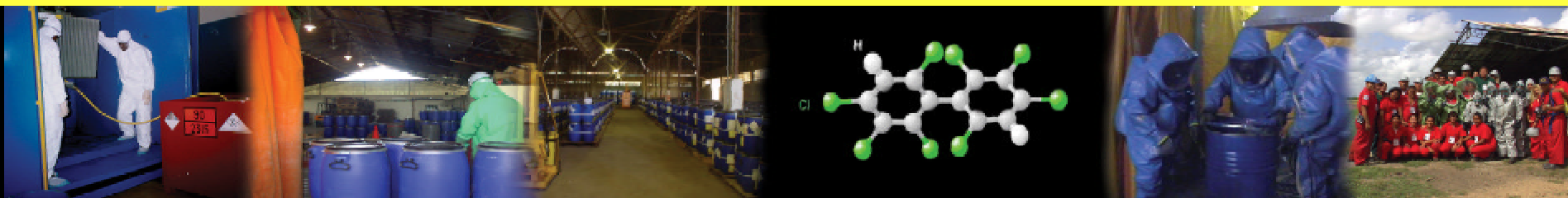


DESTRUCTION AND DECONTAMINATION TECHNOLOGIES FOR PCBs AND OTHER POPs WASTES UNDER THE BASEL CONVENTION

A Training Manual for Hazardous Waste Project Managers

Volume A

Secretariat of the Basel Convention



Destruction and Decontamination Technologies for PCBs and Other POPs Wastes

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- Part I. Basic Principles and Background**
- Part II. Project Strategies**
- Part III. Technology Selection Process**

**DESTRUCTION AND DECONTAMINATION
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Foreword

This Training Manual has been prepared by the University of Auckland, New Zealand in the context of the convening of the First Continental Conference for Africa on the Environmentally Sound Management of Unwanted Stocks of Hazardous Wastes and their Prevention, Rabat, Morocco, 8-12 January 2001.

It has been designed to assist those governments or organisations, not only in Africa, charged with the task of managing the destruction or decontamination of POPs (Persistent Organic Pollutants) with procedures that assist with the planning and selection of appropriate technologies that suit the particular circumstances whilst complying with the need for environmentally sound management principles and the principles of sustainability. In that context special consideration should be given to the local national frameworks and the responsibilities of the relevant competent authority.

New ideas and technologies are emerging rapidly and good practices are still evolving. The Training Manual however will remain useful in providing a selection process allowing new technologies to be evaluated under the provisions of the Training Manual and enabling organisations to continue to adopt new technologies as they become available. There are four parts to this Training Manual. Part Four is a detailed Field Application Training Manual to the handling and environmentally sound management of POPs as wastes covering obsolete pesticides and PCB's in particular.

The Training Manual should be considered in conjunction with other technical guidelines adopted by the Conference of the Parties to the Basel Convention and governing the environmentally sound management of hazardous wastes, in particular the Technical Guidelines on Wastes.

Comprising or Containing PCB's, PCTs, and PBB's (Y10), Technical Guidelines for Incineration on Land,(D10), Technical Guidelines for Specially Engineered Landfill (D5), and Technical Guidelines on Wastes collected from Households (Y46). The document should be considered in conjunction with other important guidelines such as the FAO Pesticide series.

The writer refers in particular to the Draft Technical Guidelines on the environmentally sound management of POPs wastes which, at the time of printing of this document, are being negotiated under the Basel Convention. Furthermore, this Training Manual aimed at providing practical training for waste managers should not be interpreted as preempting any of the principles, guidance and recommendations that will form part of the Technical Guidelines on the ESM of POPs wastes mentioned hereabove.

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How to use this Training Manual

This Training Manual is designed as a desk top manual for planners, project managers and government department staff. Its style aims to provide for ease of reference and absorption of complex ideas and areas of uncertainty. The Training Manual has been designed as a complete technical Training Manual for the management of POPs as waste in an Environmentally Sound Manner. This Training Manual not only covers the basic principles of hazardous waste such as POPs but seeks to provide a step by step Training Manual as to how such wastes are to be managed, packaged, stored, transported, decontaminated and disposed of. The step by step strategy culminates in a set of Work Procedure Instructions that will allow a party to establish and manage a POPs waste project. At the end of Part IV there is a sample set of Tender and Contract documents that a party can use to create a contract for the management and handling of a POPs project. This technical Training Manual is based on the integrated matrix system of waste management and no part of the project can be initiated without the preceding parts being carried out. The reader must understand that all parts of this Training Manual have been consolidated to form a management programme.

The Training Manual is designed to be used in several complementary ways:

- In creating a project strategy for disposal or decontamination
- In establishing the appropriate technology to be used
- In establishing a set of rules and methods to actually perform a destruction or decontamination project.
- In providing the principles for site establishment and the basis for an operational manual.

The Training Manual can help with

Planning

- understanding background and principles
- correct inventory collation
- inventory analysis

Writing project Plans

- produce an overall plan for disposal or decontamination

Technology Decision making

- appraisal of appropriate technology
- selection of technology for destruction or decontamination

Writing tender documents

- produce tender documents for destruction or decontamination

Hazardous waste project Implementation

- produce implementation plans

Project manual

- produce comprehensive destruction or decontamination manual

Structure of the Training Manual

I BASIC PRINCIPLES AND BACKGROUND

This section covers the background to the POP's problem and the actions of international organisations to deal with the toxic waste problems.

II POPs PROJECT STRATEGIES

The formulation of strategies for destruction and decontamination depends on the inventory analysis. When the information is available then the strategy selection process commences.

III TECHNOLOGY SELECTION PROCESS

When the destruction and decontamination strategy is in place then the specific technology decisions can be made and the appropriate technology selected. Several destruction and decontamination technologies are presented in this section

IV IMPLEMENTATION PROCESS

Tendering and project management documentation and plans. This section provides design guidance for site appraisals, packaging of hazardous wastes, storage, transportation as well as guidance for the destruction and decontamination processes.

Scope of the Training Manual

- The Training Manual can be used to prepare plans and strategies for the project management of hazardous waste projects involving intractable chemicals such as PCBs and other POP's.
- The scope is such that any organisation can use it to prepare simple plans for a small scale waste problem involving less than 5 tonnes of material or for a large scale operation involving say 5000 tonnes of material.
- In the final Part of the Training Manual there are planning guides so that large projects that demand a high standard of quality assurance are available.

PART I : BASIC PRINCIPLES AND BACKGROUND

Background

- Persistent Organic Pollutants (POPs) are chemical substances which are extremely stable, and are known to accumulate in biological tissue thereby posing a risk of adverse effects to human health and the environment. With the evidence of long-range transport of these substances to regions where they have never been used or produced and the consequent threats they pose to the global environment, the international community has on several occasions called for urgent global actions to reduce and eliminate releases of these chemicals.
- POPs, wastes fall under the scope of the Basel Convention which calls for the environmentally sound management of hazardous wastes and the control of their transboundary movements. The environmentally sound management conceptual framework as agreed and defined by the 5th meeting of the parties (Basel Convention, December 1999) is as follows; "Within the framework of integrated life-cycle management, prevention to the extent possible and minimise the generation of hazardous wastes, treat and dispose in such a way as they do not cause harm to health and the environment, and eliminate or reduce transboundary movements of hazardous wastes".
- In its decision 19/13C of February 7, 1997 the Governing Council (GC) requested that the Executive Director of the United Nations Programme (UNEP), together with relevant international organisations, convene an intergovernmental negotiating committee (INC). The INC was asked to prepare an internationally legally binding instrument for action on twelve specified POPs. The GC also requested that UNEP develop and share information on the following topics: alternatives to POPs, inventories of PCBs and available destruction technology, and sources of and management strategies for PCDD/PCDF. The negotiations under the INC led to the adoption of the Stockholm Convention in 2001.

Legislative Authority

- UNECE LRTAP POPs Protocol (Long Range Transboundary Pollution)
- Oslo-Paris Convention (NE Atlantic)
- Barcelona Resolution (Mediterranean)
- Arctic Environmental protection
- NAFTA/NACEC Resolution
- UNEP Global Programme of Action
- Stockholm Convention (2001)

- The twelve specified POPs covered by the Stockholm Convention are :
Pesticides: aldrin, dieldrin, DDT, endrin, heptachlor, hexachlorobenzene, mirex, toxaphene.
Industrial Chemicals: PCB,
By-Products: Dioxins and Furans
Pesticides and PCB are covered by this Training Manual .
- This Training Manual will attempt to provide the practical application of these sentiments while maintaining a realistic approach to destruction and decontamination. There are real issues involved with the treatment, decontamination and disposal of hazardous wastes particularly POPs and PCBs. This Training Manual will concentrate on POPs as waste and in particular PCBs and unwanted pesticides and will provide practical guidance to solving the issues of complexity that surround the Basel Convention statement on Environmentally sound management of POPs and PCBs. In parts of this Training Manual POPs are treated separately from PCBs as their situations and dispositions are different and require different approaches.

Unwanted and Obsolete Pesticides

- Obsolete pesticides are stored and unused pesticides that can no longer be used for their original intended use and therefore require disposal. There are many reasons for the existence of stocks of unwanted pesticides. These can range from the pesticide being banned and unsold stocks have remaining in storage, deterioration of the pesticides due to the length of time in storage or improper storage, the products suitability is unsatisfactory and can no longer be used for the original intended use, or other reasons such as chemical changes that make the product unusable. It is difficult to ascertain whether or not the pesticides product has become unusable. Generally it is not so difficult to ascertain if the product is unwanted. It may be however that the product while unwanted in one situation is capable of being used in another.

Key References

UNEP Basel Convention, 1989, Technical Guidelines for the Environmentally Sound management of PCB's
 FAO Pesticide Disposal series
 UNEP Chemicals Toolkit for Dioxins and Furans, 2000
 UNEP Stockholm Convention, 2001
 UNEP Basel Convention, Technical Guidelines for the Environmentally Sound Management of POPs Wastes (draft)

- Unwanted pesticides are a major problem in many countries. For decades obsolete and unwanted pesticide stockpiles have been building and accumulating in developing countries so that now it is estimated that there are more than 200,000 tonnes of such material located at thousands of sites all around the planet. Many of these chemicals (POPs) have long been banned or are unusable for other reasons. Today there are often found in dangerous storage conditions, leaking from rusted containers, contaminating ground water and soils and poisoning the health and environment of people everywhere.

POPs (PCBs)

- Polychlorinated Biphenyls are a class of chlorinated hydrocarbons that have been used extensively since 1930 for a variety of industrial uses. They consist of two benzene rings joined by a carbon-carbon bond with chlorine atoms substituted on any or all of the remaining carbon atoms. PCBs include mobile oily liquids and hard transparent resins, depending on the degree of substitution. PCBs are generally found either as stored liquid with contaminated equipment or still operating in the field. This Training Manual also covers PCB in either case.
- The value of PCBs derive from their chemical inertness, resistance, non flammability, low vapour pressure and high dielectric constant. As electricity came into widespread use during the first half of the 20th century, equipment suppliers became major users of PCBs. The major application involved PCB being used as a coolant and dielectric fluid in power transformers and capacitors.
- The uses of PCBs can be classified as either closed or open. In closed applications it was the intention to prevent any loss of PCB by containment within the sealed unit.

Declaration : New Zealand Government 1988

"Disposal of PCB wastes"

The Government's policy is that ALL PCBs shall be withdrawn from service in five years time. All owners of PCBs therefore need to prepare to replace existing equipment and to remove it to storage and ultimate disposal. Disposal of PCB oil and contaminated equipment shall be by high temperature incineration or by other approved method. Owners of PCB shall pay for all costs involved with the disposal of PCBs.

Contamination of the environment was the consequence of equipment leak. In open applications the PCB's were exposed to the environment, and some loss to the environment was inevitable. The major closed applications were coolants in transformers and dielectrics in capacitors.

- Between 1929 and 1989, total world production of PCBs was 1.5 million tonnes. After the US banned the manufacture or sale of PCB except in Closed systems in 1976 production continued at a rate of 16000 tonnes per year from 1980 to 1984 and some 10,000 tonnes per year from 1984 to 1989.
- Many of the characteristics that make PCBs ideal for industrial applications create problems when they are released into the environment. The effects on humans and the environment primarily follow continual exposure. Like many other chlorinated hydrocarbons, PCBs associate with the organic components of soils, sediments, and biological tissues, or with dissolved organic carbon in aquatic systems. PCB's volatilize from water surfaces in spite of their low vapour pressure, partly because of their hydrophobicity. The chemical properties of PCBs hampers their long range transport, and PCBs have been detected in Arctic air, water and organisms.
- Despite the cessation of production in many countries from the mid 70s, PCBs continue to be a pollutant of major concern on an international scale. There is still a substantial amount of PCB still in use. This results from the long lifetimes of power equipment such as transformers, and the exemption made in many countries for contained use for the lifetime. There are relatively high quantities in storage awaiting disposal.
- Part of the world production has been destroyed, part remains in use or awaits destruction, whilst a substantial proportion has been released into the environment. **Depending on the type and concentration levels there are several destruction and disposal options available.**

Sustainability

Sustainable engineering and technology focuses on pollution and the adaptation of cleaner production. Pollution prevention minimises effluents and waste streams from products and eliminates the need for treatment and control. Sustainable technologies are those that reduce pollution through significant technical advances. For communities to be sustainable they must be free from pollution in all its forms. This Training Manual attempts to integrate the elements of recovery and management of PCBs and POPs and dispose of them in a manner that is Sustainable. The Training Manual has detailed descriptions of example operating manuals for such activity and has descriptions of various destruction and decontamination technologies, including high temperature Incineration. It is the authors opinion that the plans and methodologies contained in this Training Manual provide for sustainable destruction and decontamination technologies for POPs and PCBs.

As the export of POPs as waste is not banned completely the concept of environmentally sound management of POPs whatever the place of disposal is valid. The principle of environmentally sound management of POPs provides that the wastes must be managed in such a way so as not to endanger human health and then environment. Whereas it is embodied in most relevant international legal instruments in a fairly vague and unspecified form it is given concrete content by reference to standards established by non binding technical guidelines or codes of conduct in the field. This document is written as a field application manual and provides a means by which environmentally sound management of POPs as waste is delivered.

POPs Toxicity (Agrochemical)

Chemicals including pesticides are widely distributed in the environment. Therefore there are many possible sources of exposure to these chemicals for humans. Substances which are in ambient or indoor air may be inhaled while those in water or food may be ingested or inhaled. Direct contact with the chemical is the most prevalent way environmental chemicals can penetrate the skin, but exposure through the skin may also occur as a result of contact with chemical contaminants in air and water.

A single agrochemical can enter the body through all three routes of exposure, inhalation, ingestion and skin penetration (dermal exposure). A pesticide can involve more than one route of exposure if precautions are not taken. A pesticide can be inhaled during use or repacking, penetrate the skin during handling and be ingested through food if not washed off hands etc.

