des opérateurs à qui sera cédé le marché. Ces opérateurs devront suivre les consignes précisées dans le cadre du plan national d'action, élaboré dans le cadre de l'inventaire réalisé en 2000-2001.

Dans le cadre de ce plan, il a été préconisé que le démantèlement des appareils par un personnel qualifié et muni d'un équipement spécialisé. Les appareils sont transportés dans des bacs de rétention ou des containers jusqu'à la plateforme de démantèlement final.

Le nombre et la localisation des appareils contenant des PCBs sont connus (carte présenté précédemment). Par conséquent, leur coût de transport sera maîtrisé avec précision si on suppose que la plateforme de traitement sera installée dans la région du Grand Casablanca.

Le linéaire total requis pour le transport de ces appareils est estimé en se basant sur l'hypothèse que les appareils sont transportés chacun à part.

Concernant les appareils contaminés, on supposera également qu'un linéaire unitaire sera affecté à chaque appareil. Ce linéaire sera parcouru par le véhicule mobile de décontamination en cas du choix de ce type de ce scénario ou par un camion transportant le transformateur jusqu'au lieu de la décontamination. En absence de détails sur la répartition des appareils contaminés au niveau national, on considérera les hypothèses vraisemblables suivantes :

- Le nombre d'appareils contaminés est d'environ 3000 unités, sur la base d'un potentiel de 3000 tonnes d'huiles contaminées ;

[17] Radical chimique représentant le squelette du biphényle
[18] Estimation dans le cadre de l'inventaire des PCB, DSPR-PNUD, 2004

- 50% des appareils contaminés sont situés dans un rayon moyen de 50 km de Casablanca
- 25% des appareils sont situés dans un rayon de 150 km de Casablanca
- 25% des appareils sont situés dans un rayon de 300 km de Casablanca

Partant de ces hypothèses, les frais de transport seraient de l'ordre de 825000 Dhs. Le transport des appareils à PCBs purs s'élèverait à 137 700 Dhs.

Les détails de ces coûts sont donnés en annexe.

Plateforme de traitement

Il est prématuré de choisir le lieu de traitement en absence d'un montage technique et le choix des variantes de traitement. Cependant, il est judicieux pour le choix des variantes de connaître les possibilités offertes au niveau national et supportables économiquement.

Dans ce sens, la rencontre des opérateurs dans le domaine de l'élimination des déchets a permis de noter que certains d'entre eux comme Altair Maroc, Nitham, Univers Electrique sont intéressés pour mettre en place une plateforme d'élimination. A ceux la, il y a lieu d'ajouter Maroc Transfo qui disposait d'une plateforme à moitié réalisée.

Tous ces opérateurs sont situés dans la zone du Grand Casablanca ou El Jadida.

Comme autre possibilité, envisageable, il y a les installations du CNEDS[19] qui devraient se situer également dans les environs du Grand Casablanca, pour des raisons de coût de transport.

En cas de manifestation d'intérêt, certains cimentiers peuvent aspirer à l'élimination des PCBs, de nombreuses unités sont localisées sur l'ensemble de la partie nord du Royaume.

Technologies disponibles pour l'élimination des PCBs[20]

Le recensement des meilleures techniques disponibles et des meilleures pratiques environnementales permet d'évaluer le niveau de gestion des PCBs pour un pays. En effet le niveau de ces deux profils conditionne, l'état de l'environnement. L'absence de bonnes pratiques environnementales et des meilleures techniques disponibles conduit à coup sûr à la dissémination des PCBs dans l'environnement.

Le renforcement des capacités en MTD et MPE et leur adaptabilité constitue une action importante dans la mise à niveau pour une gestion écologique des PCBs.

La convention de Stockholm a défini les PCB en différentes catégories en fonction de la teneur en PCB (voir tableau ci-après).

Tableau*: Niveaux de contamination des transformateurs à PCB*

1	Non PCB	Huile minérale	PCB < 50 ppm
2	Contaminé PCB	Huile minérale	50 ppm < PCB < 500 ppm
3	PCB	Huile minérale	> 500 ppm

La répartition des transformateurs par types de diélectrique et de niveau de contamination par les PCB est explicitée dans le diagramme ci-dessous. Les transformateurs contenant des PCB sont, soit des transformateurs à huiles minérales contaminées par les PCB, soit des transformateurs 100% diélectrique chloré.

[19] cneds : centre national d'élimination des déchets spéciaux
[20] Document rédigé initialement par Dr Zakarya, repris dans le cadre de cette étude et dans le cadre de l'étude du renforcement des capacités nationale en matière de gestion des POPs, MATEE-PNUD, 2003

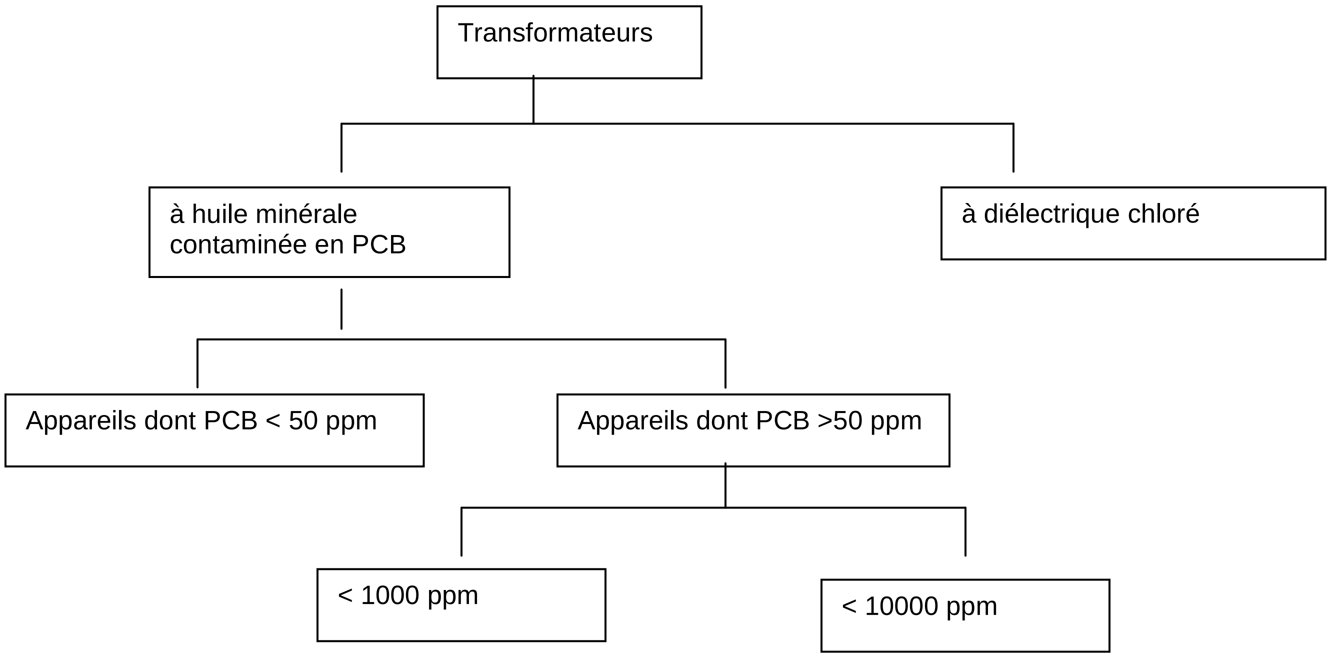

Figure 4 ***: Différentiation des transformateurs selon leur degré de contamination par les PCB***

Le niveau de contamination des transformateurs à huile minérale se situe généralement entre 50 et 10 000 ppm[21].

Les sources de contamination proviennent notamment :

- des fabricants qui ont utilisé les mêmes équipements de remplissage des appareils
- des opérations de mise à niveau avec du PCB (cas assez rares)
- des opérations de régénération de diélectrique utilisant le même matériel pour les huiles minérales et les PCB.

Il est donc important d'introduire dans la classification nationale une classe supplémentaire : **Les éléments constitutifs d'un matériel électrique contenant des PCB**

Les transformateurs et les cellules peuvent être différenciés en fonction de la nature de leurs composants par rapport aux moyens de destruction :

1 - Les masses métalliques :

- la cuve du transformateur dont les parois internes sont traitées avec une peinture
- les radiateurs
- les tôles magnétiques
- les enroulements de cuivre enrobés de résines
- les roulettes

2 – les masses non métalliques solides

- les isolateurs en céramique

[21] Information obtenue auprès de Y. Guibert, expert en PCBs, dans le cadre du renforcement des capacités nationales, EDIC, MATEE-PNUD, 2003

- les bois de calage
- les papiers et cartons

3 – les masses liquides

- le diélectrique

Le récapitulatif de cette séparation est présenté dans le diagramme qui suit en distinguant dans un premier temps entre les transformateurs en activité, dont la réforme est prévue au plus tard en 2025, et les transformateurs réformés destinés à la destruction.

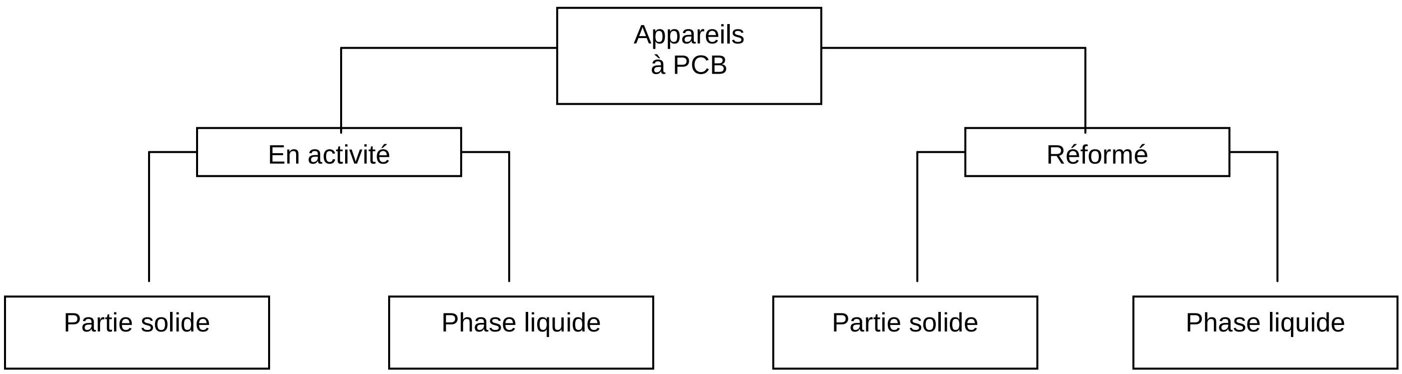

Figure 5 *: Différentiation des parties d'un transformateur*

Les technologies relatives au PCB sont spécifiques à chaque catégorie.

Traitement des transformateurs en activité

Le traitement d'un transformateur à PCB (pur ou contaminé) est généralement réalisé selon deux méthodes :

- le re-remplissage avec ou sans rinçage de la cuve et des composants internes et;
- la régénération de l'huile par traitement chimique en boucle fermée

Chacune de ces méthodes présente des avantages et des inconvénients mais le choix de l'une ou l'autre devra tenir compte de l'objectif quantitatif visé (teneur finale en PCB) et de la situation particulière du transformateur.