Once a agrochemical enters the body, it is often absorbed into the bloodstream and can move throughout the body. The amount absorbed and the rate of absorption depends on the chemical involved and the means of exposure. This movement of the agrochemical through the bloodstream is called distribution. Through distribution a chemical can come into contact with all parts of the body, not only the original site of entry. In some cases, contact located far from the point of entry can lead to adverse health effects. For example the ingestion of the pesticide parathion into the stomach can lead to substantial damage to the lungs.

Once a agrochemical is absorbed into the bloodstream, it can have several different fates. In many cases, it is rapidly removed from the body. In other situations it may be stored in various parts of the body, such as fat or bone and remain in the individual for many years. A compound may also lead to a toxic effect through interaction with certain organs or tissues in the individual or with other compounds in the body.

Often a agrochemical which is absorbed into the body interacts with particular body chemicals and is changed into one or more other chemicals. This process is called metabolism.

The particular properties of the absorbed chemical are quite critical to its fate in the body. Certain Agrochemical are very resistant to metabolism and readily dissolve into fat and are then stored. Dieldrin is a good example of this type of compound. Other chemicals are more rapidly metabolised and excreted before they can cause adverse effects. The organophosphate pesticides tend to behave this way at low doses.

In the case of a single event exposure it is the total amount of agrochemical to which a person is exposed that determines the severity of the toxic effect if any. The greater the amount of exposure the greater the potential for adverse health effects. In some cases this is due to the inherent toxicity of the agrochemical and in others to the inability for the body to defend itself. In the latter case the body may not be able to metabolise the chemical rapidly enough to prevent an increase in concentration to toxic levels. In such a situation there is a clear threshold above which toxic signs and symptoms appear.

In the case of repeated multiple exposures to an agrochemical it is not only the total amount of exposure but also the rate or timing of exposure that is quite important. All processes in the body normally proceed at specific rates so that metabolism excretion and storage occur during a particular period of time after a chemical is absorbed. For one occurrence exposure the time needed for the various processes that breakdown the compound to be completed will determine the length of time that a toxic response if any persists.

However if there are repeated exposures to the same chemical the situation is more complicated. If there is enough time between so that all of the chemical from the initial exposure is excreted and no effects persist then each exposure is essentially independent of the previous one and can be treated as a single exposure. However if the time between exposures is so short that some of the chemical remains from the first exposure then a build-up can occur. Over time this build up can lead to levels that are toxic.

The total amount of exposure can have different results depending on whether the exposure occurred all at once or repeatedly over time. A high dose given once may have the same toxic effect while the same total given in small doses over time will not.

The possible toxic effects of exposure to a particular agrochemical depends on many factors. These include characterisation of the chemical and the individual exposed, the route of exposure, the total dose and the time course exposure. Unfortunately scientists have not been able to determine exactly how each of these factors will affect any specific individual so that present understanding of agrochemical exposures only provides general guidance.

The procedures specified in this manual are designed to minimise exposure and this minimise the potential for adverse health effects.

POPs PCBs Toxicity

Polychlorinated Biphenyls (PCBs) are a mixture of chemicals and may be clear to yellow oily liquids or solids, vapour is invisible, and PCBs are heavier than water.

PCBs are a group of Chlorinated Hydrocarbons. Up to 209 different compounds exist in the PCB group. PCBs have the chemical composition $C_{12}H_{10-n}Cl_n$. Specific chemical properties vary with the amount of chlorine.

PCBs are generally stable chemically and resistant to heat. They are fire-resistant, have a strong odour, are insoluble in water, and can be mixed with oils used in transformers and capacitors as insulating fluids ("Dielectrics"). Other uses included heat transfer fluids, hydraulic fluids, in brake linings, paints, sealants, varnishes, carbonless copy paper, cosmetics, etc.

PCBs do not break down readily. They persist in the environment and are absorbed by animals, and in fatty tissues. Once in the food chain they increase in concentration the further up the chain one goes ("Bioaccumulate").

As well as the risk from PCBs themselves, there is a risk from fires effect involving equipment containing PCBs. Such fires can produce toxic by-products including dioxin (Polychlorinated Dibenzoparadioxins, Poly Chlorinated Dibenzofurans and Hydrogen Chloride).

PCBs are thought to be hazardous to human health. The path of PCBs entering to the human body is by breathing, swallowing and passing through the skin.

No matter what, PCBs must be handled with extreme caution. Most commonly, inhalation of PCBs may lead to nausea and eye, nose and throat irritation. PCBs may also damage the liver.

High exposure to PCBs may damage the nervous system, causing numbness, weakness and tingling (pins and needles) in the arms and legs. Also high exposure to the skin may cause itching, sweating and burning sensations. Long-term high skin exposure may result in ridges in finger and toe-nails, acne and skin pigmentation.

High exposure through inhalation may irritate lungs and cause gastro-intestinal problems such as a reduced bowel capacity. Also the nervous system and skin problems mentioned above may be caused through inhalation in high exposure sites.

Research results do not confirm or conclusively show a causal relationship for the following effects :

1. PCBs may be teratogens (can cause fetal malformation in the first three months of pregnancy)
2. They may damage an adult's reproductive system.

The symptoms of high PCB levels in the body, as listed above, are often (and possibly erroneously) directly related to the concentration of PCBs in the blood.

PART II PROJECT STRATEGIES

The process to developing an Environmentally Sound Management Project strategy for destruction and decontamination is essentially the same for all POPs, PCBs and unwanted and obsolete pesticides. There are seven steps involved and these steps are the same for all. The Training Manual deals with each separately but follows the same seven steps.

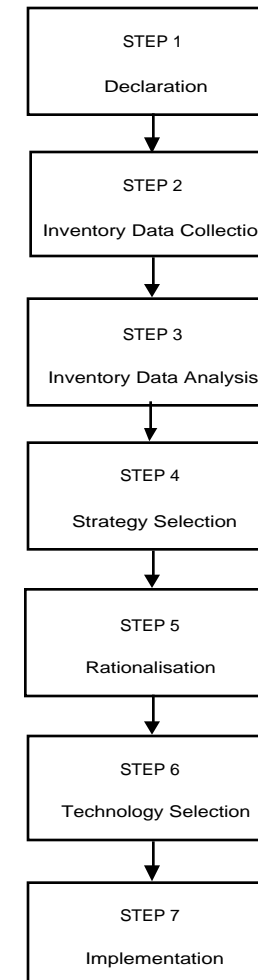
Step one	Declaration to dispose PCBs and POPs
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The decision to dispose is where the whole process starts. When a country or organisation decides that a POP or PCBs will be collected and disposed of and this is declared the entire process commences at the point of declaration. The important key issues at the point of declaration are also to state the boundaries of the disposal. Will it be only government agencies that have stock of PCBs or POPs or will it also cover private or public companies. Will stocks without owners be included and who will pay for the disposal. At the point of declaration the rules about end of service life for equipment contaminated with PCBs will need to be stated. The declaration of disposal needs to be short, clear and concise as to the boundaries of the project. Without a clear declaration it will be difficult to determine which stocks are to be disposed of and which are not. Once the declaration has been published then the project follows specific steps.

Step two	Inventory data collection POPs(PCBs)
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The process involved with determining and selecting an appropriate destruction or decontamination technique begins with the inventory stage. It is important to understand that the whole process of selecting the destruction or decontamination stage is entirely dependent on the quality and quantity of the information obtained during the inventory phase. It is not possible to correctly select an appropriate technology unless the inventory stage is rigorous and detailed. The range of concentration and disposition of PCB for instance is so vast that it is unacceptable to determine the destruction or decontamination technology without the inventory analysis being in place.

Steps for the Environmentally Sound Management of POPs as waste



Step two - Inventory data Collection POPs(PCBs) continued

When the inventory analysis is complete and the stock's size, concentration and disposition is known then and only then can the process begin in order to establish the appropriate technology or combination of technologies that will deal with the waste in a sustainable manner.

Depending on the inventory analysis there are many options available and this Training Manual will provide a method for working out the best technology and management plan as well as provide details of the available technologies.

The inventory data collection must be detailed enough to provide the following information. When collecting data for PCB inventory there are four fundamental questions to be asked.

What is it?

Where is it?

How much is there?

Who owns it?

These questions are answered by the provision of the following data against the following segments:

In service transformers

Out of service transformers

Inservice capacitors

out of service capacitors

Bulk storage tanks, drums and containers



Compiling a National PCB inventory

Scope

- determine the regions to be inventoried
- locate areas where PCBs are likely to be found
- divide areas into logical units to be inventoried

Selection of facilities to inventory

- select those facilities that are likely to have significant quantities of PCBs
- also consider facilities that may have disposed of PCBs inadequately

Facilities that may have PCBs

- electric utilities
- industrial facilities
- railroad systems
- military installations
- research labs
- manufacturing plants
- mining operations
- landfills

Priority facilities

- electric utilities, power companies
- electronics manufacturing
- petrochemical plants
- railroad systems
- transformer repair
- mining operations

Step two - Inventory Data Collection POPs(PCBs) Continued

For each of the segments there are several data required as follows.

In service transformers

KVA rating
Fluid qty
number (EPA)
Year of manufacture
weight

Brand name
location
PCB concentration
Scheduled year of replacement
status/owner

Out of service transformers

KVA rating
Fluid qty
number (EPA)
Year of manufacture
status/owner

Brand name
location
PCB Concentration
weight

In service capacitors

KVA Rating
Weight
location

Brand name
number (EPA)
status/owner

Out of service capacitors

KVA rating
weight
location

Brand by name
number (EPA)
status/owner

Bulk storage, drums, tanks etc.

Type
weight
PCB Concentration

location
fluid qty
status/owner

The data entry for status can include codes for leaking, stable, packed etc.

Which Inventory system to use

Self reporting or physical inventory

Considerations:-

- Scale of inventory
- how many facilities
- where are they located
- complexity of facilities
- responsiveness of industry

Self reporting management

- notifications
- education
- transmission of information
- handling of responses
- performing spot checks

Self reporting Notification/Education

- send forms and instructions to identified facilities
- use advertising
- contact professional and trade associations
- specify places to call for assistance

Transmission of PCB survey information

- to whom should you send forms?
- how long to wait for a response?
- how should you follow up?

Handling of Responses

- check form for completeness
- enter the information into the database
- devise a process to ensure quality of data

Step two - Inventory data Collection POPs (PCBs) Continued

Selecting the equipment to be inventoried

- must do
 - transformers
 - capacitors
- ought to do
 - hydraulic fluids
 - oil filled cables
- get information on
 - PCB containing wastes
 - Soil contamination

Determining if the equipment contains PCB.

- look for manufacturers label
- locate other records or information about the equipment
- apply assumption rules

Assumption rules

Transformers and capacitors with no information

Assume PCB

Transformers with mineral oil dielectric fluids and no other information

Assume PCB contaminated

Circuit breakers, voltage regulators, Fluorescent light ballasts with no information

Assume PCB contaminated.

Inspect service records

- determine if the equipment has been retrofilled
- if retrofilled obtain records ppm levels

Sampling and analysis

- direct sampling of dielectric fluids
 - from equipment drums etc.

Testing for PCBs

- simple screening tests (done on site using kits)

- density
- chlorine content

Laboratory testing

- gas chromatography

Communicating with facility management

- obtain co-operation of facility managers before conducting the inventory
- explain the purpose of the inventory
- schedule the inventory visit
- discuss equipment locations, if possible
- learn plant safety procedures

Conducting the inventory

- facility entry
- preinventory meeting with facility managers
- selecting the equipment to be inventoried
- working with facility managers to conduct the inventory
- inventoring
- sampling and analysis
- completing the inventory form
- post inventory meeting

Step two**Inventory Data collection
POPs and Unwanted and obsolete pesticides**

In many respects the inventory data collection for POPs other than PCBs including unwanted and obsolete pesticides is very similar to that of PCBs. The four questions are the same;

- What is it?
- Where is it?
- How much is there?
- Who owns it?

Whereas the testing and sampling of PCB is a relatively straight forward exercise, in the field for pesticides and POPs as waste in general it is a different matter. In many cases of long term storage of POPs and unwanted and obsolete pesticides the question "What is it?" becomes very difficult. However it is very important that during the inventory process the "what is it?" question is answered fully. There are many experts available that can readily identify the class of pesticides and agri-chemicals in general and at the very least the class must be identified. This is because unlike PCB the segregation of the various unwanted agri-chemicals classes is very important when the material is to be transported.

During the process of repackaging of POPs, waste streams must be kept separate and hence the inventory data collection process must identify the streams. A waste stream can be made up of separate types of waste so long as they are compatible with each other. The first step is to keep liquids and solids separated from the very beginning. The inventory data collection must therefore contain information that permits the construction of a segregation strategy which will eventually impact on the transportation strategies.

Pesticides are categorised into groups of pesticides, such as organic chlorine pesticides, organic phosphorus pesticides and pyrethroid pesticides. Pyrethroid pesticides have a low toxicity level, chlorinated pesticides are toxic, but not acute, phosphorus pesticides are acute toxic.

Class segregation rules

- (a) Formulations. All powder, liquid and aerosol formulations of agri-chemicals shall be kept segregated.
- (b) Herbicides. All herbicides should be stored in a segregated area of the store, and on their own, to prevent cross contamination.
- (c) Sodium Chlorate/Potassium Chlorate. These are scheduled class oxidising agents and must be segregated in storage so that they do not come into contact and react with any combustible materials, or acids.
- (d) Pool chemicals. Calcium hypochlorite shall not be stored with any agri-chemicals (or any other chemical) as contamination can cause spontaneous explosion.
- (e) Soil Fumigants. Methyl bromide, chloropicrin, dichloropropane, dichloropropene and other soil fumigants shall be segregated in storage so that they cannot come into contact with any other chemical at any time.
- (f) Lubricants, Brake fluids Under no circumstances shall these be stored with any agri-chemicals.
- (g) Potassium, calcium and ammonia nitrate fertilisers. Under no circumstances shall these fertilisers be stored with agri-chemicals.

Step two - Inventory Data Collection - POPs and Unwanted Pesticides (Cont)

Inventory data for unwanted and obsolete pesticides should include:

- location
- classes and type of material
- weight and volumes of each material
- Owner information
- storage situation
- leakage and contamination information
- product information - active ingredient, formulation, concentration
- product age and condition

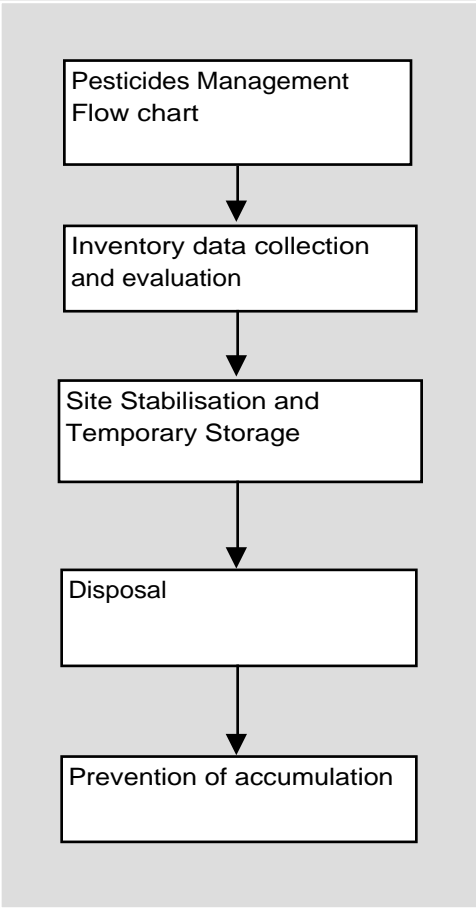
As for PCBs the inventory data collection for other POPs is the starting point for the formulation of a project plan to deal with the unwanted and obsolete pesticides. An additional factor for a pesticides project is site stabilisation. During the inventory data collection information is collected that provides details of the site situation and disposition of the chemicals so that during the project activity a stabilisation of the site can be applied. Within the project plans outlined in this Training Manual this is covered in the site clearance and site preparation plans.

FAO STANDARD INVENTORY FORMS FOR RECORDING OBSOLETE PESTICIDES

Product Form

A product sheet needs to be completed for each product (if one product is kept in different types of containers, one sheet should be completed for each type of container)

SHEET NUMBER: DATE:
 OWNER OF PRODUCT: STORAGE SITE:
 LABELS ON CONTAINERS:
 TRADE NAME: ACTIVE INGREDIENT(S):
 FORMULATION TYPE: CONCENTRATION: g/litre or g/kg
 MANUFACTURER: BATCH NUMBER:
 MANUFACTURE DATE: ARRIVAL DATE:
 CONTAINER TYPE: UNIT SIZE:
 NUMBER OF CONTAINERS: QUANTITY:
 ORIGIN: purchased by Government / received as donation (name donor):
 imported by private company (name company):
 CONDITION OF PESTICIDE: usable / unknown / deteriorated
 CONDITION OF CONTAINERS: good/ minor damage / serious damage
 transportable / not transportable
 description of damage:
 HAVE CONTAINERS BEEN OPENED? yes / some / no / not certain
 REASON FOR NOT USING THE PRODUCT:
 expired / deteriorated / banned / wrong formulation
 no need / stock too large / no longer recommended
 Other:
 REMARKS:



Step three	Inventory Analysis POPs (PCBs)
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The information contained in the inventory analysis allows us to commence the planning required to derive a destruction and decontamination strategy. There are several steps to this phase.

Inventory Analysis Step 2 - Data Breakdown

With the data collected during the inventory phase a breakdown of the information is required. This breakdown is designed to discover the size and nature of the waste material so that groupings can be assigned so that the appropriate technology selection process can be applied. Ultimately there are two overall categories. The first is material that is to be decontaminated and the second is material for destruction. It is very important to get the waste PCB properly assigned so that the appropriate technology can be selected. While the inventory data may refer to simply PCB transformer it is necessary to know the amounts and the concentrations of PCB as this will have a material effect on the technology selected to either decontaminate the transformer or to export it for destruction.

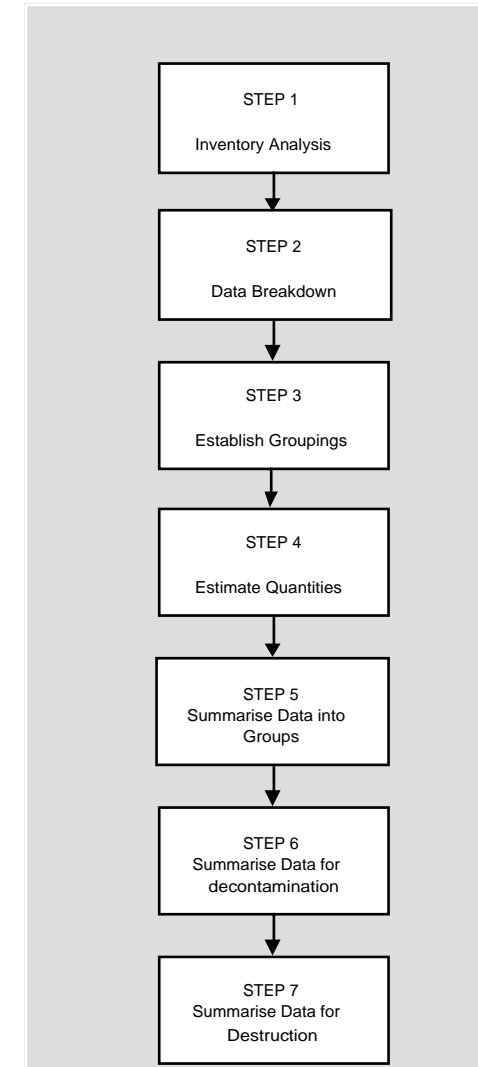
Inventory Analysis Step 3 - Establish groupings

For PCB contaminated equipment it is necessary to establish groupings for the waste to be categorized into. The groupings below are a suggestion for likely groupings that are based on appropriate technology for the decontamination or destruction of the PCB. The groupings should be laid out on a matrix so that amounts can be entered into and then the summarising can be done.

Likely PCB groupings

- Gp 1 In service transformers (all sizes) with less than 50ppm PCB
- Gp 2 In service transformers (less than 500KVA) with 50-5,000 ppm
- Gp 3 In service transformers (less than 500KVA) with 5,000-50,000 ppm
- Gp 4 In service transformers (More than 500KVA) with 50-5,000 ppm
- Gp 5 In service transformers (more than 500KVA) with 5,000-50,000ppm
- Gp 6 In service transformers (more than 500KVA with 50,000-900,000ppm)

Inventory Analysis process for POPs (PCBs)



Step three	Inventory Analysis (Cont) POPs (PCBs)
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- Gp 7 Out of Service transformers (all sizes) with less than 50ppm
- Gp 8 Out of service transformers (less than 500KVA) with 50-5,000ppm
- Gp 9 Out of service transformers (less than 500KVA) with 5,000-50,000ppm
- Gp 10 Out of service transformers (less than 500KVA) with 50,000-900,000ppm
- Gp 11 Out of service transformers (more than 500KVA) with less than 50ppm
- Gp 12 Out of service transformers (more than 500KVA) with 50-5,000ppm
- Gp 13 Out of service transformers (more than 500KVA) with 5,000-50,000ppm
- Gp 14 Out of service transformers (more than 500KVA) with 50,000-900,000ppm
- GP 15 Empty out of service transformers
- Gp 16 In service Capacitors
- Gp 17 Out of Service capacitors
- Gp 18 Storage tanks with oil less than 50ppm
- Gp 19 Storage tanks with oil greater than 50ppm



Photo : Type 7 storage

This grouping breakdown is placed on a matrix with the quantities from the inventory analysis and then the matrix is passed to the next step in the process which is the strategy selection.

Step 2 Data Breakdown involves the organising of the inventory data types and quantities into the grouping.

PCB Inventory Analysis - Step 2 Data Breakdown

PCB	Manu	Type	Service	Owner	KVA/r	Total	Oil Wt	Oil Qty	PCB	Gp
Type		No.	No.			Weight Kg	Kg	Litres	ppm	
T/F	ABB	TM	134	TPC	250	450	185	250	<50	1
T/F	Tyree	OB	145	TPC	5000	12500	2500	4000	>50000	6
Caps	T&J	TYT	1485	PDC	125	60	25	35	5000	16

Step three	Inventory Analysis (Cont) POPs (PCBs)
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PCB Inventory Analysis - Step 4 Estimate quantities

	Oil Wt	Oil Qty	PCB	Gp	Qty Decon	Qty Decon	Qty Destr
	Kg	Litres	ppm		Oil Kg	Mat Kg	PCB Kg
	185	250	<50	1	185	265	0
	2500	4000	>50000	6	2500	10000	2500
	25	35	5000	16	25	55	55



Photo : Type 10 Storage

PCB Inventory Analysis - Step 5 Summarise data

Gp	Qty Decon	Qty Decon	Qty Destr
	Oil Kg	Mat Kg	PCB Kg
1	2560	9562	0
2	3540	10000	3540
3	2687	55	55
4	15000	28000	15000
5	29500	48900	29500
6	16500	29500	16500

Step 4 Inventory analysis involves estimating the quantities of PCB oil and PCB contaminated materials

Step 5 Inventory analysis involves reordering the data into the group total quantities and summarised across decontamination and destruction.

Step three	Inventory Analysis (Cont) POPs (PCBs)
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PCB Inventory Analysis - Step 6 Decontamination

Gp	Qty Decon		Total
	Oil Kg	Mat Kg	Decxon Kg
1	2560	9562	12122
2	0	10000	10000
3	2687	55	2742
4	0	28000	28000
5	0	48900	48900
6	0	29500	29500
		TOTAL	131,264



Photo : Type 6 Storage

Step 6 Inventory analysis involves summarizing the total amount to be decontaminated

PCB Inventory Analysis - Step 7 Destruction

Gp	Qty Decon		Total
	Oil Kg	Mat Kg	Destr Kg
1	0	0	0
2	3540	0	3540
3	0	0	0
4	15000	0	15000
5	29500	0	29500
6	16500	0	16500
		TOTAL	64,540

Step 7 Inventory Analysis involves summarising the amount to be destroyed

Step 3

Inventory Analysis

POPs (Unwanted and Obsolete pesticides)

The analysis for unwanted pesticides and POPs is somewhat simpler than for PCBs. Generally the waste falls into the broad classes of segregation and in the main these products must be exported for destruction rather than local decontamination. Decontamination procedures may be required for soil and water clean up and this in the main involves extraction of the contaminated soil rather than treatment of it. There are some technologies however that can be used in situ for soil contaminated with pesticides and involve bioremediation or phytoremediation.

The analysis must provide detailed summaries of the quantities of stored waste and the location and disposition of it. Whereas the inventory analysis for PCBs generally falls into two categories, decontamination or destruction, the analysis of inventory for pesticides should be broadly placed into the four categories as follows;

Obsolete products requiring disposal

Products requiring further identification and testing

Usable products

Usable after reformulation



Obsolete products requiring disposal

- products that are banned
- Products that are deteriorated beyond usability
- Products that testing has show to beyond usability
- Contaminated products rendering them unusable

Products requiring further identification

- Unidentified products
- Older products passed use by dates

Usable products

- Use is still permitted and not unusable

Usable after reformulation

- Products in good condition but need reformulating so they can be reused.

Step 4	Strategy Selection POPs (PCBs)
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The quality of the inventory analysis becomes important at this stage. So that the correct technology is selected that data contained in the matrix from stages 1,2 and 3 must be accurate.

The actual grouping make up will also have a bearing on the combination of technology selection. If there is much more of one grouping over another then a single technology may be chosen to cover all the stock.

The possible technology selections for PCBs that can be made against each of the groupings above are as follows:

Gp1 In service transformers (all sizes) with less than 50ppm PCB

In general in service transformers with less than 50ppm may be left in service and not touched. Retrofilling is possible but this creates stocks of lightly contaminated oil. In the main most countries prefer to treat below 50ppm as not PCB. From an environmentally sound management point of view with retrofilling producing stocks of contaminated oil the best option is to leave the less than 50ppm as it is.

Gp2 In service transformers (less than 500KVA) with 50-5,000 ppm

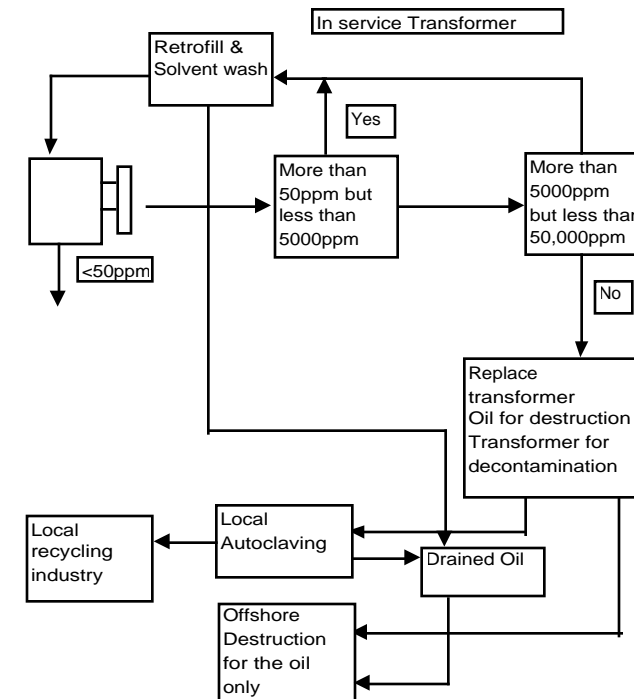
For transformers in service with less than 5000ppm retrofilling is cost effective and valid with in situ treatment not cost effective for transformers of this size.

Gp 3 In service transformers (less than 500KVA) with 5,000-50,000 ppm

Retrofilling with in situ treatment of solvent washing or bio reaction and circulating polishing with Perchloroethylene. Also replacement option is valid

Gp 4 In service transformers (More than 500KVA) with 50-5,000 ppm

Retrofilling with in situ treatment is required due to the size of the transformers and the capacity for long term leaching. Removed oil which may be up two two times the transformer capacity will require to be destroyed. Replacement option not valid due to high capital cost and destruction costs.



Note : Only Oil, Internal Transformer cardboard, wood and ceramics etc is ever destroyed. All other transformer components, steel, copper, aluminium are recovered and recycled.

Step 4 - Strategy Selection - POPs - PCBs (Cont)

Gp 5 In service transformers (more than 500KVA) with 5,000-50,000ppm

Retrofilling with in situ treatment for residual leaching. Recovered contaminated oil must go for destruction.

Gp 6 In service transformers (more than 500KVA) with 50,000-900,000ppm

Oil for destruction and transformer for decontamination and recycling after autoclaving.

Gp 7 Out of Service transformers (all sizes) with less than 50ppm

Oil for destruction, transformer may be reused or recycled

Gp 8 Out of service transformers (less than 500KVA) with 50-5,000ppm

Oil for destruction, transformer for solvent washing and reused or recycled

Gp 9 Out of service transformers (less than 500KVA) with 5,000-50,000ppm

Drain Oil for destruction, transformer to autoclaving, solvent washing and recycling

Gp 10 Out of service transformers (less than 500KVA) with 50,000-900,000ppm

Drain Oil for destruction, transformer for autoclaving, solvent washing and recycling

Gp 11 Out of service transformers (more than 500KVA) with less than 50ppm

Drain oil for destruction, transformer for autoclaving, solvent washing and recycling

Gp 12 Out of service transformers (more than 500KVA) with 50-5,000ppm

Drain oil for destruction, transformer for autoclaving, solvent washing and recycling

Gp 13 Out of service transformers (more than 500KVA) with 5,000-50,000ppm

Drain oil for destruction, transformer to solvent washing, autoclaving and recycling



Photo:Type 1 Storage

Step 4 Strategy selection - POPs - PCBs (Cont)

Gp 14 Out of service transformers (more than 500KVA) with 50,000-900,000ppm

Drain oil for destruction, transformer for autoclaving and recycling

GP 15 Empty out of service transformers

Autoclaving and/or solvent washing and recycling

Gp 16 In service Capacitors

Remove and send for shredding and destruction or autoclaving

Gp 17 Out of Service capacitors

Shredding and autoclaving or destruction

Gp 18 Storage tanks with oil less than 50ppm

No action

Gp 19 Storage tanks with oil greater than 50ppm

Drain oil for destruction, solvent wash tank.