Les déchets solides

Les contraintes techniques de destruction ou de décontamination des parties « solides » sont liées à la nature des composants à traiter, que l'on peut distinguer selon le type de contamination :

- contamination surfacique concernant :
  - la cuve et les radiateurs
  - les tôles magnétiques
- contamination massique concernant :
  - les enroulements de cuivre
  - les bois de calage
  - les papiers et cartons

Les parties solides ayant une contamination surfacique peuvent faire l'objet d'un procédé de décontamination qui consiste à extraire les PCB de la partie surfacique par lavage en phase liquide ou en phase vapeur.

Les parties solides ayant une contamination massique peuvent être également décontaminés par procédé de décontamination (les bois de calage (imprégnation massive du bois) remplacés), mais aussi par décomposition thermique de la molécule PCB (pyrolyse ou incinération).

Ces procédés peuvent s'appliquer indifféremment aux transformateurs à huile minérale contaminée et aux transformateurs à diélectrique chloré.

Il est également nécessaire de prendre en compte des déchets solides contaminés massivement par des PCB tels que les bétons, les sols, les absorbants, chiffons, gants, et fûts métalliques ou plastiques.

Les déchets liquides

Les parties liquides doivent être traitées en fonction de leur teneur en chlore.

- les huiles minérales contaminées (< 10 000 ppm)
- les diélectriques

Elles peuvent être traitées :

- soit par décomposition thermique de la molécule PCB (pyrolyse ou incinération)
- soit par décomposition chimique de la molécule PCB et sa transformation en composants inorganiques

Les technologies de décomposition thermique peuvent s'appliquer à la fois aux huiles minérales contaminées et aux PCB.

Les technologies de décontamination chimique s'appliquent principalement aux huiles minérales contaminées (< 10 000 ppm)

De ce fait, la classification actuelle de Stockholm est insuffisante car elle ne fait pas de différence entre les diélectriques chlorés purs et les huiles minérales dont la teneur est supérieure à 500 ppm.

Le re-remplissage

Le transformateur est vidangé de son huile polluée sous atmosphère contrôlée (azote ou air très sec) pour éviter toute pollution de l'intérieur de la cuve et de l'huile neuve qui sera injectée, par l'air ambiant ou l'eau. L'huile vidangée sera, soit décontaminée par traitement chimique, soit détruite par incinération. La cuve du transformateur est soumise à égouttage pendant 1 à 3 jours. Ensuite, un rinçage de celle-ci et de tout matériel ou composant ayant eu un contact avec est effectué. Une fois ces opérations terminées, le remplissage avec une huile minérale neuve peut se faire.

Les intérêts de cette méthode de re-remplissage (en anglais retrofilling) sont multiples :

- Elle peut être réalisée sur site;
- Elle permet de traiter des appareils moyennement contaminés sans limitation de volume avec une simple vidange et un rinçage de la cuve. Un seul re-remplissage avec rinçage permet de diviser la teneur initiale en PCB au moins par 10. Cette loi empirique, mais généralement vérifiée, favorise donc l'application du re-remplissage à des appareils contenant jusqu'à 500 ppm de PCB pour les rendre conformes à la réglementation (< 50 ppm selon la convention de Stockholm) ;

Il s'agit d'une méthode simple et rapide à peine 5 jours et demi pour un gros transformateur contenant plusieurs tonnes d'huile:

- 1 jour pour la vidange et l'égouttage de l'huile polluée,
- 1/2 journée pour le rinçage et l'égouttage,
- 1 jour pour le remplissage de l'huile neuve et
- 3 jours pour régénérer l'huile neuve (traitement physique pour dégazer et déshydrater l'huile);

C'est une méthode qui peut s'avérer économique car le coût d'un re-remplissage est généralement moins élevé que celui d'un traitement par régénération, avec une durée de consignation du transformateur réduite par rapport à celle des autres méthodes.

La technique du re-remplissage présente, cependant, les inconvénients suivants:

- Doit être pratiquée sur ces appareils hors tension et consignés,
- Risque de pollution de l'huile neuve et des éléments internes (papiers et cartons) du transformateur en particulier par l'humidité ambiante lors de la vidange,
- Coût d'une charge d'huile neuve de l'élimination de huile polluée au PCB et éventuellement d'éléments internes pollués.
- Phénomène de relargage de PCB dans un transformateur après traitement:

Régénération par traitement chimique

Les réactions chimiques qui dégradent les PCB font intervenir des réactifs capables de déchlorer la structure organo-halogénée des PCB. Les produits de la dégradation chimique sont des sels chlorés. Ces produits sont classés comme Déchets Industriels Banals (DIB).

Deux systèmes réactionnels génériques ont été développés au stade industriel: le premier utilise un réactif à base de sodium métallique et le second un réactif d'hydroxyde de potasse associé à une résine glycol.

Le procédé utilise du sodium métallique comme réactif pour déshalogéner les huiles polluées par les PCB. Il nécessite des conditions d'utilisation assez strictes pour éviter tout risque d'explosion du réactif.

Le système résine-glycol est plus souple d'utilisation. Il a été développé pour dépolluer les huiles de transformateurs aux Etats-Unis, au Royaume Uni et en Italie; son intérêt réside dans la possibilité de dimensionner des unités de traitement mobiles et de dépolluer sur le site de l'appareil concerné.

Cette méthode permet de traiter des appareils très pollués jusqu'à quelques milliers de ppm en PCB) et de réduire très fortement la teneur initiale:

- on peut atteindre après traitement des valeurs de l'ordre de quelques ppm.
- Elle peut être réalisée sur site par une unité mobile autonome.
- Pas de vidange de la cuve du transformateur. Mais l'huile circulant à l'extérieur du transformateur dans les unités de chauffage puis de traitements chimique et physique, il faut s'assurer que celui-ci est toujours convenablement rempli d'huile.
- Pas d'huile polluée au PCB à éliminer et tous les produits issus de ces réactions de dégradation des PCB sont traités comme des déchets industriels banals (DIB).

Comme limitations de cette technique, il y a lieu de citer:

- Les opérations qui doivent être pratiquées sur ces appareils hors tension et consignés.
- La dépollution par déshalogénation-régénération d'un transformateur peut être une opération assez longue : un ou quelques jours pour le chauffage initial de l'huile du transformateur, plusieurs jours voire quelques semaines pour la régénération en

traitement continu de l'huile (souvent plusieurs cycles complets) et encore plusieurs jours pour le traitement physique (déshydratation, dégazage et restauration des qualités diélectriques) de l'huile dépolluée.

- Pour des volumes d'huile importants, les difficultés techniques s'accumulent (utilisation de plusieurs unités en parallèle...) si bien que le re-remplissage peut être préférable pour dépolluer de gros transformateurs peu contaminées, Toutes choses égales par ailleurs, le traitement par déshalogénation reste plus coûteux qu'un re-remplissage simple.

Le re-remplissage des transformateurs faiblement contaminés est intéressant dans le cas du Maroc en raison de son faible coût et du seuil de 50 ppm que préconise la convention de Stockholm.

retrofilling	déchloration	destructuion
<50 ppm	50-10000	>10000

Elimination des PCB (appareils réformés)

<u>Les condensateurs</u>

Les condensateurs sont composés d'un caisson métallique, d'un noyau et de diélectrique.

Le caisson métallique peut être traité séparément du condensateur. L'opération consiste à :

- ➢ Vidanger le condensateur de sa phase liquide par vidange gravitaire en pratiquant une ouverture à l'aide d'un outil à percussion mécanique. Cette vidange doit être effectuée à une température suffisante pour liquéfier le diélectrique.
- ➢ ouvrir le caisson par sciage à froid et extraction du noyau
- ➢ décontamination du caisson selon le même procédé que celui applicable aux cuves de transformateurs

Les céramiques doivent également faire l'objet d'un lavage même à titre préventif.

Les noyaux de condensateurs sont composés d'un enroulement de papier et d'un film de polyéthylène téréphtalate ou de feuille d'aluminium. Ces éléments sont massivement imprégnés de PCB. Ils peuvent être traités :

- ➢ soit par décontamination par extraction avec solvant dans un autoclave, ce qui permet de recycler l'aluminium électrolytique. Le résidu d'extraction contenant du solvant et du PCB peut être distillé pour recycler le solvant d'extraction
- ➢ soit par incinération après broyage et mélange avec d'autres déchets chlorés solides
- ➢ soit par distillation sous vide. Le distillat contenant du PCB peut être incinéré ou décomposé thermiquement

Le diélectrique PCB résultant de la vidange gravitaire peut être incinéré, par exemple.

Les opérations de séparation des éléments constitutifs des condensateurs et de vidange doivent être effectuées dans des conditions de rétention totale et sous régime d'autorisation au même titre que les cuves de transformateur

D'une manière générale, le démantèlement des condensateurs permet de réduire la quantité de matériaux à traiter par extraction et le transfert transfrontalier si ces matériaux sont traités dans des installations offshore.

Destruction par décomposition thermique

Incinération

L'incinération est la filière la plus utilisée et la plus développée industriellement. Elle traite toutes les formes de contamination, que les déchets soient liquides (PCB purs, huiles minérales), ou solides (carcasses et structures internes de transformateurs, de condensateurs, jeux de barre, terres contaminées).

Une température minimale de 1200℃ est nécessaire pour minimiser la formation de produits toxiques tels que les dioxines et furanes et un temps de rétention de 2 secondes au minimum dans la chambre de combustion des gaz.

L'huile polluée aux PCB doit être incinérée dans une usine agréée pour l'élimination des PCB. Cet agrément de l'installation implique le respect de contraintes très strictes, d'une part sur les fumées qui seront traitées et lavées pour éliminer les rejets toxiques et d'autre part sur les déchets solides (boues et cendres) qui sont conditionnées dans des fûts étanches. Ces derniers seront alors stockés, cas de la France, dans des centres d'enfouissement souterrains adéquats (il en existe une dizaine en France), les seuls autorisés à recevoir pour stockage des déchets hautement toxiques pour l'environnement.

Parmi les autres produits issus de la décomposition des PCB, on peut citer le chlore, principalement sous forme d'acide chlorhydrique qui peut être récupéré et valorisé, mais également sous forme moléculaire (très réactive).

Il est possible de recycler le cuivre et les différents métaux utilisés dans les matériels électriques grâce à des techniques de dépollution en autoclave avec des solvants qui seront ensuite incinérés.

Pyrolyse sous vide

La décomposition thermique se réalise sous forme d'aérosol submicronique et chauffage inductif sans oxygène à une température de 1 600 ℃. Le résidu final est un chlorure. Ce procédé peut être mis en œuvre sur des petites capacités et également sur des unités mobiles.

Destruction par voie chimique

Les procédés industriels les plus efficaces utilisent des réactifs organo-métalliques à base de sodium. Ils nécessitent tous des températures relativement élevées (entre 130 et 300℃) ainsi que la maîtrise rigoureuse de la teneur en eau et des risques d'incendie inhérents à tout système contenant du sodium métallique.

En France, les sociétés DAFFOS, BAUDASSE et LEMAHIEU utilisent cette technique pour dépolluer les huiles de transformateurs (procédé « Dégussa ») et les recyclent sur le marché des huiles neuves de qualité moyenne.

Destruction par voie physico-chimique

Bien que ces procédés ne conduisent pas à la destruction des PCB, ils sont importants car souvent impliqués dans une phase préliminaire à leur élimination.

L'approche la plus développée consiste à séparer les PCB des huiles minérales de transformateurs par extraction grâce à un solvant adapté (DMF[22], DMSO[23], CCl_4, ou le méthanol). Les PCB sont concentrés par distillation du solvant. La destruction des PCB peut alors intervenir sur des volumes plus faibles (par incinération...).