Photo : Temporary bunding for transformer decanting

Step 4

Strategy selection
POPs Unwanted Pesticides

Compared to management of PCBs unwanted and obsolete pesticides have another step that must be applied before the disposal strategy is selected. This involves site stabilisation. Generally it is helpful if this process is done with the inventory and data collection phase but in reality it is done at a later date. Stabilisation of sites is necessary to reduce further loss to the environment and increasing risks to the local population and site workers. Site stabilisation involves repackaging of the unwanted chemicals that are leaking from unstable and deteriorated containers. Site stabilisation also involved segregation of classes and separation of dangerous combinations. It is during this phase along with the information from the inventory analysis that the strategy selection for destruction and decontamination can commence.

In the main for unwanted and obsolete pesticides and POPs in general decontamination is not an option apart for contaminated soils. Destruction is required for those products that cannot be reused as they are, or reused after reformulation. The disposal or destruction method chosen will depend on the type and quality of product involved and local circumstances. While a destruction technology may be suitable for one situation it may be unsuitable for another. This means that the process of formulating a strategy will have to consider the combination of the technology and the chemicals involved at the particular site.

The five main alternatives for strategy selection are :

- high temperature incineration
- landfill
- chemical treatment
- long term storage
- ball milling

These alternatives are discussed in PART III of the Training Manual.



Step 5**Rationalisation
PCBs**

Given the amount of PCB oil to be disposed of, should the country import the technology to incinerate the oil using a mobile incinerator or due to the low quantities should it be exported to another country that is set up with incineration facilities. Would it be feasible to import Plasma Arc technology and dispose within the country. What are the issues of dioxins and furans that impinge on this decision and are they managed by the chosen technology. Is storage long term a feasible option so that when a cheaper more friendly option is available then disposal can occur. Should the country import dechlorination, solvent washing, autoclaving technology or biotech technologies to decontaminate the PCB equipment? Can the recycling business cope with the materials from the autoclaving process. All of these decisions depend on the quantity of the material, the concentration (PCBs) of the material, the infrastructure available within the country and the logistical framework necessary to handle the project. The steps involved in the rationalisation activity are as follows:

- After the basic strategy selection has been performed the matrix is updated to show the reality of the chosen strategies and thus the quantities of materials that will be available to each part of the chosen strategies.
- It is then appropriate to rationalise the process by examining the matrix to see where the bulk of the material lies and determine where a particular group may be combined with another group as far as treatment is concerned.
- Major decisions are made at this point based on the reality of the country situation and the disposition and size of the waste to be disposed. It is during this stage that the requirements of environmentally sound management are delivered. Decisions in this step include;
- export all or part of the PCBs

Extracts from the Basel Convention

(d) Ensure that the Transboundary movement of hazardous wastes and other wastes is reduced to a minimum consistent with the environmentally sound and efficient management of such wastes , and is conducted in a manner that will protect human health and the environment against the adverse effects which may result from such movement:

(e) Not allow the the export of hazardous waste or other wastes to a State or group of States belonging to an economic and/or political integration organisation that are Parties , particularly developing countries, which have prohibited by their legislation all imports, or if it has reason to believe that the wastes in question will not be managed in an environmentally sound manner, according to criteria to be decided on by the Parties at their first meeting.

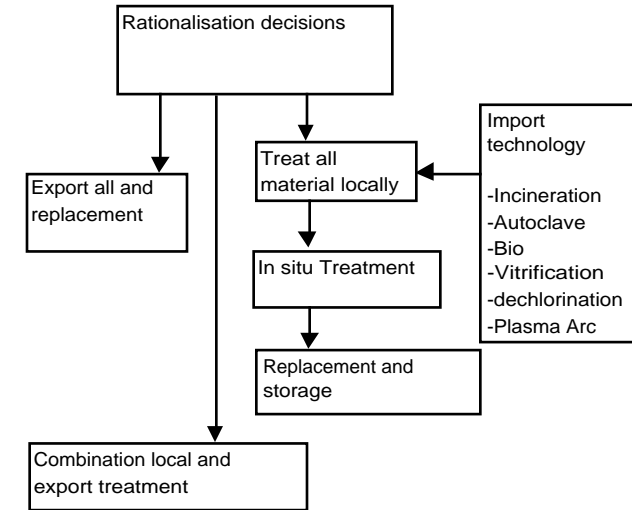
(f) Require that information about proposed Transboundary movement of hazardous wastes and other wastes be provided to the States concerned according to annex V.A to State clearly the effects of the proposed movement on human health and environment:

(g) Prevent the import of hazardous wastes and other wastes if it has reason to believe that the wastes in question will not be managed in an environmentally sound manner:

Step 5 - Rationalisation - PCBs (Cont)

- Construct or import PCBs destruction or decontamination technology
- remove PCB contaminated equipment from service or leave in situ and treat

All of these questions and decisions must be framed within the concept of environmentally sound management, minimisation of transboundary movements, sustainability and sound management practice as well as economic considerations. A balance must be achieved here that provides a solution that is best for all the elements described. It will not be possible to satisfy all of the requirements. It may be that the best environmentally sound management solution involves total export because the rationalisation analysis has indicated that it is not technically feasible nor economically feasible to develop an indigenous technology or import a technology to dispose of small amounts of highly contaminated PCB oil. On the other hand it may be feasible to import autoclaving systems to take care of decontamination of empty transformers with the concentrated PCB oil being exported for destruction. These are the decision that can only be made after the rationalisation procedure is complete and that procedure is dependent on an accurate inventory analysis.



Step 5

Rationalisation

POPs - Unwanted or obsolete pesticides

In a similar manner to that of rationalisation for PCBs, POPs and unwanted or obsolete pesticides must go through rationalisation. Because unwanted or obsolete pesticides are generally sent for destruction the rationalisation involves the feasibility of the various options open to the country involved. If high temperature incineration is chosen should it be a mobile machine imported to the country or should the waste travel overseas to a developed country that provides a service of destruction using a HTI. It is usually not an option for a developing country to consider constructing its own high temperature incinerator as a fixed plant. The cost for this is prohibitive and there are issues related to operational safety and training etc. It is feasible to import a mobile High temperature incinerator that can be transported from site to site should there be sufficient material available to make it economic. Quantities at each site would need to be in the order of 7000 tonnes for this option to be successful.

Cement kilns can provide a useful alternative for purpose built HTI but it needs to be a rotary kiln with appropriate gas treatment systems such as an electrostatic precipitator. Often the owner of the cement kiln will not allow its use for pesticide destruction. The time taken to evaluate and determine such kilns can be used usually exceeds that required for other options.

Export to a HTI incinerator in a developed country is a valid option for all quantities from one tonne to 10,000 tonnes and more. These days the cost of HTI incineration for pesticides is very competitive and is the preferred technology at this time.

In situ chemical treatment is an option but there are many problems associated with performing treatment within developing countries. Generally it is often not cost effective when compared to incineration and difficult to ensure environmental protection during treatment. Chemical treatment is generally viewed as simply preparing the product for further treatment such as landfilling or incineration rather than an end in itself.



Ball milling is an emerging technology that has huge promise for on site treatment and destruction of obsolete pesticides - details in Part III

Step 5**Rationalization Project Strategy Management**

For hazardous waste projects of some size there needs to be a project management strategy for the implementation of the strategies chosen. While PART IV has a full set of implementation plans there needs to be an understanding of basic project management and that is defined here, There are five distinct areas that are required to be “managed” so that the waste project is successfully completed. These five areas of the waste project areas that must be managed by the project team and they are described as management functions.

Managing Scope

Managing Project Organisation

Managing Quality

Managing Cost

Managing Time

Each of these elements is delivered within the Implementation plans in PART IV.

Within each of these five elements is the element of risk management and this is discussed separately.

Before these elements are considered the project definition must be formulated. The project definition initiates the project and therefore relates the work to projects objectives.

Step 5

Rationalization Project Strategy Management (Cont)

Managing the Scope

Scope management is often the most overlooked aspect of project management. It is within this element that the project objectives are set and generally where the biggest failure component occurs. It is within the definition of scope and its subsequent management that the true direction of the boards intentions can be lost. The purpose of scope management can be summarised as follows:

The management of the project scope shall be defined so that the activity engaged ensures that enough, but only enough, work is undertaken to deliver the project's purpose.

Within this definition are three key elements (J Turner) :

- an adequate, or sufficient, amount of work is done
- unnecessary work is not done
- the work that is done delivers the stated business purpose

There are four steps to make this definition a reality for this project and they are:

1) Develop the concept through the projects objectives

2) Define the scope through the work breakdown structure

3) Authorise and execute the work, and monitor and control progress

4) Commission the facility to produce the system and obtain the benefits.

Step 5 Rationalization Project Strategy Management (Cont)

The main emphasis is at the start of this process, as the mistakes made here are rarely corrected. Item 3 above is the purpose behind the “Ownership” of the project. The development of the Project Concept (1) is a critical issue and this must be properly completed after the project leader has had the opportunity to evaluate the site situation .

Work Breakdown structure (2) is a process by which during the first stage of formulating the management of the project the work of the project is divided and subdivided for management and control purposes. In preference to breaking the project into a low level of detailed in a single step the idea is to devolve through increasing levels of detail. Therefore the work breakdown structure is developed by breaking the project into intermediate and sub project steps and the work required to execute that sub group is identified.

There are three fundamental levels of work breakdown:

Integrated
Strategic
Detail



Step 5

Rationalization Project Strategy Management (Cont)

For this project due to its nature of involving the entire Business the Work breakdown must start at the first Breakdown level and progress down. As it devolves downwards then the detail level breaks down into project phase, task, activity etc and there will be probably about seven levels that are finally listed. This process as mentioned devolves as the project unfolds and the detail of the project becomes clearer as a result of the business purpose clarification.

The advantages of the Work Breakdown concept are:

- It provides better control of work definitions
- It allows work to be delegated in coherent packages
- It allows work to be defined at an appropriate level for estimating and control of the current stage
- It allows risk to be contained within the work breakdown structure

The use of work breakdown structures will satisfy the principles of good management:

- 1 Manage through a structured breakdown of the project
- 2 Focus on results: what to achieve and how to achieve it
- 3 Balance results through the work breakdown, between areas of technology, people, systems and organisation
- 4 Organise a contract between all the parties involved, by defining their role, responsibilities and working relationships
- 5 Adopt a clear and simple reporting structure

In order to create the work breakdown the process of defining the project must be carried out :

Defining Projects

The project definition always has the role of initiating the project and therefore as previously mentioned relates the work of the project to management's requirements. The following three requirements should be defined:

- the purpose
- the scope
- the objectives

Step 5**Rationalization Project Strategy Management (Cont)**

The purpose statement should be clear and concise and once the project is underway it will become the mission of all those involved in the project, both as team members and as resource providers.

The scope is an initial high level description of the way in which the purpose will be commissioned.

The Statement of Scope should include two elements:

- The work that falls within the remit of the project and is required to achieve the benefits
- the work that falls outside of the remit of the project

The objectives should be quantitative and qualitative measures by which the completion of the project will be judged. In effect they define the outcome that will be produced. The objectives should address:

- address all the work within the scope of the project
- not address work outside of the scope of the project
- begin to set the parameters for managing quality, cost and time.

Summary of Managing Scope

The purpose of scope of management methodology is to ensure that :

- adequate work is done
- unnecessary work is not done
- the project's purpose is achieved

There are four steps of scope management:

- develop the concept through the projects objectives
- define the scope through the work breakdown structure
- authorise and execute the work, and monitor and control progress
- commission the project and produce the benefit

Work breakdown is a process by which the work is subdivided for management,control purposes and logical arrangement purposes.

The project is defined at the strategic level through;

- the purpose
- the Scope inclusions and exclusions

- the objectives

At the strategic level the Milestones plan:

- shows how the deliverables build towards the final objectives
- sets a stable framework
- controls the unfolding and devolution of the management of the scope

A good milestone plan

- is clear, simple and concise
- focusses on necessary sections
- gives an overview of the project

There are seven steps in milestone planning

- agree the final milestone
- brainstorm milestones
- review the list
- experiment with result paths
- draw the logical dependencies
- make the final plan

Plans at the lower level include:

- subsidiary milestones plans
- work package scope statements
- activity plans developed on a rolling wave basis.

Managing Project Organisation

The next major project management objective is that related to managing the project Organisation. Through this process the project Manager defines the type and level of resources inputs, and how they are to be managed in order to achieve the purpose of the project that has been stated in the management of scope.

When the Scope and the Organisation have been fully defined they represent the Project Contract that then exists between the project team and the Corporate Management.

The purposes, principles and processes of project organisation are defined as below;

Project Organisation Purpose is defined for this project as follows:

to assemble sufficient resources (human, material and financial) of the appropriate type and quality to undertake the work of the project and to deliver the strategic intention of the project.

Three of the principles of good project management are discharged by the management of the project organisation:

- negotiate a contract between all parties
- assign roles and responsibilities at all levels of work breakdown
- adopt a clear and simple reporting structure

Negotiating Contracts

The Project must establish an organisational structure and the project manager must establish a contract between all parties involved at all levels as follows:

- between Management and the Project Manager Level
- between the parties making up the PCG at the Strategic Level
- between the members of the project team at the tactical level

The project manager is responsible for negotiating the “Contracts” by building a clear vision of the project and devolving that mission or vision down to objectives at each level of the organisational structure.

Defining Roles and responsibilities

The “Contract” is defined by the process of defining roles and responsibilities of the parties involved for the work elements at each level of the breakdown. This can take the following format;

For work	Who is to undertake the task
For management	Who is to make decisions
	Who is to manage progress
	Who Training Manuals new resources
For Communication	Who must provide information and opinions
	Who may provide information and knowledge
	Who must be informed of outcomes

The responsibility chart should be kept simple and clear. It should be a single page defining resources and inputs. It defines the “Contracts” at all levels of breakdown and is the document against which the “contracts” are negotiated and agreed. The responsibility chart is the document that is used to foster cooperation and ensure that the project operation is brought on quickly and effectively.

The use of a responsibility chart is now widespread in project management of the project type that water is engaged in. Typically the chart is a matrix with work elements shown as rows and organisational elements as columns. Symbols placed in the body of the matrix show the level of involvement of a particular organisational unit. Communications assisted by the use of identification letters as shown on the sample responsibility chart attached with the report.

Step 5 Rationalization Project Strategy Management (Cont)

Use of the Responsibility chart

This chart can be used at all levels within the Work Breakdown Structure. Specifically it can be used in three fundamental levels.

Project level : Procedural Responsibility Chart

This level is used for defining procedures to be employed on the project and include:

- procedures for monitoring and control
- change control procedures
- quality control procedures

Strategic Level : Milestone responsibility chart

This level is used for defining roles and responsibilities for achieving milestones. Sometimes both milestones and procedures can be used on the same page and the two levels are then merged into one management level.

Tactical Level : Activity schedule

At this level the responsibility chart defines the roles and responsibilities of named people and resources to do the work to achieve a milestone. Because these activity schedules are to be planned on a rolling wave basis during implementation planning, the people involved can now be named. As previously described the Milestone plan is developed during the initial stages by group negotiation and agreement. The same principle applies to the responsibility chart. By using the group principle all inputs from all members can be integrated into the responsibility chart result and then the end product is bought by all. The responsibility chart is built up after the Milestones chart which is after the Work Breakdown Structure.

Summary of Managing project Organisation

The purpose of project organisation is:

- assemble adequate resources
- to execute the work of the project
- the ensure successful outcome

The principle elements of Organisational management are;

- the contract between the parties involved
- organisational breakdown structure which matches the work breakdown
- responsibility charts

There are two critical elements when choosing an organisational structure:

- type of organisational structure
- location of resources

The Contract requires recording estimates of work content, so that resource providers can commit themselves to the release of their people.

Drawings, materials, plant and equipment are managed using registers and lists against the activities in which they are required.

Step 5 Rationalization Project Strategy Management (Cont)

Managing Quality

Quality is the first project constraint. The scope and organisation sections mentioned above are the primary project objectives and the methodology required to achieve them. The next three sections refer to the constraints on the project and the methodology required to manage them. The first constraint on the project is that related to quality.

There are two aspects of quality that must be managed. The first is that quality aspect that involves the work, materials, drawings, equipment etc of the project. The second aspect is that related to the management of the project itself. The quality management of the project management structure, the quality maintenance of the responsibility chart and the work Breakdown structures etc. The second aspect of quality involves all aspects of the internal documentation, communications and reporting systems and the on line tracking of the project against the corporate strategy etc.

Project Quality

Project quality has traditionally been a difficult concept to define within the concepts of the project itself. Obviously a definition of project quality is required for this project if it is to have any use at all. J Turner defines quality as a concept that has three essential elements:

- good quality vs High quality
- fitness for purpose
- conforming to the project requirement

Good Quality Vs High quality

Good quality does not imply High quality. It means supplying a product or service to a standard or a specification and thus supplying what the end user wants, with a predictable degree of reliability and uniformity at a price that is acceptable.

Fitness of Purpose

The concept is often adopted as a measure of good quality and it can be applied equally well whether the facility produced is an organisational change, an information system or an engineering product. The project that is the subject of this methodology is an integrated example of all of these.

Conforming to the project requirement

Saying something is fit for the purpose begs the question of who makes the judgment. The answer to this of course is management and this implies that quality means meeting management's requirement or specification. This is the definition of quality that is now normally applied. In order to set the measure of quality it is therefore necessary to set out management's requirement in advance in a formal document or specification. This usually takes the form of a Statement of User requirement and is part of the project definition report.

In order to assure the quality of the project it is essential to have the following:

- a clear specification
- use of defined standards
- historical experience
- qualified resources
- impartial design reviews
- change control

Assuring the quality of the management processes

This is similar to that applied to the project output itself and it means having a set of defined procedures for managing projects. Procedures clearly specify how projects are to be

managed by qualified resources. This can be own experience or standard practice.

In this type of project it would be beneficial to apply the ISO 9001 standards for quality assurance on the management processes. This will mean automatically many of the project quality issues will be covered by the ISO approach as the management has total responsibility for all aspects of the project including such matters as quality control over drawings and design decisions etc.

Summary of management of Quality

There are five quality elements to total quality management on projects

- quality of the design
- quality of the management processes
- quality assurance
- quality control
- the right attitude

Assuring the quality of the project requires

- a clear specification
- use of defined standards
- historical experience
- qualified resources
- impartial design reviews
- change control

Controlling the quality of the project must be:

- planned
- tested
- recorded
- analysed
- independent

Assuring the quality of the management processes requires defined procedures for managing projects, which are fully implemented. These procedures can then be used to conduct audits to control the quality of the management processes.

The Standard to be used for this project should be ISO 9001 Quality Management Systems.

Managing Cost

This is the fourth project objective managing cost by which the project manager ensure that the project cost is financially viable, worthwhile and within the project budget constraints.

Normally this process would start at the estimating of the project costs but this has already been performed for the approval stage. While a budget approval has been received it is the project managers responsibility to control all aspects of the total budget so that costs do not run out of control.

The activity that is performed during the setting of the Work Breakdown Structure leans itself to applying the cost estimates so that the monitoring system can be applied. In addition to this the business unit runs its own counter cost system and this will be run in parallel to the managing cost regime.

Controlling Costs : Obtaining Value for Money

The common mistake that many project managers make and a mistake that often gets management support is to control cost by using as the measure the rate of monthly expenditure and compare this with the monthly estimate rate. The cost estimate is to be prepared against the Work breakdown structure. This is then scheduled in time by scheduling the work elements to

produce an expenditure profile. This profile is what is normally referred to in Water as the predicted cash flow of the project.

To actually control the costs some measure of the actual work done must be determined so that accurate comparisons can be made. The Work Breakdown Structure provides the means to do this. As an element of work is complete, you can compare how much it actually cost against what it was estimated to cost. Within the Counter Cost method this is usually referred to as the earned value.

The earned value for a work package or the whole project is the sum of the estimate of the completed activities which constitute it. Cost is controlled by comparing the earned value to the actual expenditure, and calculating a cost variance.

Step 5

Rationalization Project Strategy Management (Cont)

A bias is introduced if the work in progress is ignored. To allow for this a subjective estimate of the percentage for activities started but not yet finished. J Turner suggests that it best to simply use an average (50%) which becomes self discharging as time goes along. We therefore have

- for activities
% completion = 0%, 50% or 100%
- for the project and work packages
% completion = earned value/Original estimate

The next problem that comes up for cost control is when to actually make the Comparisons. Many systems do the analysis only based on monies paid. This is still a valid approach but when the sums are done it is too late to change anything. Usually the way to overcome this is to use the committed funds approach where the entry is made to the cost control system when the money is committed but not necessarily paid. This way the costs can be controlled as the variances can be calculated well before the project cost overruns have occurred and something can then be done about it.

Summary of Managing Costs

A cost estimate is prepared:

- as a basis for control
- to estimate durations
- to prepare tenders

generally the cost estimates structure is:

- Proposal estimate
- budget estimate
- sanction estimate
- the control estimate

For this project the proposal and budget estimates have already been prepared and the approval reached. The sanction estimate will be left out but the control estimate will be prepared as part of the implementation process and so that cost control can be conducted on the basis of a sanction estimate.

The control estimate is prepared as a function of the Work Breakdown Structure where the allocation of costs is coordinated with the WBS.

Cost is controlled by comparing the earned value, a measure of the amount of work performed to date, to the actual expenditure to date.

Step 5 Rationalization Project Strategy Management (Cont)

Managing Time

This is the last of the project objective strategies. This is an objective of the project manager which ensures that the project is delivered on time to achieve the project objectives.

The Time schedule

The time schedule is set against the work breakdown structure. This schedule is constructed with forecast record of the time expected or when the work will occur and when the work actually does occur.

Purpose of the schedule.

The purpose of recording these dates and times within the work breakdown structure is as follow;

- to ensure that the project benefits are obtained on a time scale that justifies the project costs
- to coordinate the resource effort

- to enable the availability of the resources when actually required
- to allow the assignment of resources and priorities
- to meet the end date

The first element mentioned above is the main reason for generating the time schedule. Overall the benefits of the projects must be understood and the time frame that is required to achieve those benefits should be recognised and formally entered into the schedule.

The second element is the mechanism for the project activity and sets the tasks in motion. The last item is of course what sets the team on the target and focusses all the activity. On a basic level, the schedule which is based on the work breakdown structure sets the planned and actual start date, finish date and the duration of each work element. Flexibility or float can also be recorded so that any adjustments that are made can be readily accommodated without the end date compromise.

Step 5 Rationalization Project Strategy Management (Cont)

Durations

This is the amount of time allocated for each work activity or task procedure to complete its work schedule. For this Integrated project there will be many work activities that are dependent on outside resources and operational constraints. Some of these elements may be outside of the control of the project team. For the purpose of the time schedule however they should be treated as fixed. As part for the time schedule therefore the project team must estimate the relevant durations for each and every activity and logically understand how they all fit together with prioritisation etc.

After the commencement of a work activity we can estimate the time remaining or the remaining duration. This may be equal to the planned duration less the time since the activity started, or we may have to estimate the remaining duration based on knowledge of the work performed to date. Once the work activity is completed we can record the actual duration and compare that with the overall critical path to ensure that the end date is not compromised.

For this project we should use early dates, late dates, float, planned, baseline and scheduled dates which are all standard time management concepts and can easily be introduced to the work breakdown structure without a large network system.

There are the following some schedule components that the system will require and these are

normally presented on gantt charts.

Early start	Duration	Early finish
Late Start	Float	Late Finish
Baseline start	Baseline float	Baseline finish
Schedule Start	Remaining Float	Schedule finish
Actual Start	Remaining duration	Actual Finish

If the work breakdown structure is carefully constructed in the first place it is possible for the time schedule to place itself manually over the top of it and little use required of a computerised project scheduling system. Only when gantt charts were required would a computer be used. This approach is preferred so that the time schedule does not become a large unwieldy system that takes many hours of effort simply to keep up to date. To communicate the time schedule in its basic form involves generally two simple structures. Firstly activity schedules which are the product of the Work Breakdown structure. These lists produce the activities with the relevant durations, start date end dates and so on, and are produced as a simple schedule. See format samples. The second presentation is that of gantt charts.

Step 5

Rationalization Project Strategy Management (Cont)

Identifying the critical path

This is a series of non float activities with the longest durations. It is important to determine the critical path and not lose sight of it. An overall milestone chart showing the critical path is most useful and is best hand drawn (using CAD) rather than a computer project package.

Controlling time

The schedule is used to control the projects duration, which is the main reason for using the schedule. There are four steps in this process

- set a measure
- record progress
- calculate the variance
- take remedial action

Set the measure

The most common mistake is to measure the project time against the most recent update of the time schedule. If this happens the project manager will lose sight of where the time schedule is against the original time scale and will lose control of the project delivery. It is essential that the project time always be measured against the baseline so that updates are

compared against the original time frame not the updated one.

Progress

By noting in the schedule the actual start and the actual end dates of each breakdown activity then progress can be properly measured.

For this project it will be appropriate to only measure actual start and end dates rather than attempt to estimate percentage complete. So long as the frequency of reporting is enough then control will be adequate. A frequency of about two weeks progress is measured against activities of two weeks duration.

Step 5 Rationalization Project Strategy Management (Cont)

Summary

The purpose of scheduling time on a project is to

- to obtain timely benefits that justify the expenditure
- to coordinate resource management
- to schedule resource availability
- to assign priorities
- to meet end dates

The schedule specifies the duration, start and finish dates and float of the activities in the project.

each activity has the following dates recorded.

- early date
- late date and float
- baseline date
- actual date and remaining duration

The schedule can be communicated and used as;

- an activity listing
- gnantt chart

The duration is calculated by comparing work content to the number of resources available and comparing and allowing for;

- lost time
- interference
- communication
- lead times
- sequencing

The early and late dates can be calculated from the durations and logical sequence of the activities using a critical path network. There are two types of network that can be used;

- precedence network
- activity on arrow

Progress can be monitored on the schedule by

- recording progress on the critical path

PART III TECHNOLOGY SELECTION PROCESS

Step 6

Technology Selection POPs, PCBs, Unwanted and Obsolete Pesticides

After the rationalisation strategy (Step 5) is complete and the basic areas of destruction and decontamination are known then the technology selection can commence. When the amount and nature of the contaminated material to be decontaminated on shore is known then the work can begin to look at what technologies are available and then select the appropriate technology from an environmental and economic point of view. There are many decontamination technologies to choose from either, on shore or off shore. The decision to go offshore is of course dependent on the rationalisation strategy (Step 5) and this decision is based on the best environmentally sound management approach which best meets the amount and nature of the POPs involved.

For destruction of POPs there are also many options and the selection must be made on similar grounds to the decontamination requirements.

Following the rationalisation process the technology selection is applied.

The summary section of the rationalisation part will determine which of the various technologies are appropriate and will be most efficient to use. There are decisions to be made regarding appropriateness of the technology, environmentally sound management principles, economics and ability of the technology to be applied.

Several technologies are described here and there are many more that are not. We have attempted to provide descriptions of the most commonly used technologies but also include emerging technologies.

Technology Types

Established

- Incineration (HTI)
- Thermal desorption
- Dechlorination
- Solvent Extraction

Emerging

- Solidification
- Stabilisation
- Bioremediation
- Vitrification
- Ball Milling

Step 6 Technology selection

Technology Type	DESTRUCTION
	HIGH TEMPERATURE INCINERATION

Description of process

Hazardous waste incinerators have a main chamber (also called the primary chamber) for burning PCBs and POPs such as unwanted and obsolete pesticides and a secondary chamber. The secondary chamber is used for extending the residence time for maximum destruction of the material and its thermal oxidation into gases and unburnable solids. Well managed incineration can destroy POPs with a destruction and removal efficiency greater than 99.99 per cent. Removal efficiencies at this level (and higher levels of 99.99995 percent) require carefully controlled conditional and management of the incinerator to achieve these efficiencies. The effectiveness depends on the type of waste, turbulence, temperature and the residence time being maintained.

Downstream of the secondary chamber is the gas treatment system. This often comprises a quench system (to reduce dioxin formation) packed tower absorbers, precipitators and other reactive absorbers. The chemistry of incineration is the controlled high temperature oxidation of primarily organic compounds to produce carbon dioxide and water. Inorganic substances such as salts, acids and metallic compounds may also be produced from these wastes. Incineration processes for management of hazardous wastes are highly complex and require control of the kinetics of chemical reactions under non steady state conditions.

Sustainability factors

Inappropriate use of incinerators and poor management procedures can cause incineration to produce hazardous by-products that pose severe threats to the environment and to human and animal health. Sometimes the by-product can be more toxic than the original incinerated product. Of major concern are the formation during the incineration process of polychlorinated dibenzodioxins and polychlorinated dibenzofurans (dioxins and furans). Dioxins and furans are

Benefits

Total destruction in proven system. Generally accepted technology by many nations. Long history of experience with management of HTI. Problem of hazardous chemicals with attendant liability problems is ended. No ongoing storage or contamination problems.