APROCHIM utilise un tel procédé de décontamination des huiles polluées jusqu'à 1000 ppm (avec du DMF); les PCB concentrés sont ensuite traités par ATOCHEM (incinération avec récupération du chlore).

[22] DMF : diméthyl formamide
[23] DMSO : Diméthyl sulfoxyde

On peut aussi laver en autoclave les parties métalliques des transformateurs grâce à des solvants et détergents et les recycler comme métaux, voire comme matériels électriques, « non PCB », Quant aux liquides utilisés, ils sont classiquement concentrés et incinérés.

Destruction par voie physique

Les procédés physiques développés pour éliminer les PCB ne sont pas à proprement parler des méthodes de destruction, mais souvent des technologies intermédiaires permettant de faciliter une destruction ultérieure, ou de stabiliser une pollution pour éviter sa dispersion au cours du temps. La dépollution de sols contaminés par des produits considérés comme PCB utilise de tels procédés. Parmi ces méthodes, la vitrification du sol contaminé utilise un courant électrique entre deux électrodes disposées dans le sol pour provoquer la fusion de celui-ci par effet Joule. Aux températures atteintes (environ 1700℃), les matières organiques présentes subissent une pyrolyse et diffusent vers la surface (où elles brûlent éventuellement). Le sol fondu refroidi forme un verre renfermant les cendres et autres matériaux non combustibles.

Les essais à l'échelle du laboratoire ont montré l'absence de PCB résiduels dans le bloc vitrifié et une très faible migration en dehors de cette zone. Les rejets atmosphériques en PCB sont relativement faibles, mais doivent être récupérés et filtrés.

Destruction par voie bactériologique

La dépollution sur place de sols contaminés par des PCB grâce à des micro-organismes est une technique très attrayante. Différentes souches de bactéries et champignons sont capables d'utiliser les PCB comme source de matière organique, tant en milieu aérobie (en présence d'oxygène) ou qu'en anaérobie (sans oxygène).

Les voies anaérobies sont plus efficaces sur les PCB fortement chlorés (et inversement pour les traitements aérobies). Le grand intérêt de cette technique est qu'en principe, si la dégradation est complète, les produits ultimes peuvent être simplement de l'eau et du dioxyde de carbone, le chlore étant incorporé dans les constituants naturels de la cellule.

Nous citons cette technique pour information uniquement car l'utilisation efficace et maîtrisée de ces micro-organismes pour la décontamination de sols n'est pas encore effective. Elle a été utilisée aux Etats-Unis pour la réhabilitation de sites et également en France

En conclusion, l'incinération est la technologie la plus largement disponible et utilisée pour la destruction des PCB et reste une solution ultime;

Bien que la décontamination de l'huile puisse être réalisée avec des technologies permettant la destruction complète des PCB, la carcasse des transformateurs et condensateurs peut présenter des problèmes à cause de la présence d'une petite part de matières poreuses, organiques, qui sont coûteux à traiter pour obtenir une décontamination complète.

Choix des MTD pour l'élimination des PCBs au Maroc et analyse comparative des variantes

Le diagnostic au niveau national, de l'emploi des meilleures techniques disponibles a révélé ce qui suit :

- Les PCB sont éliminés, par des sociétés locales ou étrangères, dans des incinérateurs étrangers en sous-traitance (France, Espagne, etc) à l'exception des huiles de transformateurs recyclées dans le circuit des huiles usées
- Il existe au niveau national des opérateurs privés en mesure de réaliser des analyses et le traitement chimique des huiles contaminés par les PCB (déchloration),
- Des opérateurs nouvellement installés au Maroc ont manifesté leur intérêt à promouvoir des technologies d'élimination éprouvées comme l'extraction par voie de solvant.

En partant du gisement actuel des PCBs au Maroc, les méthodes les plus adaptées à notre sens sont les suivantes :

Pour les PCBs purs et leurs déchets

Le tonnage actuel des PCBs purs est globalement faible (243 t) pour le montage d'un système de traitement dédié uniquement à ce gisement, auquel, il convient de soustraire les transformateurs de l'ONEP et de Cosumar qui sont en cours d'élimination[24].

L'élimination des PCBs purs va s'opérer dans le cadre du Pilier I, tel que décrit dans le cadre du projet élaboré par le PNUD. Partant de ce constat, il parait judicieux d'étudier deux variantes :

- Variante 1 : Elimination des appareils à PCBs purs, en entier
- Variante 2 : Démontage des appareils, élimination par destruction des PCBs à l'étranger et valorisation de la carcasse au Maroc

Une analyse comparative de ces deux variantes est donnée ci-après :

Tableau 2 : Analyse comparative sommaire des coûts de l'élimination des appareils à PCB dans le cadre du Pilier I

Désignation	PU/t	Quantité	S/ total en Dhs HT
Variante 1			
	10000	690	- 6 900 000
		Total	- 6 900 000
Variante 2			
Elimination des PCB purs	20000[25]	243	- 4 860 000
Valorisation de la carcasse (7% en cuivre)	13000	31,29[26]	+ 406 770
Elimination des déchets contaminés	20000	31,29[27]	- 625 800
Valorisation de la ferraille	1000	379,95[28]	+ 379 950
		Total	-4 699 080

Si on se base uniquement sur les coûts d'élimination par des opérateurs, il apparaît clairement que la variante 2 est favorable. Cette variante consiste à démonter les appareils au Maroc, puis valoriser les déchets métalliques au niveau national. Ceci nécessite en effet la mise en place d'une plateforme de démontage dont l'amortissement peut être fait en opérant sur les transformateurs contaminés. Le coût de cette plateforme est détaillé ci-après avec un budget d'investissement pour sa mise en place et un coût de fonctionnement.

Conception de la plateforme de démontage des transformateurs

La plateforme de démontage des transformateurs est réduite à :

- Une zone de stockage des appareils réceptionnés ;
- Une plateforme de démontage et de récupération parties séparées

[24] marchés en cours d'adjudication
[25] coût d'élimination doublé par rapport au coût d'élimination actuels du marché, pour des appareils entiers
[26] estimé sur la base d'un taux de cuivre de 7% (scénario défavorable)
[27] estimés à 7% du total de la carcasse du transformateur
[28] Masse restante : 86%

- Un bureau
- Un local de contrôle
- Des moyens de manutention, notamment un plan et un élévateur hydraulique
- Des outils

La dalle de la plateforme sera bétonnée pour éviter des infiltration ou une contamination du sol ou des eaux. La zone de démontage sera munie d'un bac de rétention.

L'ensemble de l'enceinte comprendra un hangar, une clôture en aggloméré et des soutènements en béton et un portail.

Compte tenu du nombre relativement faible de transformateurs, nous prévoyons un personnel se limitant à :

- Un gardien
- Deux mécaniciens
- Deux ouvriers
- Un responsable de la plateforme

La superficie totale retenue est de 2400 m2.

Un plan et un bordereau estimatif des prix de réalisation de la plateforme sont donnés ci-après.

Tableau 3 : Bordereau des prix pour la réalisation de la plateforme de démontage

N°	Désignation des prestations	Unité	Quantité	Prix U HT	Prix Total en Dhs
1	Terrassements en pleine masse dans tout terrain	M3	480	30	14 400
2	Fouilles en puits ou en rigoles dans tout terrain sauf rocher	M3	387	35	13 545
3	Fouilles dans le rocher	M3	194	60	11 640
4	Béton de propreté 0,1 d'épaisseur	M3	85	35	2 975
5	Remblaiement ou évacuation à la décharge	M3	866	20	17 320
6	Maçonnerie de moellons en fondations	M3	954	50	47 700
7	Chape étanche sur maçonnerie	M2	424	50	21 200
8	Herissonnage en pierres sèches	M2	2032	60	121 920
9	Forme de béton	M2	2032	180	365 760
10	Armature de forme	Kg	32502	10	325 020
11	Béton armé en fondations pour tout ouvrage	M3	461	2000	922 000
12	Armatures pour béton armé en fondations	kg	46040	12	552 480

13	Armatures pour béton armé en élévation	kg	12258	12	147 096
14	Cloisons en agglomérés de 0,20 m	M2	552	150	82 800
15	Caniveau en béton armé	ml	86	130	11 180
16	Fosse sceptique	U	25000	1	25 000
17	Puits perdu	U	15000	1	15 000
18	Fourniture et pose de portail d'entrée en métal	U	35000	1	35 000
19	Enduit sur couronnement de clôture	ml	55	1060	58 300
20	Fourniture et pose de buses diamètre 300 en ciment comprimé	ml	103	350	36 050
21	Confection de regards de visite de 1m*1 m	U	9	4000	36 000
22	Citerne de stockage de l'eau (en plastique)	U	1	2000	2 000
23	Extincteur de feu 50 kg	U	1	5000	5 000
			Total HT- Dhs		2 869 386

L'investissement dans une plateforme semble rentable et peut être amorti en grande partie grâce au recyclage des métaux précieux et de la ferraille que l'on valorise.

Par ailleurs, la possibilité d'un marché plus consistant pour la décontamination des appareils à huile minérale, est bien réelle. Ce marché permettra de rentabiliser encore plus la plateforme.

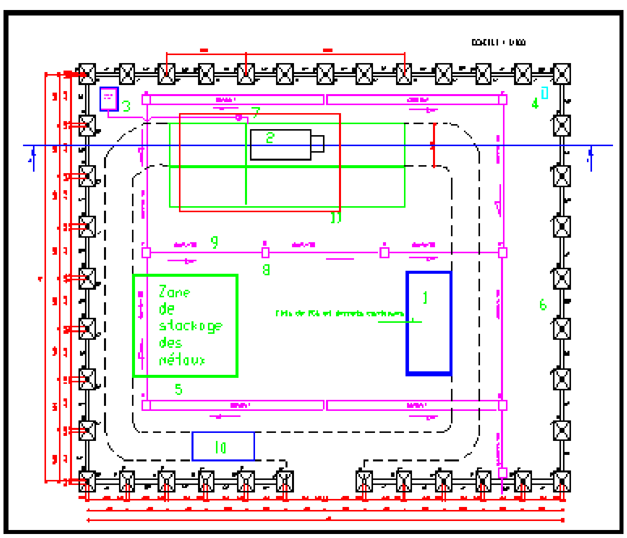

Figure 6 : Plan de réalisation de la plateforme

En conclusion, la comparaison des variantes d'élimination des PCBs purs, penche vers la réalisation d'une plateforme et le démontage des appareils au Maroc. La valorisation des métaux et l'abaissement des coûts d'élimination permettent un équilibrage des coûts d'investissement dans la plateforme et d'élimination des appareils.

Cette plateforme qui restera un acquis pour la décontamination des huiles minérales souillées par les PCBs.

Décontamination des appareils à faible taux de PCBs (<50 ppm)

Dans l'état actuel de la reconnaissance des appareils saints, aucune indication n'existe sur le potentiel en appareils faiblement contaminés. Cependant, nous proposons pour ce type d'appareils, un re-remplissage par une huile minérale neuve. Le relargage ne permettra par une augmentation du taux en PCB au delà de la concentration détectée lors de l'analyse. C'est une option facultative, étant donné que le seuil de contamination selon la convention de Stockholm demeure 50 ppm.

Huiles contaminées entre 50 et 14400 ppm

Les appareils contaminés (>50 ppm) peuvent être décontaminés suivant la méthode de déchloration ou par extraction des PCBs à l'aide du DMSO/DMF. Ceci dépend de l'état de service du transformateur considéré.

La déchloration devrait s'imposer car elle est praticable in situ sans arrêt du transformateur, alors que l'extraction suppose le changement d'huile ou l'arrêt du transformateur.

La déchloration offre également la possibilité de réutiliser l'huile minérale décontaminée.

La répartition géographique des appareils, et leur état de service milite en faveur d'un système mobile de décontamination, qui est justifié par la comparaison faite ci-après :

Tableau 4 : Avantage et inconvénients du système mobile et d'un système fixe de décontamination des huiles minérales

	Système mobile	*Système fixe*
Avantages	***Evite la délocalisation des appareils de grande taille***	**Peut être connecté à un réseau d'égout pour l'évacuation des rejets**
	Pas besoin de d'arrêter le transformateur	**Maîtrise de la gestion des produits chimiques**
		Les risques de l'installation peuvent être bien maîtrisés par la protection civile qui peut intervenir en cas de problème
Inconvénients	***Risque de transport des produits chimiques nécessaires à la déchloration comme le sodium***	**Nécessite le transport de tous les appareils à décontaminer**
	Le personnel en charge de l'installation doit être très qualifié et formé en sécurité industrielle et gestion des risques	***Le transformateur doit être déconnecté***

En conclusion, nous adoptons pour une unité mobile de décontamination des huiles souillées

Dimensionnement de l'unité de déchloration

Le dimensionnement de l'unité de déchloration a été basé sur les hypothèses suivantes :

- Volume des huiles à décontaminer : au moins 3000 t et un maximum de l'ordre de 15000 t,
- La durée de fonctionnement de l'unité retenue : 4 heures/j. Le reste du temps est consacré aux déplacements
- La durée de décontamination des appareils, estimée à 3-4 ans pour la tranche prioritaire de 3000 t d'huiles contaminées.
- L'unité traitera 1 appareil tous les trois jours
  - 1 jour pour l'arrivée et le montage
  - 1 jour pour la décontamination
  - 1 jour pour la remise en état et le départ

Sachant que la contenance moyenne des appareils est de l'ordre de 900 kg d'huile, nous estimons que l'appareil mobile devrait avoir une capacité de traitement de l'ordre de 200-250 l/h.

Estimation des coûts de la décontamination

L'estimation des coûts de la décontamination est scindée en deux parties :

- Les coûts d'investissements et
- Les coûts de revient par tonne d'huile décontaminée

Investissement

Pour des raisons de crédibilité des coûts d'investissement, nous nous sommes renseigné auprès d'opérateurs de la technologie de déchloration.

L'unité mobile ayant un débit de traitement de l'ordre de 2m3/h coûte environ 16 millions de Dhs. En absence d'un devis pour un appareil de moindre capacité, nous avons retenu cet investissement qui pourrait permettre la décontamination de l'ensemble du potentiel en huile minérale, estimé à 15000 tonnes.

Coûts de fonctionnement de l'unité de décontamination

Les coûts de décontamination considérés sont :

- L'amortissement de l'unité
- Les consommables en produits chimiques
- Les salaires du personnel
- Les frais en carburant et en maintenance inclus dans le coût du transport[29]

Le tableau suivant récapitule les coûts d'investissement et de fonctionnement sur la base de 3000 tonnes d'huiles souillées par les PCBs.

Tableau 5 : Indicateurs sur les coûts de décontamination incluant le fonctionnement et l'investissement (pour 3000 t d'huiles contaminés)

[29] le coût kilométrique considéré (1 Dh/km/t) incluse la maintenance et le carburant

Désignation	Investissement	Fonctionnement
Achat de l'unité	16 000 000	
Deux techniciens		480000
Transport		825000
Produits chimiques		300000
Coût en Dhs/t	5333,33	535,00
Coût total en Dhs/t[30]	5868,33	

Le coût de revient pour la décontamination des huiles minérales s'élève à 0,6 Dhs/l d'huile. Ce coût pourrait être abaissé si l'unité est utilisée pour la décontamination du gisement des 15000 t mis en évidence.

Le coût de revient estimé est du même ordre de grandeur que les coûts généralement avancés de l'ordre de 1-5 US$/t, voir moins comme indiqué dans un tableau en annexe.

9 Conclusion et recommandations

Les investigations réalisées ont permis de mettre en exergue les méthodes d'élimination des PCB de l'environnement national. Ces méthodes se résument en :

- Une élimination par destruction à l'étranger pour les PCBs purs et leurs déchets contaminés. Cette opération serait plus intéressante financièrement pour le Maroc si l'élimination est faite uniquement pour les PCBs. Les carcasses contenant des métaux nobles et prisés par l'industrie seront valorisés localement.
- Une décontamination des huiles minérales souillées par les PCBs, cette décontamination serait de préférence par déchloration en raison de l'efficacité de cette méthode et les contraintes, moindre pour sa mise en œuvre sans dérangement pour le client,
- Selon les éléments économiques et la flexibilité de mise en œuvre, le choix s'est porté sur une unité mobile. Cependant une plateforme conçue pour le démontage des appareils réformés ou à PCBs purs, peut être utilisée pour un parcage de l'unité.

L'achat de l'unité ou sa location permettrait de réduire les coûts de décontamination des appareils souillés.

[30] Basé sur un US$ = 8 Dhs et 1kg de sodium au Maroc à 1300 Dhs

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- Mr Steiner, SD Myers
- Mr Barthelemy, Holcim
- Mr Bediri, Ecoval- Groupe Holcim

11 Annexes

11.1. Estimation de l'enveloppe pour le transport et les analyses

Prestation	Nombre	coût moyen	sous total
Analyses	80000	300	24
Transport transformateurs contaminés	1500	100	150000
	750	300	225000
	750	600	450000
		Total	825000
Transport des transformateurs PCB pur			
Layoune	30	2400	72000
Tan Tan	4	1800	7200
Sidi Ifni	1	1400	1400
Akka	2	1400	2800
Zagora	1	1200	1200
Ouarzazate	5	1000	5000
Marrakech	17	500	8500
Essaouira	5	800	4000
Errachidia	1	1200	1200
Azilal	2	800	1600
Safi	3	500	1500
El Jadida	6	200	1200
Settat	1	120	120
Casablanca	6	50	300
Rabat	2	200	400
Mohammadia	39	120	4680
Khouribga	16	250	4000
Khenifra	1	700	700
Kénitra	1	300	300
Meknes	2	300	600
Fes	2	600	1200
Taza	1	800	800
Al Hoceima	1	1400	1400
Oujda	3	1200	3600
Tetouan	5	800	4000
Tanger	10	800	8000
		Total	137700

11.2. Liste des appareils électriques et stocks d'huiles échantillonnés

N° de série	Fabricant	Date de fabrication	Adresse	Date de prélèvement
2H8003/1	ITALTRAFO	1977	Z.I. KENITRA	39464
3M8019/5	ITALTRAFO	1975	Z.I. KENITRA	39464
3M8019/3	ITALTRAFO	1975	Z.I. KENITRA	39414
588901	SEIMENS	1953	Z.I. KENITRA	39414
325894	ALCATEL	1975	Z.I. KENITRA	39434
7 FUTS EN STOCK DE 200 LITRES CONTAMINE PCB				
372673	CGE MAROC	1993		06/02/2008
372115	CGE MAROC	1978		06/02/2008
1558157	ALSTHOM	?		06/02/2008
2136	CGE MAROC	1966		06/02/2008
300822	CGE MAROC	1972		06/02/2008
320570	CGE MAROC	1974		06/02/2008
300821	CGE MAROC	1978		06/02/2008
372112	CGE MAROC	1977		06/02/2008
372663	CGE MAROC	1993		06/02/2008
372972	NEXANS	2001		06/02/2008
972417	NEXANS	2002		06/02/2008
372593	CGE MAROC	1991		06/02/2008
372015	CGE MAROC	1978		06/02/2008
310219	CGE MAROC	1975		06/02/2008
372017	CGE MAROC	1975		06/02/2008
301050	CGE MAROC	1975		06/02/2008
372664	CGE MAROC	1993		06/02/2008
LEL 91751	SIEMENS	2002		06/02/2008
372791	ALCATEL / ALSTHOM	1996		06/02/2008
302860	CGE MAROC	1991		06/02/2008
34851	CGE MAROC	1969		06/02/2008
372640	CGE MAROC	1992		06/02/2008
301049	CGE MAROC	1973		06/02/2008
321679	CGE MAROC	1983		06/02/2008
307859	MERLIN GERIN	2001		06/02/2008
2502	CGE MAROC	1961		06/02/2008
372677	CGE MAROC	1993		06/02/2008
372676	CGE MAROC	1993		06/02/2008
204632	MERLIN GERIN	1997		06/02/2008

351166	CGE MAROC	1991		06/02/2008
2293	CGE MAROC	1958		06/02/2008
2137	CGE MAROC	1956		06/02/2008
196701	MERLIN GERIN	1996	Z.I. SALE	08/02/2008
11584	SOMATEL	1985	Z.I. RABAT	08/02/2008
243253	MERLIN	1998	220 Bd. Chefchaouni, Casablanca	07/02/2008
4482	BEL TRANSFO	2000	ROCHE NOIR	10/06/2006
372400	CGE MAROC	1986	ROCHE NOIR	10/06/2006
R3897	MERLIN GERIN	1979	ROCHE NOIR	07/02/2008
11458	MERLIN GERIN	1986	ROCHE NOIR	07/02/2008
R3907	MERLIN GERIN	1980	ROCHE NOIR	07/02/2008
214422	MERLIN GERIN	1997	ROCHE NOIR	07/02/2008
224894	MERLIN GERIN	1997	ROCHE NOIR	10/06/2006
232210	MERLIN GERIN	1997	ROCHE NOIR	10/06/2006
373006	CGE MAROC	1975	TAG NORD TETOUAN	26/03/2007
135695	GANZ ANSALDO	1993	TAG NORD TETOUAN	26/03/2007
M3017/01	STEM TRENTO	1993	TAG NORD TETOUAN	26/03/2007
301431	CGE MAROC	1974	TAG NORD TETOUAN	26/03/2007
5407	SOMATEL	1983	PORT LARACHE	06/02/2008
186218	MERLIN GERIN	1996	PORT LARACHE	06/02/2008
315180	CGE MAROC	1985	PORT LARACHE	06/02/2008
T1 PRINCIPAL	CGE MAROC	1991	PORT LARACHE	06/02/2008
357183	CGE MAROC	1991	PORT LARACHE	06/02/2008
315862	CGE MAROC	1986	PORT LARACHE	06/02/2008
351131	CGE MAROC	1990	PORT LARACHE	06/02/2008
351182	CGE MAROC	1994	PORT LARACHE	06/02/2008
T10 POSTE 2	CGE MAROC	1994	PORT LARACHE	06/02/2008
T9 POSTE 2	CGE MAROC	1991	PORT LARACHE	06/02/2008
315255	CGE MAROC	1985	PORT LARACHE	06/02/2008
300759	CGE MAROC	1972	BOUKHALEF	07/02/2008
302784	CGE MAROC	1987	BOUKHALEF	07/02/2008
REMPLACEMENT	NEXANS	2007	BOUKHALEF	07/02/2008
300213	CGE MAROC	1970	BOUKHALEF	07/02/2008
6001826	NEXANS	2006	BOUKHALEF	07/02/2008