Disadvantages

Dangerous air emissions if incinerator operation or design inadequate. Transboundary movement across oceans. Overall high cost.

Key Points

- large capacity
- located in developed countries
- total destruction
- high DRE
- medium cost

extremely ecotoxic and persist in the environment for long periods of time. Dioxins and furans are formed during the cooling of the gasses after the secondary chamber. It is a formation reaction that is effected by the gas temperature, the occurrence of chlorine or other halogenated compounds and the presence of a catalyst. Modern HTI are now built with rapid quenching systems that quickly cool the gas to safe temperatures at which reformation does not occur and the use of wet scrubbers. In addition incinerators are now being fitted with dioxin removal facilities such as catalytic reduction. From a sustainability point of view there are many who say that high temperature incineration is unsustainable in that the pollution to the air is unacceptable due to the emissions of dioxins and furans as well as greenhouse gases such as CO₂. In the past this view was correct. However modern incinerators that are designed for high temperature and are equipped with reformation prevention and dedicated dioxin removal facility have removed the problem of dangerous emissions. Dioxins and furans is one of the most controversial issues surrounding HTI. Dioxins are a family of organic chemical compounds known as polychlorinated dibenzodioxins (PCDDs) with 75 different forms that are characterised by the placement of 1-8 chlorine atoms and their aromatic rings. Tetrachlorodibenzo-p-dioxin (TCDD) is the most widely known and is found as an unwanted contaminant in pesticides. Furans (polychlorinated dibenzofurans or PCDFs) are a family of 135 organic compounds. Of the 210 compounds, seventeen are considered to be harmful to the environment. Dioxin is a natural by product of most combustion processes and is created by forest fires, woodstoves, automobiles, power plants and smelters. Although incineration has been often cited as the major cause of dioxins, recent USEPA data suggests that hazardous waste incinerators produce less than 0.2% of the dioxin that is produced by wood stoves and indeed are not a major cause of dioxin in the environment.

Cost effectiveness factors

It is not possible to simply consider the cost of the incineration process in isolation when comparing with other technologies. Given that it is likely that an incineration process will be unavailable in a developed country the costs of packaging, containerisation and shipping of the waste must also be considered. The cost of the incineration (which is anywhere between US\$200 to US\$5000 per tonne) is often the lower component of the costs compared to the recovery, stabilisation, repackaging, separation and transport of the waste. As rule of thumb for the on shore activity and the transboundary movement of the waste, this cost will be up to five times the cost of incineration.

Selection of pesticides for destruction by incineration

Selection of incineration depends on the type of pesticide, the type of incinerator and its associated gas treatment system. Inorganic pesticides cannot be incinerated.

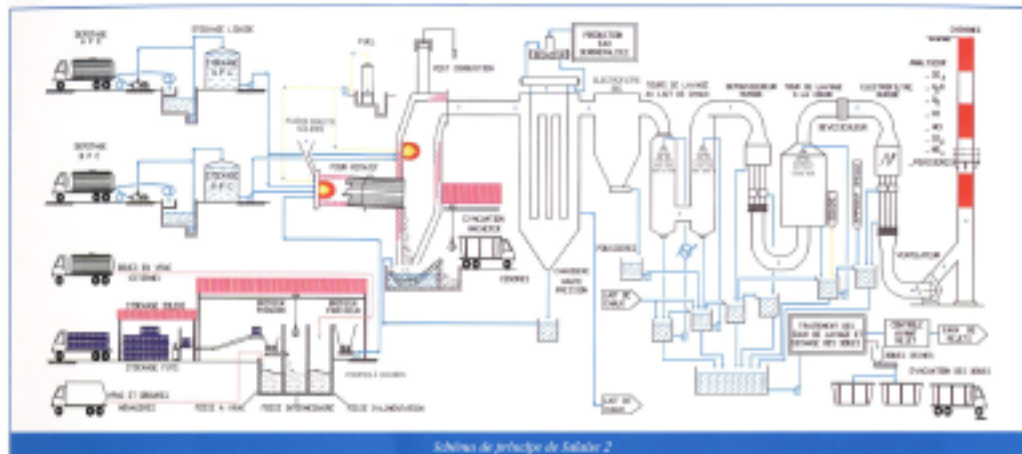
Organic pesticides must be burned in HTI at over 1100 degrees centigrade for more than 2 seconds. Organic products with heavy metals content can only be incinerated in special facilities.



PCBs and POPs HTI in Europe

Country	Facility Operator	Contact
Denmark	Kommunekeimi a/s	Fax 45 65 30 27 63
Finland	Ekochem Oy Ab	Fax 35 8 19 715 300
France	Tredi	Fax 00 33 4 74 61 52 44
Germany	Entsorgungsbetrieb (GSB)	Fax 49 8453 91-151
Germany	Bayer	Fax 49 2133 515893
Netherlands	AVR-Chemie	Fax 31 181 242 502
Netherlands	Akzo Nobel Chemicals	Fax 31 10 4389295
Norway	Norcem AS	Fax 47 35 57 1400
Sweden	SAKAB	Fax 46 19 577027
Switzerland	ETI	Tel 41 81 253 54 54
Switzerland	EMS-Dottikon AG	Fax 41 56 616 8120
Switzerland	Novartis Services AG	Fax 41 61 468 3348
UK	Cleanaway Ltd	Fax 44 151 357 3313
UK	Reychem International	Fax 44 1495 759 019

Not all of these operators will import PCB or POPs



Incinerator types

Rotary kiln incinerators

Rotary kilns consist of an inclined rotating tube so that the waste moves horizontally as well as radially through the cylinder. Rotation speeds are low at 0.5 to 2 rpm in order to encourage turbulence. Waste is fed into the high end and ash is discharged at the low end. Combustion gases pass from the kiln into the secondary combustion chamber.

Liquid injection incinerators

Liquid injection incinerators are refractory lined cylinders, either horizontal or vertical and are equipped with a primary burner for waste and additional fuel to atomise the waste into the combustion chamber. Mainly used for highly mobile liquid waste.

Static kiln incinerators

Static kilns use a two stage combustion process on a horizontal grate in the primary chamber. In large units a ram constantly charges the unit and removes the ash at the same time.

Fluidised bed incinerators

Fluidised bed incinerators employ a bed of sand held in suspension by air in which the waste is injected.

Cement kilns

Wastes with a suitable calorific value is used as fuel and solid materials can be fed in part way down the kiln. For chlorinated wastes the residues are contained within the clinker.

Step 6 - Technology selection

Technology Type	DECONTAMINATION	PCBS
	AUTOCLAVE	

Description of process

Autoclaving is a technology that has been around for many years now and is well proven. In general for PCBs, only the oil and transformer components such as ceramics, cardboard and wood are incinerated. The rest of the transformer is autoclaved and after decontamination the various metals such as copper, steel and aluminium are sent to the metals recycling industry. Autoclaving is a solvent decontamination process that extracts PCBs from contaminated material. The process can only be used for PCBs not for any of the other POPs. It is most often used in projects in conjunction with HTI. For capacitors the process involves shredding and placing all the material into the autoclaving chamber and by vacuum extraction with solvent remove the PCB. The resulting decontaminated capacitor materials can then be landfilled with the extracted oil and PCBs being sent for HTI incineration. Transformers on the other hand are drained, completely disassembled including the core and windings and the casing and all components are placed in the autoclave chamber and decontaminated.

Autoclaves may either be fixed or mobile. If sufficient quantities exist in the country then a mobile autoclave can be considered. Obviously the unit can be moved about according to location of PCB stock. It is also possible to build a fixed autoclave plant in the origin country. When looking at Autoclaving as a fixed plant in origin country consideration must be given to utility supplies such as energy, Compressed air, water, trade waste etc.

Sustainability factors

Autoclaving is a very good option when quantities of transformers and capacitors are large. Only the oil is sent overseas for destruction thus reducing the amount of material, weight, space and

Benefits

Excellent decontamination standard (to NDT) and recovery of metals often contributes to reducing the overall cost of autoclaving. In some cases the recycling revenue exceeds the autoclaving costs. If done onshore vast cost reduction to disposal costs for PCBs. Low emissions.

Disadvantages

Complex plant requiring expertise to run in origin country. Need large amounts of waste to justify location in origin country (in excess of 2000 tonnes). Large amounts of solvent used initially although solvent is recovered during the process.

Key Points

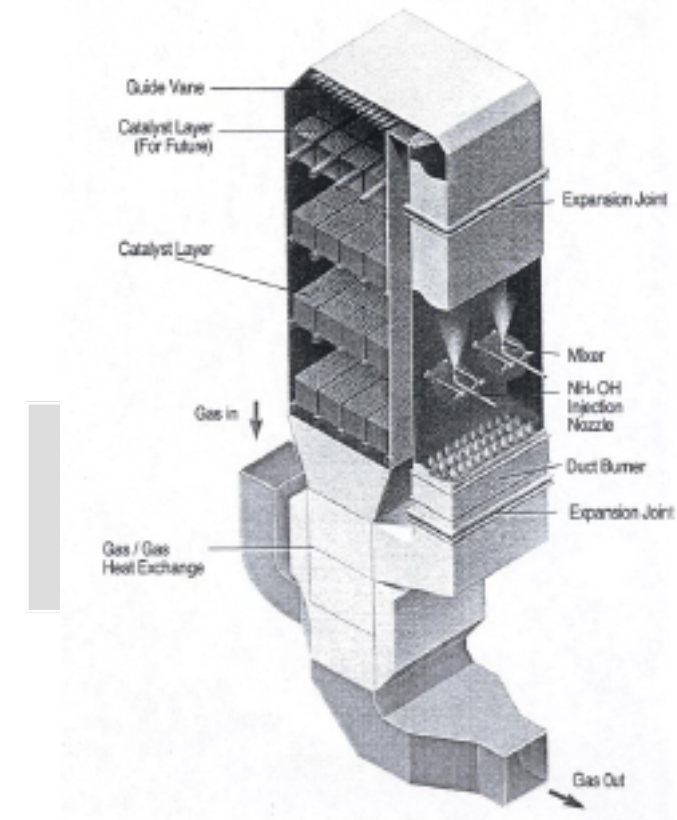
- Transformers and capacitors decontaminated
- Need large quantities for origin country installation
- expertise of operators
- mobility of plant
- utilities availability

danger in the shipment. The copper, steel and aluminium is recycled in origin country. For PCBs and PCB contaminated equipment decontamination of the equipment is to be preferred over complete incineration. It is unsustainable to incinerate transformer coils, windings and tanks.

Cost effectiveness factors

Autoclaving is very cost effective given the correct circumstances. For large onshore origin country stocks of contaminated equipment then mobile or fixed autoclave plant can offer excellent opportunities for cost reduction compared to sending all the material offshore. The costs are comparable with incineration but has none of the attendant cost of packaging and transportation. Indeed the recycling of the materials will often produce a positive cost result.

Dioxin Removal Facility



Step 6 - Technology selection

Technology Type	DESTRUCTION	PCBs
	PLASMA ARC	POPs

Description of process

Plasma systems technology use a plasma arc device (often called a plasma torch) to create extremely high temperatures up 10,000 degrees centigrade for destruction of highly toxic wastes such as PCBs and POPs. Plasma arc destruction has only recently moved from the pilot stage to full scale production stage for hazardous wastes but shows promise for liquid PCB and POPs. Emissions are gaseous and slag and are treated in a gas treatment system similar to that of HTI but on a much reduced scale. The most common form of plasma arc generation is via an electrical discharge via a gas. In passing through the gas, electrical energy is converted to thermal energy and is absorbed by gas molecules which are activated into ionised states. Plasma Arc is a pyrolysis process. It does not need energy to heat excess air like conventional incinerators. Because of this the downstream gas treatment systems are very small as there is no excess air. Plasma Arc systems use electrical energy as their energy source and as such is expensive. Plasma arc installations are easily set up in origin countries and occupy a small footprint.

Sustainability factor

For significant quantities of liquids in country of origin Plasma Arc technology represents a good option from a sustainability point of view. There is no shipping offshore for PCB oil or pesticide liquids. This means that coupled with autoclaving this technology can be very effective providing the quantities are adequate.

Benefits

Very small footprint. low emission simple gas treatment systems. Portable and mobile easily set up in origin country.

Disadvantages

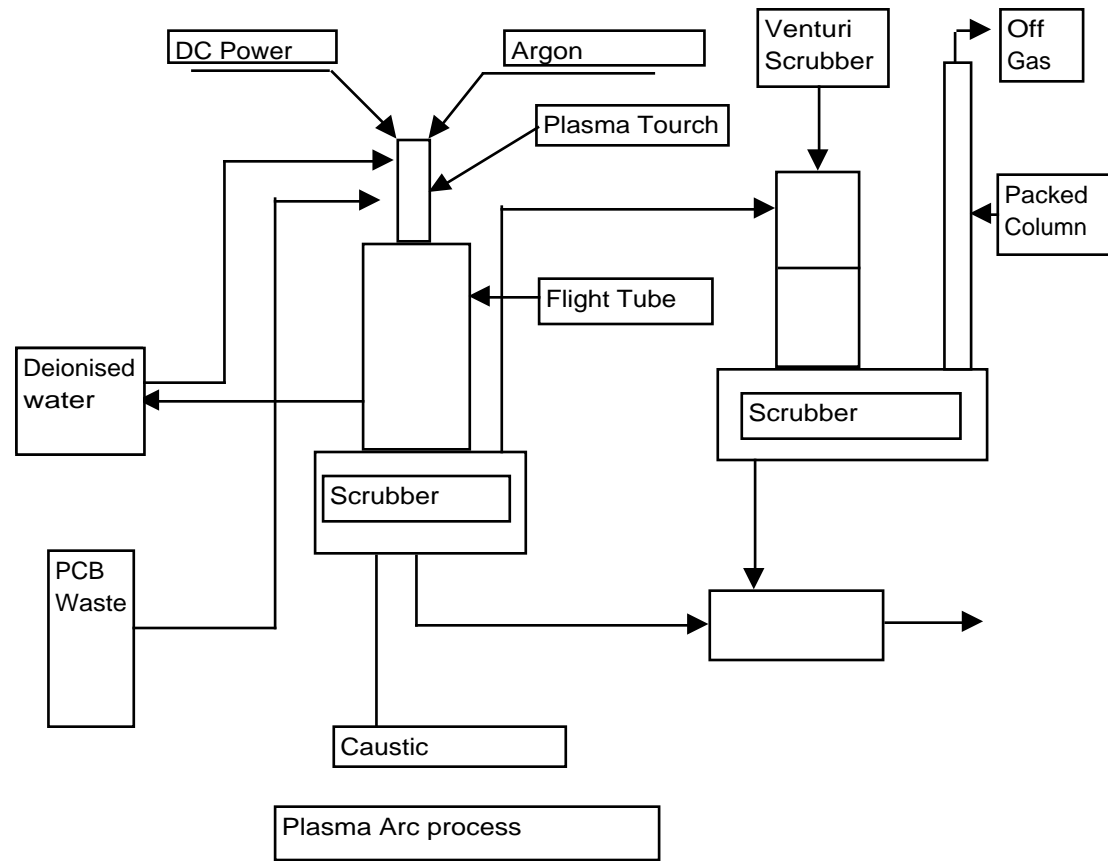
Generally restricted to liquids and for PCBs must be located with autoclave or solvent washing plant. Expensive in comparison to incineration.