409614	ALSTOM	2000	BOUKHALEF	07/02/2008
602269	BELTRANSFO	?	BOUKHALEF	07/02/2008
6003401	NEXANS	2006	BOUKHALEF	07/02/2008
6003399	NEXANS	2006	BOUKHALEF	07/02/2008
6003398	NEXANS	2006	BOUKHALEF	07/02/2008
T1 RETRAITE	?	?	BOUKHALEF	07/02/2008
T2 RETRAITE	?	?	BOUKHALEF	07/02/2008
317937	CGE MAROC	1989	BOUKHALEF	07/02/2008
317983	CGE MAROC	1989	BOUKHALEF	07/02/2008
602268	BELTRANSFO	2006	BOUKHALEF	07/02/2008
302797	CGE MAROC	1987	BOUKHALEF	07/02/2008
312288	CGE MAROC	1979	Z.I. TANGER	07/02/2008
312287	CGE MAROC	1979	Z.I. TANGER	07/02/2008
308559	MAROC TRANSFO - MERLIN GERIN	2002	Z.I. TANGER	07/02/2008
236829	MAROC TRANSFO - MERLIN GERIN	1998	Z.I. TANGER	07/02/2008
320075	MAROC TRANSFO - MERLIN GERIN	2005	Z.I. TANGER	07/02/2008
258928	MAROC TRANSFO - MERLIN GERIN	1998	Z.I. TANGER	07/02/2008
303496	MAROC TRANSFO - MERLIN GERIN	2001	Z.I. TANGER	07/02/2008
62402	BELTRANSFO	2006	RT DE KENITRA, SALE	07/02/2008
502395	BELTRANSFO	2006	RT DE KENITRA, SALE	07/02/2008
502215	BELTRANSFO	2006	RT DE KENITRA, SALE	07/02/2008
G10223	SAVOISIENNE	1965	ONE TR MARRAKECH	10/11/2000
218200/2	ITALTRAFO	1979	RT COTIERE MOHAMMEDIA	28/10/2007
3N8010/1	ITALTRAFO	1978	RT COTIERE MOHAMMEDIA	28/10/2007
218200/4	ITALTRAFO	1979	RT COTIERE MOHAMMEDIA	28/10/2007
3N8010/2	ITALTRAFO	1978	RT COTIERE MOHAMMEDIA	28/10/2007
218200/3	ITALTRAFO	1979	RT COTIERE MOHAMMEDIA	28/10/2007
218200/1	ITALTRAFO	1979	RT COTIERE MOHAMMEDIA	28/10/2007

3N8010/4	ITALTRAFO	1978	RT COTIERE MOHAMMEDIA	28/10/2007
3N8010/3	ITALTRAFO	1978	RT COTIERE MOHAMMEDIA	28/10/2007
93275	BELTRANSFO	1999	Z.I. RABAT	08/02/2008
16284	BELTRANSFO	2001	Z.I. RABAT	08/02/2008
CITERNE HUILE USAGEE ATELIER		2008	Z.I. RUE L'ECRIVAN CASABLANCA	18/02/2008
CITERNE HUILE NEUVE ATERIER		2008	Z.I. RUE L'ECRIVAN CASABLANCA	18/02/2008
27809	MERLIN GERIN	1994	Z.I. RUE L'ECRIVAN CASABLANCA	18/02/2008
T 630289	ENERGY TRANSFO	2007	Z.I. RUE L'ECRIVAN CASABLANCA	18/02/2008
SPARE 3	CGE MAROC	?	Z.I. RUE L'ECRIVAN CASABLANCA	18/02/2008
SPARE 2	CGE MAROC	1985	Z.I. RUE L'ECRIVAN CASABLANCA	18/02/2008
317580	CGE MAROC	1988	Z.I. RUE L'ECRIVAN CASABLANCA	18/02/2008
374-140	CGE MAROC	1977	TALBORJT	8/17/2005
1190-1	METZ	1973	TALBORJT	29/01/2005
1190-3	METZ	1973	TALBORJT	29/01/2005
300108	CGE MAROC	1971	RT COTIERE MOHAMMEDIA	11/03/2006
300464	CGE MAROC	1972	RT COTIERE MOHAMMEDIA	25/01/2006
TRANSFOS A SEC	9 TRANSFOS	2005	Z.I. SKHIRAT	15/01/2008

11.3. Indicateurs de coûts d'élimination des PCB

Tableau 1 : Estimations des coûts liés aux méthodes de destruction et de transformation irréversible[31]

Méthodes de réduction et de transformation irréversible	Estimations des coûts	Source
Réduction par un métal alcalin	i. Huiles de transformateurs : US$0,15/L, £500 - £1000/t, CAN$4/gallon, CAN$0,90/kg; et ii. Huiles usagées : CAN$0,60/kg	Fournisseurs PNUE, 2004b
Décomposition catalysée par une base[1]	i. Droits de licence variables; ii. Redevances d'exploitation : 5 %- 10 % des recettes/ventes brutes; iii. Dépenses d'investissement (réacteur pour la décomposition de 2 500 gallons) : US$800 000 - US$1,4M; iv. Dépenses d'exploitation : US$728 - US$1 772 selon la concentration des POP.	Trouvé en 2004 sur le site Web de la société BCD Inc
Hydrodéchloration catalytique	Pas de données disponibles	
Co-incinération en four de cimenterie	Pas de données disponibles	
Réduction chimique en phase gazeuse[2]	i. AUS$4 000 à $6 000/tonne de pesticides organochlorés sous forme solide; ii. AUS$4 000 à $8 000/tonne de PCB et de pesticides organochlorés sous forme liquide; iii. AUS$6 000 à $11 000/tonne de condensateurs contaminés par des PCB	CMPS&F – Environment Australia, 1997
Incinération des déchets dangereux	Voir le tableau 2 ci-après	
Réactions de déchloration photochimique et de déchloration catalytique	Données disponibles sur demande : i. Droits de licence; ii. Redevances ou dépenses d'exploitation	
Jet de plasma	Dépenses d'investissement[1] (unité Plascon™ de 150 kW) : US$ 1 million, selon la configuration. Dépenses d'exploitation : inférieures à AUS$	CMPS&F – Environment Australia, 1997; Rahuman et al.,

[31] Projet de directives techniques générales actualisées pour la gestion écologiquement rationnelle des déchets constitués de polluants organiques persistants (POP), en contenant ou contaminés par ces substances, PNUD

Méthodes de réduction et de transformation irréversible	**Estimations des coûts**	**Source**
	3000 (y compris la main-d'œuvre); généralement comprises entre $AUS 1 500 et $AUS 2 000 par tonne. Elles dépendent de facteurs tels que: i. Les déchets introduits – structure moléculaire, poids et concentration; ii Le coût de l'électricité; iii. Le coût de l'argon et de l'oxygène; iv. Les questions liées à l'emplacement géographique et au site; v. Le coût de la soude; et vi. Les limites d'émission à respecter	2000; PNUE, 2004b
Méthode au tert-butoxide de potassium	Pas de données disponibles	
Oxydation dans l'eau supercritique et oxydation dans l'eau sous-critique	Coûts : US$120 - US$140/tonne sèche[3]	CMPS&F – Environment Australia, 1997

1 On ne sait pas si ces estimations incluent les coûts potentiels liés au prétraitement et/ou à l'élimination des résidus.

2 On ne sait pas si ces chiffres incluent les coûts liés au prétraitement des déchets solides.

3 A supposer qu'il est procédé à un certain prétraitement. On ne sait pas si cette estimation inclut les dépenses d'investissement ou les coûts liés à l'élimination des résidus éventuels.

11.4. Méthodes d'analyse des PCB

Méthode qualitative : kit de détection rapide

La méthode permet de réaliser les transformations chimiques suivantes :

- déchloration des molécules de PCB et,
- association des ions chlorures avec une quantité définie d'ions sodium contenues dans une solution avec le kit; suivie d'un,
- virage colorimétrique en fonction du dépassement ou non d'une valeur seuil.

Le virage colorimétrique peut être programmé à 50, 100 ou 500 ppm. Cette méthode a été utilisée pour vérifier la présence ou l'absence de PCB dans les huiles avant élimination des transformateurs.

Méthode semi-quantitative : l'électrode ionique sélective

Cette méthode représente un compromis entre une analyse de laboratoire précise, mais longue et coûteuse, et une détection par kit, facile à mettre en œuvre, mais de portée limitée.

Cette méthode utilise une électrode ionique spécifique pour le dosage des PCB. L'ensemble des éléments constitutifs de ce type d'appareil peut être transporté sur site. Le volume nécessaire à l'analyse est très faible (5 ml d'huile). Le principe de la méthode est basé sur la libération des ions chlorures par action du sodium métal sur les molécules de PCB, ces ions sont mis ensuite en solution aqueuse. L'électrode plongée dans cette solution permet de lire directement la concentration en PCB après quelques minutes.

Les analyses réalisées par cette méthode donnent des concentrations totales en PCB toujours supérieures à celles données par chromatographie gazeuse. Ce fait peut être expliqué que l'électrode mesure tous les ions chlorures présents dans l'échantillon analysé. Elle mesure aussi les ions chlorures peuvent provenant d'autres molécules organiques contenues dans l'échantillon, comme le trichlorobenzène utilisé comme solvant dans les huile à PCB.

La méthode par électrode sélective permet des mesures de concentration en PCB de l'ordre de 10 à plusieurs centaines de ppm, mais elle ne peut pas être utilisée pour quantifier de façon exacte la teneur en PCB ; notamment autour de la valeur seuil requise (50 ppm).

Méthode quantitative : chromatographie en phase gazeuse (CPG)

La chromatographie en phase gazeuse (CPG, figure ci-après) est la méthode d'analyse la plus répandue, elle est très sensible, très précise et très fiable. Elle est utilisée pour l'analyse de pratiquement tous les composés organiques moyennant l'emploi de la phase stationnaire appropriée à chaque famille chimique.

Cette méthode permet aussi la séparation quantitative des constituants de différents mélanges. Ainsi, une fois séparés dans la colonne, les congénères PCB sont détectés en sortie et apparaissent sous forme de pics sur le chromatogramme, leurs identification et dosage quantitatif se fait respectivement par la mesure du temps de rétention des pics et de leur surface.

La chromatographie en phase gazeuse (CPG) est une méthode normalisée pour le dosage des PCB, il existe certaines normes qui régissent les procédures de cette analyse comme par exemple :

- NF C 27-234 (1990) ou CEI 60997 (1989) décrit le dosage des PCB dans l'huile minérale par CPG sur colonne remplie ;
- NF EN 61619 (1993) ou CEI 61619 (1992) détaille le dosage PCB dans l'huile minérale par CPG sur colonne capillaire ;

Le seuil de détection se situe généralement autour de 2 ppm (exprimé en PCB totaux). La précision est de l'ordre du ppm. L'annexe C donne une liste de laboratoires agrées prestataires pour le dosage des PCB.

ANNEX F ANALYSE ENVIRONNEMENTALE STRATEGIQUE DU PROJET D'ELIMINATION DES PCB AU MAROC

Table of content

0 Liste des abréviations

POP : Polluant organique persistant
DE : Département de l'Environnement
CS : Convention de Stockholm
MTD : Meilleures techniques disponibles
MPE : Meilleures pratiques environnementales
ONE : Office national d'électricité
PCB : Polychlorobiphényles
RTM : Radiotélévision marocaine
PNUD : Programme des nations unies pour le développement
DGCL : Direction Générale des Collectivités Locales
PNM : Plan National de Mise en œuvre
CPG : Chromatographie en phase gazeuse
ONEP : Office national de l'eau potable
UATRS : Unité d'appui technique à la recherche scientifique

1 Etude d'impact stratégique et risques du projet d'élimination

Les PCBs, dont le danger a été démontré par les scientifiques, sont des substances toxiques persistants dans l'environnement. Ils ont la particularité de résister aux dégradations biologiques classiques, de s'accumuler dans les tissus vivants et de se déplacer sur de longues distances.

Pour cerner leur problématique, la communauté internationale élaboré deux traités internationaux que sont La Convention de Stockholm et le Protocole d'Aarhus. Ces traités visent la réglementation et la gestion écologiquement durable de l'élimination, la production et l'utilisation des POPs. Parmi les POPs existants, une liste de 12 familles/classes/catégories de produits chimiques reconnus comme les plus dangereux, a fait l'objet de ces traités. Elle est composée de huit pesticides chlorés, deux familles de produits chimiques industriels dont les polychlorobiphényles (PCBs) et de dioxine/furanes chlorés, sous-produits générés lors des processus de combustion et d'incinération.

Le Royaume du Maroc fait partie des pays signataires de la convention de Stockholm et vient de la ratifier très récemment courant mai 2004. Pour respecter les dispositions de cette convention, il se doit de mettre en place des moyens de prévention et de gestion écologique des POPs.

Un projet d'élimination des PCB au Maroc a été élaboré pour cofinancement par le GEF. Dans ce cadre, la présente étude d'impact stratégique a été réalisée pour mieux mettre en exergue les bénéfices à atteindre avec un tel projet et éventuellement les retombées négatives.

A noter qu'une telle analyse stratégique est rarement réalisée au Maroc pour des projets d'une telle nature, elle constitue alors une avancée en elle-même pour le projet et le renforcement des capacités nationales en matière de prise de décision mettant en jeu l'environnement.

2 Démarche suivie pour l'élaboration de l'EIS

La réalisation de l'étude d'impact stratégique poursuit les objectifs suivants :

- Identifier le projet d'élimination des PCB au Maroc
- Identifier l'état actuel de l'environnement en lien avec ces PCB
- Analyser l'état de l'environnement en absence de toute action (projet)
- Analyser l'évolution de l'état de l'environnement écologique et social à la lumière du projet d'élimination des PCB

3 Consistance du projet d'élimination des PCB au Maroc

Le gisement des PCB et leurs déchets contaminés est en constante diminution

L'inventaire des PCBs au Maroc a été réalisé à trois reprises : i) une première fois en 2001, une seconde fois en 2004 et une dernière fois dans le cadre de l'évaluation de l'état des lieux en termes de PCB à éliminer, en 2007.

Le gisement de ces PCBs, sous différentes formes : déchets, PCBs purs, huiles contaminées et sols contaminés sont listés ci-après[32].

- Transformateurs à PCB : 371 (dont 224 t de PCB)
- Condensateurs : 394 unités (dont 2,5 T de PCB)
- Autres équipements à PCB : 129 tonnes (49 t PCB)
- PCB en vrac : 5,6 tonnes
- Huiles de transformateurs contaminées 15 000 tonnes (selon une estimation)

[32] DSPR, Amal Lemsioui, présentation du projet PCB au Maroc

La répartition de ce gisement montre que le secteur industriel domine avec le nombre de détenteur, suivi par les administrations. Le secteur des télécommunications se place en troisième position. Toutefois, il est à noter que le gisement des PCBs et leurs déchets décroît régulièrement en raison des actions d'élimination opérées par les détenteurs.

Malgré la diminution du gisement, le projet d'élimination demeure justifié

Le Plan National de mise en Œuvre (PNM) de la Convention de Stockholm, déposé en mai 2006 au Secrétariat de la Convention, a reconnu l'importance de la problématique des sols contaminés et des PCBs stockés ou sous la forme de déchets contaminés. Il a inscrit parmi ses actions prioritaires la réalisation du projet "Renforcement des capacités de gestion et d'élimination des PCB, du matériel contenant des PCB et des sols contaminés par les POP".

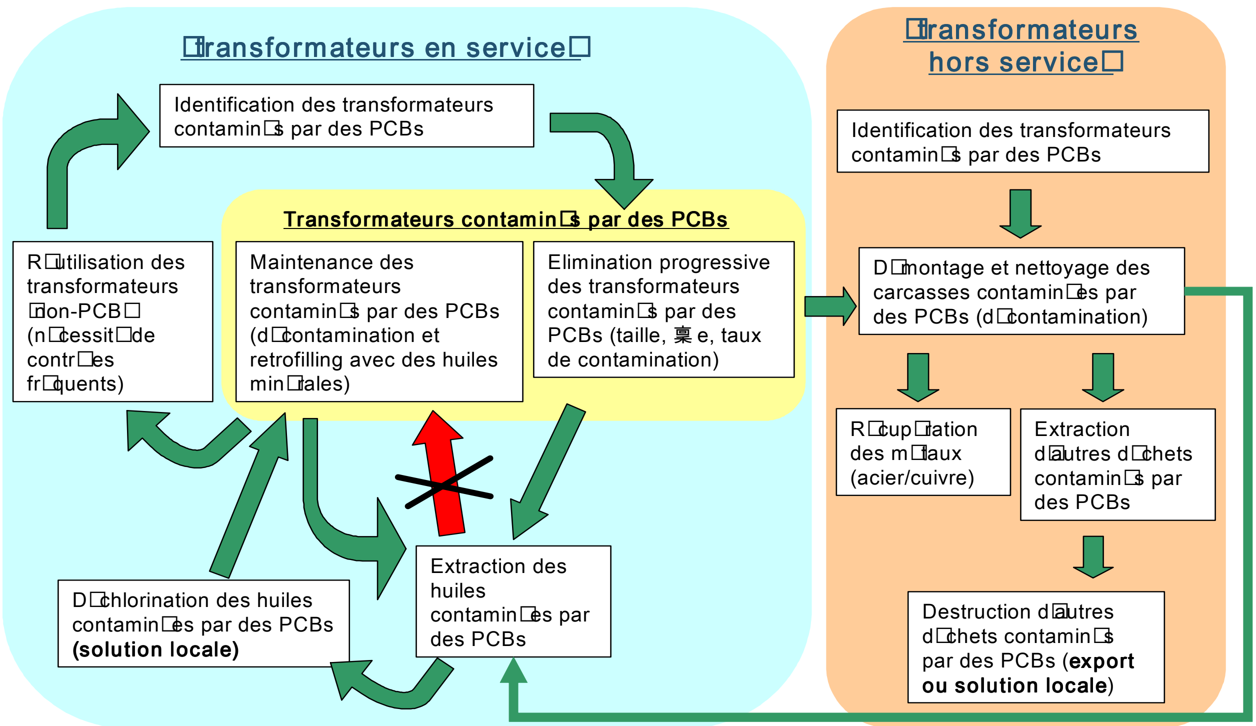
Ceci justifie amplement la réalisation du projet dans sa globalité.

Un projet d'élimination en deux phases

Le projet d'élimination des pesticides comprend deux phases :

- Une phase d'élimination des PCBs purs et
- Une autre phase d'élimination des PCB

L'organigramme suivant[33] éclaire davantage la stratégie d'élimination envisagée.



Justification du projet : Etat des lieux de l'environnement national en absence d'actions d'élimination des PCB

Pour appréhender l'impact du projet élimination des PCB sur l'état de l'environnement national, il est judicieux d'établir cet état pour les éléments primordiaux à savoir l'air, l'eau, le sol, la faune et la flore et enfin le milieu humain et ses activités socio économiques.

Le descriptif donné ci-après se focalise également sur la présence et la concentration des PCB au niveau des éléments environnementaux.

[33] Organigramme repris du projet Onudi, pour le Maroc, F. Moser, 2008

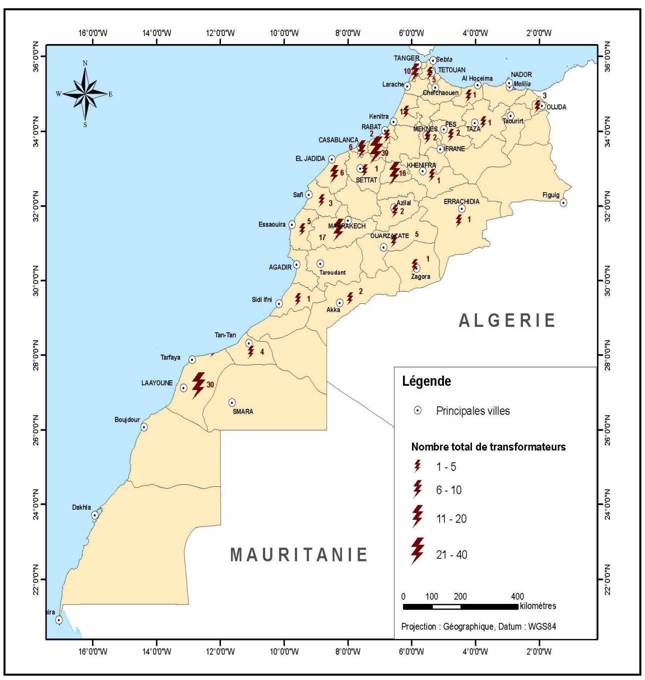
4 Sur le plan environnemental : le territoire national est vulnérable à la contamination par les PCBs

Les PCBs existent encore sous la forme de produits purs dans des transformateurs ou des emballages (comme c'est le cas au site de l'ex voix de l'Amérique). Ils existent également sous la forme d'huiles contaminées dont la dissémination entraîne inévitablement une contamination des écosystèmes vulnérables.

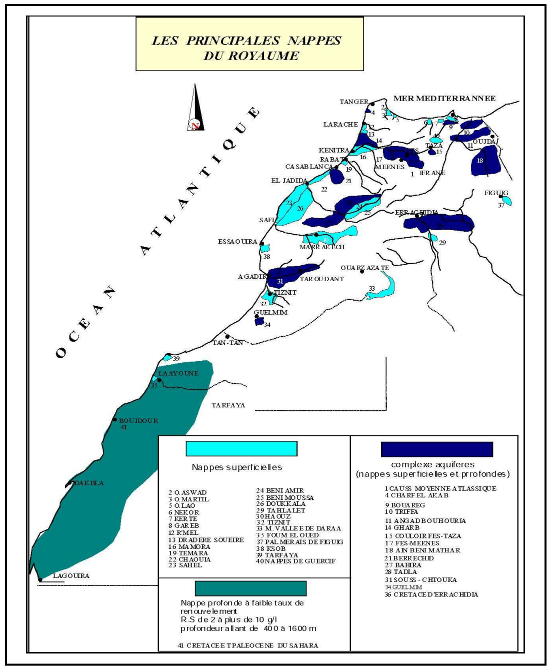
Le plan national d'action pour une gestion écologique des PCBs a bien mis en évidence les zones vulnérables aux PCBs. Il s'agit des zones du Tangérois, du Souss, Casablanca, Kénitra (Maâmora), Fès-Meknès, Marrakech et Rabat-Salé. Ces zones recèlent des eaux souterraines très vulnérables à la pollution (faibles profondeurs).

Des ressources en eau souterraines vulnérables

L'analyse de la vulnérabilité des ressources en eau souterraines montre que de nombreuses nappes où sont concentrés les équipements à PCB, sont vulnérables. C'est le cas, entre autres, des aquifères du Haouz de Marrakech du Souss, de Rmel, où sont implantés de nombreux forages de l'ONEP. Notons que cet office a affirmé à plusieurs reprises avoir réalisé le retrofiling de ses transformateurs ayant contenu des PCB.