Key Points

- **Portability**
- **small footprint**
- **liquids**
- **expensive**
- **simple operation**
- **high DRE**
- **best in origin**

Cost Effectiveness factor

This type of technology is best used in the country of origin and should involve significant amounts of liquid PCBs or POPs. Cost is about \$US1200 per tonne with set up costs of up to \$US 1 million.



Step 6 - Technology Selection		
Technology Type	DECONTAMINATION	PCBs
	DECHLORINATION	POPs

Description of process

Chemical Dechlorination is based on reactions with either an organically bound alkali metal or an alkali metal oxide or hydroxide.

Dechlorination processes are well developed for the treatment of liquid PCBs and PCB contaminated oil. The chlorine content is converted to inorganic salts, which can be removed from the organic fraction by filtration. Reactions take place under inert atmosphere and can be used on an operating transformer in the field.

The Base Catalysed Dechlorination process (BCD) is a batch process operated in a series of stages and can treat wastes up to 10 % PCB. The key to the BCD process is the hydrogen donor with an oxidation potential low enough to produce nucleophilic hydrogen in the presence of base NaOH at low temperatures. Capacitors cannot be treated with this process and solvent washing is required for the transformer components. The Base Catalysed Dechlorination (BCD) process, was developed to treat halogenated organic compounds. The process was developed from work by the USEPA on earlier forms of dechlorination (in particular the "KPEG" process). This work was undertaken at the Cincinnati Risk Reduction Research Laboratory. The proponents claim BCD is suitable for treatment of wastes which contain up to 100000 mg/kg of halogenated aliphatic or aromatic organic compounds such as PCBs. In practice, the formation of salt within the treated mixture can limit the concentration of halogenated material able to be treated. Reduction of chlorinated organics to less than 2 mg/kg is achievable.

The BCD process can involve direct dehalogenation or decomposition of the waste material, or can be linked with a pre-treatment step such as thermal desorption which yields a relatively small

BCD Process Performance

The process has been shown to reduce contaminated soils from 10,000ppm to below detectable with two hours.

For PCBs and contaminated transformer oils the BCD treatment process will typically reduce the contamination to below detection.

Direct treatment of capacitors by the BCD process is not possible and solvent extraction is required. Although some facilities shred the capacitors and treat the material with sodium hydroxide. The shredded material can then be treated with the BCD process.

Benefits

- PCB and POPs destroyed in one step.
- Simple process with very small emissions
- Proven technology
- Small facility foot print.

Disadvantages

Must use solvent extraction with transformers and capacitors or other pre-treatment

quantity of a condensed volatile phase for separate treatment by the BCD process. The BCD process involves the addition of an alkali or alkaline earth metal carbonate, bicarbonate or hydroxide to the contaminated medium containing one or more halogenated or non-halogenated organic contaminant compounds. Alkali is added to the contaminated medium in proportions ranging from 1 to about 20 percent by weight. The amount of alkali required is dependent on the concentration of the halogenated or non-halogenated organic contaminant contained in the medium.

A hydrogen donor compound is added to the mixture to provide hydrogen ions for reaction with the halogenated and non-halogenated contaminants, if these ions are not already present in the contaminated material. The hydrogen donor compound may comprise the high boiling point solvent in which the alkali or alkaline earth metal compound is added, or it may include fatty acids, aliphatic alcohols or hydrocarbons, amines or other similar compounds. In order to activate these compounds to produce hydrogen ions a source of carbon must be added, either in solution or in suspension. An inexpensive carbon source which is water soluble and suitable for use, is a carbohydrate such as sucrose.

The mixture is heated at a temperature and for a time sufficient to totally dehydrate the medium. This may be performed at atmospheric or at reduced or elevated pressure. The water which is included in the aqueous solution allows homogeneous distribution of the alkali throughout the mixture and acts as a wetting agent and penetrant. When the water is removed from the medium during the dehydration step, the alkali is concentrated to a reactive state.

After dehydration, the medium is further heated at a temperature between 200oC and 400oC for a time sufficient to effect reductive decomposition of the halogenated and non-halogenated organic contaminant compounds, typically 0.5 to 2 hours. At this temperature the carbon source (eg the carbohydrate) acts as a catalyst for the formation of a reactive hydrogen ion from the hydrogen donor compound. Finally, the mixture is neutralised by the addition of an acid, preferably to a pH of 7 to 9. Depending on the nature of the feed material, the reagent additions and the site use, it may be possible for the treated material to be returned to the site if desired, although this may not be possible if the treated material is oily or has a high salt content.

Cost Effectiveness

Up to USD1000 per tonne PCB contaminated oils and up to USD 250 for contaminated soils

Safety and Environmental Considerations

Potential to form dioxins and furans is very small and if formed then the BCD process will Dechlorinate. Emissions low. Low operating temperatures.

Eco Logic Process

A gas reduction process uses high temperature hydrogen as a reducing agent to destroy chlorinated organic compounds. Eco Logic International Inc. (Eco Logic), Canada has developed a hydrogenation process known as Gas-Phase Chemical reduction (GPCR). The process is based on gas-phase thermo-chemical reaction of hydrogen with organic compounds. At 850°C or higher, hydrogen combines with organic compounds in a reaction known as reduction to form smaller, lighter hydrocarbons, primarily methane. For chlorinated organic compounds, such as PCBs, the reduction products include methane and hydrogen chloride. This reaction is enhanced by the presence of water, which acts as a reducing agent and a hydrogen source.

Organics such as PCBs, PAHs, chlorophenols, dioxins, chlorobenzenes, pesticides, herbicides and insecticides are quantitatively converted to methane. Approximately 40% of the methane produced can be subsequently converted to hydrogen via the water shift reaction and the remaining methane converted to hydrogen in the catalytic steam reformer. Thus, the process can operate without an external supply of hydrogen.

The mixture of gases and vaporised liquids are heated as they pass electric heating elements situated around the central ceramic-coated steel tube of the reactor. Gases and any entrained fine particulates proceed up the central tube providing in excess of 2 seconds retention time at 900°C. The reactions come to completion before the gases reach the scrubber where the water, heat, acid and carbon dioxide are removed. A caustic scrubbing agent is added, if required, to maintain the scrubber water pH at between 6 and 9. The temperature of the exit gas is maintained near 35°C by cooling the scrubber water using dual plate heat exchangers and cold water from an evaporative cooler.

Eco Logic Process Performance

As the Process is a hydrogenation process and thus will add hydrogen molecules to any incomplete hydrogenated organic molecule the process will Dechlorination molecules and break down chlorine rings and will therefore treat PCP, PCP and other POPs and dioxins in a similar manner and achieve very high destruction rates.

Benefits

- low emissions
- treats all chlorinated molecules
- complete destruction
- converts chlorinated compounds into fuel

Disadvantages

- large fixed plant (Mobile and portable units available)
- use of hydrogen

Contaminated equipment processed in the pretreatment desorber unit (TRBP) constitutes a relatively small organic load to the reactor and high strength organic wastes such as Askarel fluids can be processed simultaneously. The TRBP is also suitable for processing high-strength organic wastes such as obsolete pesticides which are sufficiently volatile to evaporate directly from drums. The advantages of this approach are that handling is reduced, drums are cleaned in place and inorganic solids remain behind in the drums. Fugitive emissions are minimised due to the reduced handling requirements and the elimination of transfer operations.

Cost Effectiveness Eco Logic

Up to USD2500 per tonne PCB and USD5000 for capacitors. Contaminated soils etc. USD3000 per tonne (If treated using TRBP). Relatively expensive option. If contaminated soils are treated using the TORBED system then costs reduce to US\$200-700 per tonne depending on soil characteristics, volumes etc.

PCB Gone

In service treatment of transformers is possible using dechlorination processes. A process developed by S D Myers called PCB Gone involves circulating the transformer fluid through a filtration system until the PCB concentrations are below the reclassification level. The PCB Gone process is very specific in the scheduled wastes it is able to treat, as it is designed to treat PCB contaminated transformer oils without the need to remove the transformer or take the transformer out of service. The fluid is recirculated through the treatment system until the residual PCB concentrations are below those required (< 2 ppm in the USA). The continued recirculation of the fluid through the transformer largely flushes the PCBs from the transformer windings and other internal components. The treated oil is then suitable for continued use.

PCB Gone Process performance

With concentrations within transformer below 50,000 ppm the PCB gone process is quite effective and will reduce the PCB concentration to below 5ppm. Leaching can occur and the transformer may continue to require polishing for some time. Easy to set up and operate.

Benefits

- For low contamination cost effective
- Portable process
- minimal air emissions
- low temperature system
- treats in service transformers

Disadvantages

- gaining approval for portable systems
- not appropriate for pure PCB transformers
- not applicable for capacitors
- collected PCB must still be destroyed.

In addition to removing PCBs, the PCB Gone treatment system also regenerates the used fluid by filtration through Fullers Earth as with other conventional transformer fluid reclamation systems. This treatment removes acids, sludges and other oxidation by-products by a mechanical filtration process, that in effect reclaims the contaminated transformer fluid. As the treated oil is reused and the transformer decontaminated without the need to remove it from service, significant cost savings could be expected from this treatment approach. The process uses a proprietary Dechlorination reagent that provides for safe operation and is non-destructive to the transformer oil's dielectric properties.

PPM Process

The process operates at ambient temperature and does not use flammable solvents, The process uses a complex organo-sodium reagent. The reagent is air and water sensitive and during reduction the process must be blanketed with nitrogen. When introduced to the reaction tank, the reagent reacts immediately with the PCBs and chlorinated hydrocarbons to form sodium chloride and a polyphenylene polymer. The reagent reacts with inhibitors, acids, thiols, and chlorides to form the appropriate sodium salts, which are then present in the oil as a insoluble sludge. After decontamination small quantities of water are added to destroy and excess reagent.

The process consists of three parts. Pre-treatment, decontamination and Clarification. In the pre-treatment part water is reduced to acceptable levels by draining the water and other impurities off the bottom of the reception tank holding the contaminated transformer oil.

After pre-treatment the oil is decontaminated The sodium reagent is added directly to the oil after

the application of a nitrogen blanket. The amount of reagent added is determined before the cleanup to determine the PCB, chlorinated hydrocarbon, sulphur and other impurity levels. As the PCBs react to the sodium they are monitored on site with a gas chromatograph.

After decontamination the oil is cleaned of salts and solids through filtration. During this stage, small amounts of water are introduced to destroy excess amounts of reagent. The solids, salts and small amounts of water solution of sodium hydroxide are removed at this stage. All wastes removed at this stage is small and non PCB. The process consists of three parts. Pre-treatment, decontamination and Clarification. In the pre-treatment part water is reduced to acceptable levels by draining the water and other impurities off the bottom of the reception tank holding the contaminated transformer oil.

Step 6 - Technology selection

Technology Type	DECONTAMINATION	PCBs
	DESORPTION	POPs

Description of process

Thermal desorbers are used to vaporise hazardous organic contaminants so that they can be separated from the solid materials to which they adhere or are adsorbed. Other systems are then required to treat the desorbed organics. Elements of a desorber unit are waste handling and feed systems, thermal Desorption chamber, off gas condensation and separation and treatment systems for the separated organic compounds. Thermal desorption separates contaminants from soil. Soil is heated in a chamber where water, organic contaminants and certain metals are vaporised. A gas or vacuum system transports vaporised water and contaminants to an off-gas (i.e., air emission) treatment system. The design of a system aims to volatilize contaminants, while attempting not to oxidise them. Based on the operating temperature of the desorber, thermal desorption processes can be categorised into two groups: high temperature thermal desorption (HTTD) and low temperature thermal desorption (LTTD). It is important to note that thermal desorption does not to destroy organics.

High Temperature Thermal Desorption (HTTD). In HTTD, wastes are heated to 320 to 560 °C (600 to 1,000 °F). HTTD is frequently used in combination with incineration, solidification/stabilisation, or dechlorination, depending upon site-specific conditions. Low Temperature Thermal Desorption (LTTD). In LTTD, wastes are heated to between 90 and 320 °C (200 to 600 °F). LTTD is most often used for remediating fuels in soil.

Thermal Desorption Performance

Generally low emissions and the process needs careful control to be effective. DRE's for PCB contaminated soils and dioxins is 6 nines. Does not use large amounts of excess air and operates under reduced pressure.

Benefits

Indirect heating

For soils very effective

can handle full range of chlorinated hydrocarbons, PCBs , POPs etc.

Disadvantages

Fixed large plant

Metal hydroxides from plant may need disposal.

Off gas requires treatment

Unless being heated to the higher end of the LTTD temperature range, organic components in the soil are not damaged, which enables treated soil to retain the ability to support future biological activity.

Treatment of the off-gas must remove particulates and contaminants. Particulates are removed by conventional particulate removal equipment, such as fabric filters. Contaminants are removed through condensation followed by carbon adsorption, or they are destroyed in a secondary combustion chamber or a catalytic oxidiser.

Treatment and control of air emissions from thermal desorption operations is an extremely important consideration. It is important that there are no emissions problems concerning metals, certain PAHs and dioxins/furans. Mercury emissions are very difficult to control, and using an afterburner is unacceptable.

Thermal desorption systems are somewhat effective in removing VOCs, SVOCs, fuels, pesticides and some metals from soil. High temperature units are more effective removing volatile metals and SVOCs.

Cost Effectiveness

Cost vary across different facility operators but generally for contaminated soils about USD250 per tonne.

Step 6 - Technology selection

Technology Type	DESTRUCTION	PCBs
	IN SITU VITRIFICATION	POPs

In situ Vitrification (ISV) is a commercially available technology used for contaminated site remediation and waste treatment. It is a mobile, thermal treatment process that uses electricity to heat and melt contaminated soils, sludges and other earthen materials. The treatment results in the permanent destruction of organic contaminants and the permanent immobilisation of inorganic contaminants within the high integrity vitreous product.

ISV has been demonstrated to be effective in the treatment of all classes of contaminants including organics, heavy metals, radioactive material, and explosive compounds. The ISV process has been successfully used at full scale to treat a wide range of soils and wastes including contaminants such as pesticides, herbicides, dioxin, PCB's, arsenic, mercury, lead etc.

The ISV process is distinguished by its ability to accommodate a wide range of wastes and debris. This eliminates the need for handling, sorting and size reduction activities. Virtually all types of debris can be accommodated by the process including drums, scrap metal, concrete, boulders wood and plastic. Using the process a destruction efficiency of 99.9999% can be achieved.