La carte donnée ci-après montre clairement que les sources d'alimentation en eau potable sont concentrées dans la partie du territoire qui connaît une forte densité des appareils à PCB.



La vulnérabilité de ces ressources en eau face à une contamination par les PCB pose inévitablement la question de la sécurité de l'alimentation en eau potable de la population desservie. A titre non limitatif, ce sont donc, des villes comme Agadir, Marrakech et Larache qui se trouveraient menacées.

Un réseau hydrographique national vulnérable à la contamination par les PCB

Compte tenu de sa situation climatique aride à semi aride, le réseau hydrographique national pérenne se limite à la moitié nord du Royaume. Ce sont les cours d'eau Moulouyia, Bouregreg, Loukous, Sebou et Oum Erbia qui ont un débit d'étiage le long de l'année.

La région du Gharb, inondable, connaît un épandage des eaux pluvieuses et marines, ce qui favorise la dissémination des polluants au delà de leur point de concentration, comme c'est le cas du site de l'ex voix de l'Amérique.

Un sol–susceptible de rétention des polluants mais ne constitue pas une barrière efficace

Les sols du territoire marocain sont diversement constitués, on relève des sols sablonneux dans la Maâmora, argileux dans le Gharb, etc. Cependant, de manière générale, et compte tenu des pratiques culturales, les sols ne sont pas suffisamment amendés en matière organiques, ce qui diminue leur pouvoir de rétention des polluants comme les pesticides et les PCB. Ceci a comme conséquence une plus grande percolation vers es eaux souterraines.

A titre d'illustration, certains champs captant de l'ONEP, sont situés dans des zones où le sol a un très faible pouvoir épurateur, comme à Agadir (champ Sud), Larache, ou Sidi Taibi (proche de Kénitra).

La qualité de l'air est globalement affectée par les installations industrielles mais localement par les PCB

Il est évident que la faible pression de vapeur des PCB, les empêche d'être volatils et par conséquent réduit leur éventuelle nuisance olfactive. Cependant, dans les sites où ces produits ont été mis en évidence, on note une odeur spécifique dégagée, lorsque les huiles ne sont pas confinées.

Ceci a été relevé lors des visites au site de l'ex voix de l'Amérique, situé à environ 25 km au Sud de Tanger, où de fortes odeurs se dégagent à l'approche des transformateurs à Askarele (photo en encadré ci après).

Fûts de PCB communiquant avec l'air libre

A noter qu'en cas d'accidents majeur (explosion des transformateurs), la pollution de l'air par les rejets d'explosion, est quasi certaine. Il y aura, entre autres, dégagement de l'acide chlorhydrique, des dioxines et des furanes.

Certains milieux protégés sont exposés au PCB

De nombreux sites d'intérêts biologiques sont localisés dans la partie Nord du Royaume. Ces sites hébergent une biodiversité très variée et parfois endémique ou en voie de disparition.

Paradoxalement, à proximité de ces zones protégées, on note la présence d'appareils à PCB, comme c'est le cas du site de Tahaddart et l'ex voix de l'Amérique. Cette proximité géographique favorise la dissémination des PCB par les eaux, par l'air ou par la mobilité de la faune.

Sibe de Tahaddart

Sur le plan socio-économique

Le recyclage des transformateurs constitue une faible part du chiffonnage

Les aspects sociaux en line avec les PCB sont limités au volet du recyclage des différentes composantes des appareils (cuivre, ferraille, etc.). En effet les appareils hors d'usage alimentent le marché du recyclage qui emploi de manière non formel plusieurs milliers de personnes.

La part du marché du recyclage dû aux appareils à PCB est difficile à évaluer, elle reste néanmoins minime, à notre sens, compte tenu des tonnages en ferraille, très importants (près de 250 000 t/an)[34] mis en jeu au niveau national.

Compte tenu de leur poids souvent assez importants, les transformateurs sont directement vendus au grossiste. Par conséquent, l'intérêt économique n'est pas négligeable pour ces opérateurs.

Le coût de l'élimination des appareils à PCB n'est pas en faveur des détenteurs

L'élimination des transformateurs ou des équipements à PCB se négocie souvent pour l'ensemble de l'appareil : PCB et carcasse. Cette dernière présente pour les opérateurs d'élimination une manne supplémentaire, puisqu'ils revalorisent les métaux précieux tel que le cuivre et l'acier à l'étranger. Les prix de ces métaux sont assez élevés pour justifier l'intérêt d'une telle procédure.

On constate donc, que le client paye l'élimination au moins à deux reprises : i) en payant le prix du marché et ii) en cédant de la matière première de grande valeur.

Le marché de l'environnement au Maroc ne profite pas suffisamment de l'élimination des PCB

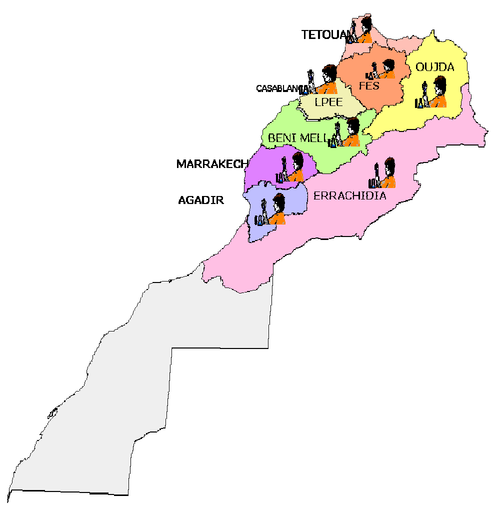
Conformément aux pratiques du marché, et l'absence de technologies locales d'élimination, les opérateurs marocains et de ce fait le marché national de l'environnement ne tirent pas des bénéfices importants. Leur rôle se limite au négoce et la sous traitance pour d'autres sociétés étrangères qui détiennent les technologies d'élimination. L'élimination des PCB pourrait donc stimuler d'avantage le marché de l'environnement au Maroc.

Sur le plan risque et niveau sanitaire

Alimentation en eau potable

L'ONEP, principal producteur de l'eau potable au Maroc, contrôle périodiquement la qualité des eaux des nappes et des barrages, du point de vue de la concentration en pesticides. Selon les données disponibles, cette pratique n'est pas systématique pour les PCB, certainement en raison des moyens spécifiques d'analyse de ces contaminants.

La direction de l'hydraulique procède également à l'analyse de ces ressources en eau à travers le Royaume. Elle dispose d'un réseau de laboratoires dans les principales régions dotées de complexes aquifères (carte ci-après).



[34] Presque 250000 t/an selon l'étude du recyclage des déchets au Maroc, MATEE-Banque mondiale, réalisée par EDIC-ADS, 2005

Partant de ce constat, on se pose la question du risque sanitaire encouru par les populations qui puisent l'eau directement dans les nappes ou les rivières sans aucune indication sur leur potabilité en général et de leur contamination par les PCB en particuliers.

Le recyclage des déchets métalliques

L'élimination non contrôlée des transformateurs à PCB se fait au niveau des grandes plateformes de recyclage de la ferraille. Lors des investigations dans le cadre des inventaires des PCB, il a été admis par les ferrailleurs que les appareils sont démontés et manipulés sans aucune précaution en raison du manque de sensibilisation au danger des PCB. A ce constat, s'ajoute le fait que la manipulation des transformateurs passe le plus souvent par un découpage oxyacétylénique, ce qui favorise la formation des dioxines et des furanes, reconnus de nos jours comme substances cancérigènes.

Comme les métaux récupérés sont valorisés dans les fonderies, le risque de contamination se poursuit au niveau de ces installations industrielles.

Le devenir des huiles PCB des transformateurs valorisés de manière non formelle

La valorisation par les ferrailleurs, des métaux des appareils électriques est une évidence bien admise par tous. Ce qui n'est pas clairement démontré c'est le devenir des huiles soustraites aux transformateurs, mais tout porte à croire quelles sont, soient valorisées de manière informelle dans les fours, les hammams, les briqueteries, etc., soit mises en épandage à même le sol. Dans tous les cas, cette pratique révèle l'existence d'un risque de contamination non négligeable.

Le risque lié à la présence des transformateurs à pyralène n'est pas non plus estimé pour la plupart des détenteurs de transformateurs à PCB. En cas d'explosion de ces transformateurs, la production des dioxines et des furanes risquerait de causer des dégâts certains au niveau de la population située à proximité. Comme exemple d'illustration d'une telle situation, il a été relevé pour une unité industrielle la localisation du transformateur à PCB sous les locaux abritant le personnel administratif.

Faible capacité de gestion des PCB au Maroc

Actuellement, la gestion des PCB au Maroc connaît des faiblesses sur le plan des capacités nationales, malgré les efforts louables déployés par le Département de l'Environnement, notamment la DSPR[35].

Les faiblesses sont notées au niveau des :

- Moyens d'analyse des PCB
- Qualification des personnes impliquées dans la gestion des PCB
- Mode de transport des équipements contenant des PCB et qualification des moyens allouées à cet effet
- Moyens de traitement des PCB ou des déchets les contenant. A cet effet, il y a lieu de noter que le secteur de la cimenterie est équipé en fours capables d'incinérer ces contaminants mais ils ne procèdent pas à le faire.

Prospective environnementale, dans le cas d'une non action

Les constats et l'état établi précédemment montre que les PCB constituent un fléau et un facteur de risque pour la santé des populations et leur environnement.

Ce facteur de risque est cerné partiellement par certains détenteurs avertis qui se sont attelés ou s'attèlent à éliminer les appareils à PCB de leurs installations.

Malgré ces efforts, relativement minimes, le risque demeure présent à cause des appareils entreposés et non inventoriés mais également les appareils contaminés. A cela, s'ajoute les sols

[35] DSPR : Direction de la Surveillance et la prévention des risques

et les déchets contaminés par les PCB et qui ne font pas partie de la présente analyse stratégique.

Dans le scénario où aucune action globale n'est entreprise pour cerner davantage le problème des PCBs au Maroc, il y fort à croire que leur dissémination continuera à progresser, sachant par ailleurs que ces contaminants sont bioaccumulables et faiblement biodégradables. Ils peuvent rester stockés dans les sédiments (par adsorption) et dans la chaîne trophique par liposolubilité.

En conclusion, l'environnement marocain devra donc s'attendre dans les décennies à venir à des conséquences visibles sur la santé des populations et des êtres vivants en raison des effets actuels des PCB.

La réalisation du projet d'élimination permettra de réduire considérablement ces effets prévisibles et préserver ainsi le cadre de vie des générations futures.

Les effets à l'échelle nationale sont détaillés et argumentés ci-après, matérialisant l'évolution de l'environnement naturel et socio-économique en cas de réalisation du projet dans ses deux composantes.

5 Analyse stratégique en cas de réalisation du projet dans ses deux composantes

La présente analyse se base sur l'élimination des PCBs de l'environnement national selon deux composantes : i) la première se focalisant sur les PCBs purs qui doivent fort probablement être éliminés par destruction et la seconde qui préconiserait la décontamination chimique des huiles.

L'analyse ci-après est présentée selon les thèmes :

- Environnement naturel en se focalisant les principaux éléments, à savoir :
    - le sol,
    - le milieu biologique,
    - l'eau et
    - l'air
- La diminution des risques liés aux POPs
- Environnement économique, à travers :
    - le recyclage des métaux,
    - le conseil,
    - la maintenance,
    - l'analyse chimique,
    - la décontamination
    - l'exportation du savoir faire dans les pays étrangers, notamment dans la région du MENA[36] et en Afrique
- La réponse aux exigences de la convention de Stockholm
- Le renforcement des capacités nationales publiques et privées en matière de gestion des POPs
    - PCBs
    - Pesticides
    - Dioxines et furanes
- Les risques liés à l'exécution du projet d'élimination

[36] MENA : Moyen orient et nord Afrique

- o Transport
- o Analyse
- o Qualification du personnel impliqué

Enfin nous formulerons à la fin du document les mesures qui paraissent judicieuses pour réduire les impacts négatifs prévisibles afin d'augmenter l'efficience du projet du point de vue écologique, économique et social.

Soulagement de l'environnement naturel

- o le sol

La réalisation du projet d'élimination des PCBs, notamment dans sa première phase, contribuera certainement à stopper la contamination des sols où les appareils défectueux sont entreposés.

Les sols déjà contaminés par des PCBs ne sont pas concernés par le projet aussi bien dans la phase 1 que la phase 2. De ce point de vue, aucune amélioration ne sera obtenue pour ces sols.

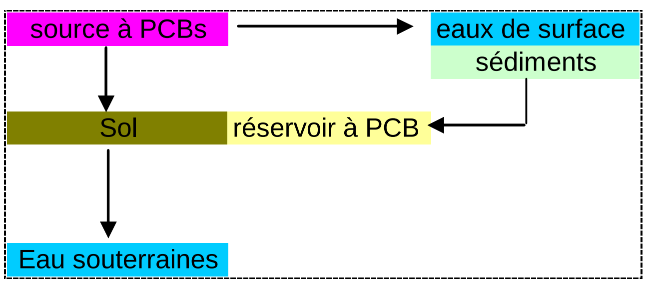
- o le milieu biologique

Dans ce paragraphe, on entend par milieu biologique, les sites groupant la biodiversité, la faune et la flore.

Globalement le milieu biologique continuera à accumuler les PCB qu'il a déjà adsorbé. Cependant, la réalisation du projet contribuera à l'éradication de la source à PCBs. Par conséquent, avec l'effet de dilution dans le temps, la concentration des PCBs dans le milieu biologique sera amenée à diminuer.

- o l'eau

L'eau constitue le milieu le plus vulnérable en raison de sa très forte sensibilité. L'eau est non seulement un milieu de vie mais un élément vital pour les être vivants. La réalisation du projet d'élimination des PCB permettra d'arrêter la source de contamination, bien que le sol, s'il est déjà gorgé de PCBs, continuera à les relarger.



La décontamination de la source des PCBs est donc insuffisante mais bien indispensable.

- o l'air

Il a été montré que la pollution de l'air par les PCBs, reste limitée aux sites où ces polluants sont non confinés. La réalisation du projet permettra d'éliminer les sources de nuisances olfactives des PCBs, notamment lors de la phase 1.

Diminution des risques technologiques liés aux PCBs

L'existence de plusieurs centaines de transformateurs contenant des PCBs constitue à l'évidence, une source de risque d'accidents technologiques majeurs (explosions). L'élimination des appareils à PCBs, dans le cadre de la phase 1, sera l'impact le plus marquant de ce projet.

Les régions où sont encore concentrés les transformateurs verront leur niveau de risque diminuer de manière très significative. Ce sont, entre autres, les régions de Casablanca, Kénitra, Tanger et Fès.

Stimulation de l'environnement économique

Le projet d'élimination des PCBs dynamisera plusieurs volets économiques du marché de l'environnement. Ainsi, les métaux des transformateurs, lorsqu'ils sont décontaminés alimenteront le marché du recyclage des métaux qui est actuellement très demandeurs de ferraille.

- le conseil, ingénierie et analyse

L'élimination des PCBs, notamment dans le cadre de la phase II, est génératrice d'opportunités de conseil, d'ingénierie et de prestations d'analyse chimique des huiles contaminées.

Le type de conseil potentiel sera dans le domaine de la sensibilisation, la sécurité industrielle. Celui de l'analyse concerne la mise en évidence des appareils contaminés par les PCBs. C'est un marché assez ouvert mais déjà monopolisé par quelques prestataires représentant des laboratoires étrangers.

Le suivi environnemental et l'accompagnement des détenteurs pendant et après élimination des PCBs. Le suivi devrait durer plusieurs années après la fin du projet.

- l'exportation du savoir faire dans les pays étrangers, notamment dans la région du MENA[37] et en Afrique

La réalisation du projet d'élimination des PCBs comprend plusieurs volets : i) l'analyse, le transport, iii) le montage des plateformes, iv) l'élimination par destruction, v) l'analyse, vi) la décontamination chimique et vii) le conseil.

Le développement des activités du projet au Maroc, permettra aux différents opérateurs d'asseoir leur savoir faire et aux sociétés locales de réaliser un renforcement de leurs capacités par un transfert de savoir faire des sociétés étrangères qui constitueraient avec elles des liens d'affaires.

Par la suite, les sociétés nationales peuvent faire valoir leur acquis pour s'introduire dans d'autres marchés de la région ou dans les pays du MENA.

Le renforcement des capacités nationales publiques et privées en matière de gestion des POPs

La réalisation du projet (pilier I et pilier II) va impliquer des institutions, des opérateurs privés, probablement des ONGs, etc. Pour atteindre les objectifs escomptés, tous ces intervenants devront travailler de concert et en parfaite harmonie.

La réussite, exigée, de la collaboration entre le public et le privé sera capitalisée pour attaquer d'autres problématiques similaires à celle des PCB, à savoir l'élimination des pesticides périmés, des pesticides POPs et la prévention contre l'émanation des dioxines et des furanes.

Le projet d'élimination présente des risques surmontables

Le présent document a montré à l'aide de plusieurs arguments, que le projet d'élimination des PCB est porteur d'améliorations prévisibles de l'état de l'environnement, notamment dans la partie nord du territoire national où sont concentrés les appareils à PCB. Néanmoins, le projet requiert ne maîtrise de certains volets, porteurs de risques, comme le transport des transformateurs, le déchets des analyses des huiles contaminées, la gestion du risque associé à la gestion de la plateforme de démontage des transformateurs, etc.

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[37] MENA : Moyen orient et nord Afrique

6 Conclusions et recommandations

L'analyse stratégique du projet d'élimination des PCBs au Maroc a été basée sur l'état des lieux de l'environnement biologique et socio-économique national en interaction avec les PCBs.

Cette analyse montre que ces environnements sont actuellement menacés par la présence et la dissémination des PCBs qui sont non biodégradables et bioaccumulables dans la chaîne des êtres vivants.

Les PCBs constituent également un facteur de risque technologique présent dans la quasi-totalité des zones industrielles. Ces facteurs de risques sont amplifiés par l'ignorance et le manque de sensibilisation des détenteurs à leur égard.

L'élimination des PCBs est donc une aubaine pour l'environnement et le milieu industriel. Tous les indicateurs analysés militent en faveur des retombées positives du projet. Cependant, dans le cas où celui-ci n'est pas réalisé dans les règles de l'art et avec l'appui logistique d'une expertise déjà éprouvée, les résultats attendus risquent ne pas être atteints.

Pour s'assurer des résultats escomptés, le projet devra être accompagné le long de sa durée de vie par un comité de pilotage et de surveillance. Après la fin du projet, un système de suivi devra être mis en place pour s'assurer que les retombées positives ne soient compromises par une gestion illicite de stocks ou d'appareils à PCB non inventoriés.

7 Sources d'information

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- Mr Barthelemy, Holcim
- Mr Bediri, Ecoval- Groupe Holcim

ANNEX G LETTER OF COLLABORATION BETWEEN GTZ AND UNIDO

LETTER OF COLLABORATION

between

UNIDO

and

GTZ-
Programme de Gestion et de Protection de l'Environnement (PGPE)

PREAMBLE/ PREFACE

UNIDO: UNIDO has recently been granted the status of direct access to POPs-related Global Environment Facility (GEF) resources based on its ability to implement projects in priority areas of the Stockholm Convention. A pipeline was developed to respond to the needs of the developing countries in three categories: capacity building, implementation of post-NIP enabling activities and technology demonstration projects.

In this regard, the GEF has recently approved PDF-B grants for the preparation of a full-sized project (FSP) on the sound management and elimination of PCBs in Morocco for joint execution by UNIDO and UNDP. The UNIDO-executed part of the PDF-B project is based on the findings of the Moroccan National Implementation Plan (NIP) under the Stockholm Convention on POPs and aimed at:

- updating Morocco's preliminary PCB inventory;
- undertaking a feasibility study for the development of national capacity for the destruction of PCB waste, including the evaluation of technical criteria and location of appropriate PCB elimination options in Morocco; and
- development of the project document for the GEF-funded FSP.

The planned FSP consists of two pillars[1] and will provide technical assistance to public and private sector actors for increasing the in-country capacity for sustainable management of PCBs, a group of hazardous chemicals covered by the Stockholm Convention on Persistent Organic Pollutants (POPs).

PGPE : International environmental conventions, the free trade area with the European Union, and the Millennium Development Goals all call for a solution to existing environmental problems. On the national level, as on the local level, considerable shortcomings persist in the drafting and implementation of environmental policy and environmental law. The Ministry of Energy, Mines, Water and Environment has approved a national environmental action plan (PGPE : Programme de Gestion et de Protection de l'Environnement) to coordinate the freeing of these bottlenecks.

The programme, which is assisted by GTZ, makes a contribution to this goal in the following activity areas:

- advising the Ministry of Energy, Mines, Water and Environment, Rabat, on environmental policy;
- establishment of a national centre for hazardous waste disposal, (in cooperation with KfW development bank);
- industrial environmental protection;
- municipal environmental protection stressing improvements in municipal waste management.

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[1] Pillar I, which will be implemented by UNDP, seeks to strengthen legal, policy and administrative framework for PCB management and disposal; to introduce environmentally sound and safe PCB management at PCB holder level; to identify further PCB sources; and to replace and dispose of pure PCBs in participating industries in an environmentally sound manner.

OBJECTIVE

Safe management and disposal of PCBs in Morocco:

The UNIDO implemented pillar II of the project aims at overcoming barriers identified in Morocco's National Implementation Plan (NIP) of the Convention with regard to the safe and sustainable management of PCB-contaminated transformers at all stages of their life cycle by achieving the following four outcomes:

Outcome 1:	Identification process set up for PCB contamination in in-service and decommissioned transformers
Outcome 2:	Environmentally sound maintenance and treatment of in-service PCB contaminated mineral oil transformers in participating industries set up.
Outcome 3:	Environmentally sound disposal of decommissioned PCB contaminated transformers and material recovery set up
Outcome 4:	Project management, monitoring and evaluation (M&E)

PURPOSE OF COOPERATION

UNIDO and GTZ-PGPE affirm their interest to avoid any duplication of work to dispose PCB-contaminated transformers. Therefore they want to collaborate in the following fields:

- Information exchange and sharing of experiences in the PCB management and disposal field,
- Training and outreach of key stakeholders on PCBs,
- Undertaking of feasibility studies for the selection of PCB destruction technologies (e.g. cement kilns, non- combustion technologies etc.).

Rabat, 2 ... 2008
(date)

... BERNARD
UNIDO Field Office in Morocco
Représentant de l'UNIDO Maroc

Rabat, 0 8 JAN. 2008
(date)

GTZ au Maroc

Coopération Technique Allemande gtz Bureau à Rabat

Dr. Brigitte HEUEL-ROLF