In Situ vitrification involves the electric melting of earthen materials at high temperature for purposes of destroying organic contaminants and permanently immobilising non-volatile inorganic contaminants in a glassy, rock-like vitrified product, thereby rendering the treated product non hazardous. The process employs joule heating and typically operates in the range of 1,600 to 2,000 degrees C for most earthen materials.

In Situ Vitrification (ISV) is a commercially available mobile, thermal treatment process that involves the electric melting of contaminated soils, sludges, or other earthen materials, wastes and debris for the purposes of permanently destroying, removing, and/or immobilising hazardous and radioactive contaminants. The process is widely applicable to all soil types and all classes of contaminants including organics, heavy metals and radionuclides.

The ISV process is a batch process that involves forming a pool of molten soil at the surface of a treatment zone between an array of four electrodes. The molten soil serves as the heating element of the process wherein electrical energy is converted to heat

via joule heating as it passes through the molten soil. ISV melt temperatures typically range between 1,500-2,000°C. Continued application of energy results in the melt pool growing deeper and wider until the desired volume has been treated. When electrical power is shut off, the molten mass solidifies into a vitreous monolith with unequalled physical, chemical, and weathering properties compared to alternative solidification/stabilisation technologies.

Extrapolating established US costs results in a cost of \$500 to \$750 per tonne for contaminated soil,

PROS

- The process is widely applicable to all soil types and all classes of contaminants including organics, heavy metals and radionuclides.
- The process is operated on an around the clock basis and can achieve treatment rates of up to 150 tonnes per day.
- High concentrations of organic contaminants, 10-20 wt%, can be treated by the process with existing equipment. Organic concentrations in excess of 20 wt% can be treated with modified equipment.
- The ISV process equipment is all trailer mounted except for the off-gas hood, which is transported to the site and then assembled. Only two personnel are required to operate the equipment.
- ISV is relatively safe and represents a low risk to the environment as demonstrated by successful commercial operations in the US and in Japan.
- a very high percentage of organic contaminants are destroyed in the ground (typically >99.9%);
- most heavy metals and all radionuclides are largely retained in the melt so the emissions of these species from the melt to the off-gas treatment system are minimal;
- the treatment process is relatively slow; the melt grows at a rate of only a few cm per hour resulting in only a small fraction of the waste material being treated at any one time;
- the off-gas treatment system is robust and has been demonstrated to be effective on a wide

range of contaminant types; provision of a back up system in case of primary system failure covers the contingency of breakdown and discharge of untreated waste gases.

- for the in situ mode of treatment, the process does not require excavation and handling of contaminated soils so the risk to workers, the public, and the environment are minimised;
- since the process treats wastes on-site, there is no requirement for, or risk from, the off-site transport of wastes;
- no organic contaminants remain in the vitrified product;
- the vitrified product is extremely effective at immobilising heavy metals and radionuclides and the product far surpasses TCLP requirements;
- the process equipment includes back-up safety systems and an alternate power supply in case of equipment or power failure.
- Liquids and non-soil wastes would be mixed with soil. Treatment costs for liquid and non-soil wastes would depend on the soil mixture ratios.

CONS

- Off-gas treatment required to treat volatile organics.

- Other major components include the process control station, a back-up off-gas treatment system and a diesel powered generator.
- 11 kV three phase electrical power which can be supplied either from the utility grid or from diesel powered generators.
- The thermal oxidiser, if used, typically requires 3 Mbtu/hr of fuel.
- A source of potable water is also required to support process operations.
- For the in situ mode of treatment, sites must be characterised to ensure that there are no high integrity sealed containers, such as drums, and that there are no other structures present where liquids can accumulate and become trapped. Sealed containers and other trapped liquids become pressurised upon heating and can result in sudden gas releases through the melt.
- Establishment costs are expected to be significant for the ISV process and therefore it is likely to be relatively expensive for smaller projects.
- ISV requires either soil or some other earthen material to serve as the treatment media (melt).

The process works by melting soil in place using electricity applied between pairs of graphite electrodes. A highly conductive starter path is placed between the electrodes to allow initiation of melting. As electricity flows through the starter path, the path heats up and causes the surrounding media to melt. Once the media is molten, it too becomes electrically conductive. Continued application of electricity results in joule heating within the molten media between the electrodes. After the melt is fully established, the melt zone grows steadily downward and outward through the contaminated volume.

The media being treated must be capable of forming a melt with adequate electrical conductivity. Most natural soils and other earthen materials meet this criterion and can be processed without modification. If necessary, additives can be used to allow treatment of otherwise unacceptable media.

Organic constituents are thermally desorbed and then destroyed by thermal decomposition (pyrolysis) within the oxygen-depleted media being treated. Non-volatile inorganics are typically incorporated into the melt and the resulting vitrified product. Such incorporation occurs within the framework of the glassy product itself, as opposed to simple encapsulation (being surrounded) by the glass. A large volume reduction (25-50% for soils) occurs due to elimination of void volume and vaporisable materials during processing.

Step 6 - Technology selection

Technology Type	DECONTAMINATION & DESTRUCTION	PCBs
	EMERGING	POPs

BIOREMEDIATION

Bioremediation refers to the use of micro-organisms to break down organic chemical compounds that contaminate soil. The key to the process is the identification of an appropriate organism to perform the bioremediation process. The effects of moisture content, temperature, oxygen levels, food sources are required to be understood so that successful application can be achieved. In situ bioremediation treats the soil in place and eliminates the need to transfer the soil elsewhere for treatment. In situ remediation usually uses the indigenous bacteria and supplements with nutrient water to increase microbial rates. Ex situ technologies treat excavated soils under controlled conditions where temperature and moisture is managed. For sites without owners that have low levels of contamination this process can be very cost effective and after time very effective in cleaning contaminated sites. Generally unsuitable for heavily contaminated pesticide sites but will work on low levels of POPs and PCBs.

SOLIDIFICATION AND STABILISATION

These technologies rely on limiting the solubility or mobility of the toxic component in hazardous waste generally by physical containment. Five containment methods are used. Solidification by pozzolan reactions, pozzolan-portland cement reactions, thermoplastic micro encapsulation, and macro encapsulation. The sorption process requires additional solid materials to take up free liquids.

SOIL WASHING

PCB and POPs and other particles that are adsorbed into the surface of particles can be leached from soil by caustic agents such as sodium hydroxide.

SUPERCRITICAL WATER OXIDATION

This technology is a high temperature and pressure system that uses the properties of supercritical water in the destruction of organic compounds. The process is applicable to the treatment of a range of contaminants including acrolonitrile wastewater, pesticide waste water, PCBs, halogenated aliphatics and aromatics. The process is established with a totally enclosed ina reactor. The oxidant is injected as required on a heat based transfer, thermal and kinetic considerations. The process results in the formation of disposable ash and releasable gases.

GASIFICATION

This process uses a low pressure steam at high temperatures and a thermochemical reaction to vaporise and separate waste into their elemental components. A reduction process takes place in a reaction vessel which is directly heated. A reductive process rather than combustion takes place. There is no reactor stack gas.

CHEMICAL OXIDATION

Hydrogen peroxide, potassium permanganate, Oxone (DuPont chemical), peroxydisulfate, ultraviolet activated hydrogen peroxide and ozone oxidation are all viable oxidants for the treatment of nonstockpile neutralents. Under appropriate operating conditions and with sufficient reagent, the organic compounds present in the neutralents can be expected to be mineralized with any of these oxidants.

For chemical oxidation not activated by UV light, conventional process equipment and procedures are used. The reactions are carried out at 80-100C at Atmospheric pressure in aqueous solutions. When an organic phase is present, vigorous agitation is necessary to suspend and disperse the organic materials in the aqueous phase.

PROS

- Relatively mild conditions (low temp and press)
- Only gas evolved is CO₂.
- Inorganic salts precipitate when water is evaporated and are sent to landfill.
- Dioxins and furans are not formed
- Low cost
- Robust
- Good pollution prevention
- No large gas streams

CONS

- Reagent cost high.
- May not fully mineralize the compounds in the neutralents, or reaction may be prohibitively slow.
- Technology not yet mature.
- Capital and operating costs are expected to be moderate.
- Large equipment

ELECTROCHEMICAL OXIDATION

At low temperature and atmospheric pressure, electrochemically-generated oxidants react with organochlorines to form carbon dioxide, water and inorganic ions. High destruction efficiencies. All emissions and residues can be captured for assay and reprocessing, if needed. An electrochemical cell is used to generate oxidizing species at the anode in an acid solution, typically nitric acid. These oxidizers and the acid then attack any organic compounds, converting most of them to carbon dioxide, water and inorganic ions at low temperature (< 80 °C) and atmospheric pressure.

PROS

- The organic content of the feed, which can be soluble or insoluble organic liquids or solids, can vary between 5 and 100 percent without affecting the process unduly.
- Likewise, the water content of the waste can vary over a wide range.
- overall costs are estimated to be some 30 percent of the current estimate of demilitarization through incineration
- Materials can be fed by gravity or by pumping, and can be solid (such as PCB-laced wooden pallets) or liquid.
- The SILVER II TM process operates at relatively low temperature and pressure (up to 90 o C and nominally atmospheric pressure).
- AEA reports that there are low volumes of by-product streams (gaseous, liquid, and solid), and that dioxins and dibenzofurans are not produced by the process.
- when organics react with SILVER II TM , they are completely mineralized
- Positive characteristics include low temperature, low off-gas, and an apparent ability to treat diverse waste streams.

CONS

- off gases passed through a scrubber and potentially through an activated carbon filter before being discharged to the atmosphere
- By-products of the process include salts (referred to on Figure 2.1.1 as miscellaneous inert solids), nitric acid, spent scrubbing solutions, and off gases.
- AEA indicated that a key factor affecting cost is electrochemical efficiency
- reactions are strongly surface area dependent, solids and some liquids require significant size reduction and/or mixing for adequate oxidation to occur, whereas soluble organics are more easily oxidized
- Because the reactions take place at low temperature and in a liquid state, the times required for the reactions are much longer than for thermal systems, and typically, more secondary waste is generated by the oxidizing agents.

ELECTROCHEMICAL OXIDATION - CERIUM

The CerOx process is similar to the Ag(II) process except that it uses 0.8M Ce(IV) solution in 3M nitric acid at 100C to oxidize and destroy organic compounds. Unlike Ag(II), Ce(IV) is stable. The Ce is produced and regenerated by the electrolysis of Ce (III) in a bipolar electrochemical cell (T-cell). Carbon is converted to CO₂; chlorine compounds are converted to elemental chlorine, which is scrubbed and converted to hypochlorite. CerOx uses few reactants, principally nitrate (recycled), nitric acid, and sodium hydroxide to treat off-gases. Biggest cost is for electricity to operate the electrolysis T-cells.

PROS

- Cerium is much cheaper than Ag and much less toxic
- Low temperature and low pressure.

CONS

- High chlorine content in feed would result in lots of chlorine gas which would have to be treated.
- Uses large quantities of nitric acid
- Inorganic salt concentration builds up in anolyte solution and solution must be replaced periodically.
- Less developed than Ag(II) technology

STEAM REFORMING

The Steam Detoxification process involves very high temperature steam reforming (ie. 1100 to 1500C) to destroy hazardous wastes. Vent gases are carbon dioxide and water. Steam Detoxification consists of a two step process, and is carried out in a Pyrolysis Detoxifier. The hydrocarbon component of the waste is first evaporated in a first-stage waste feed evaporator unit and the vaporised gases are then mixed with superheated steam and fed into a "pyrolysis reactor" where they are further electrically heated under a slight vacuum. A carbon monoxide converter oxidises the detoxified gases and an activated carbon adsorber removes the last of the trace organics and metals.

PROS

- As the reactor is heated electrically the gases are free of the fuel combustion particulates common to incinerator systems.
- is small enough to readily fit into existing buildings;
- provide acceptable installation costs;
- destroy liquid solvents and their contaminants;
- destroy organic contaminants adsorbed onto activated carbon;
- destroy organics in the vapour phase;
- process continuous liquid feed streams;
- process drummed wastes without removal of drums;
- operate with a high temperature waste feed evaporator for solid organics;
- serve as part of a process to purify ground water; and reactivate vapour and liquid phase activated carbon canisters.
- Costs are estimated by the proponent at approximately half the average cost of incineration or

landfill in the US.

- Most promising technology according to DOE (DOE/SEAB)

CONS

- The process requires potentially elaborate gas treatment systems, and the overall system can be expected to be of similar complexity to the Eco Logic system
- Some pretreatment required for solid wastes (shredding, grinding, desorption).
- Some of the solid residues left over after the evaporation stage may require solidification and fixation before landfill disposal.
- The high temperatures used in the process require specialised equipment and reactor materials. The process requires containment of potentially hazardous gases at high temperatures and therefore will require careful design and operation.
- Mainly suitable to liquid and aqueous wastes.

WET AIR OXIDATION

The WAO process oxidizes and hydrolyzes organic contaminants in water at temperatures of 150-315°C and pressures of 150 to 3150psi, below the critical temperature of water and pressure (374°C and 3,204psia). If pure oxygen is used instead of air as the oxidizing agent, the gas volumes that must be managed are greatly reduced.

Organic compounds containing carbon, hydrogen and oxygen are converted to CO₂, H₂O and short chain biodegradable compounds such as acetic acid and formaldehyde. Depending on reaction conditions, further biotreatment of residues may be necessary. Toxic heavy metals in the neutralent would have to be precipitated and filtered out prior to biotreatment. Sulphur containing organics are mineralized to sulfate ions in solution, Phosphorous to phosphate ions, chlorine to chloride ions, nitrogen to ammonium and nitrate ions and nitrogen and nitrous oxide gas, cyanides are converted to CO₂ and ammonium ions.

PROS

- Mature technology, Zimpro has installed more than 300 units worldwide
- Requires only the addition of air/oxygen and water
- No dioxins formed, proponent claims they are destroyed.
- Titanium liner prevents corrosion
- Costs lower than for incineration.

CONS

- Most effective on dilute aqueous solutions
- May not be effective against PCBs and HCB.
- Effluent needs to be treated biologically.

BALL MILLING

The Ball Milling process is a mechano/chemical process, relying on the energy released at the point of collision between balls in a ball mill to activate a reaction between the waste and CaO (lime), breaking down the organochlorine compounds. By-products of the destruction of organochlorine compounds using CaO are generally of low toxicity and may include graphite, calcium chloride and calcium hydroxide. The process may be applied to concentrated forms of halogenated hydrocarbons such as PCBs and DDT. In the case of contaminated electrical components, the possibility exists to destroy the encapsulating container in the same process.

Disperse wastes (eg contaminated soil) would preferably be concentrated by solvent extraction or a similar process prior to destruction within the ball mill treatment system.

PROS

- treated materials are expected to be suitable for disposal to landfill in the case of solid wastes, or other normal disposal methods in the case of liquid wastes
- In the case of contaminated electrical components, the possibility exists to destroy the encapsulating container in the same process.
- the low energy potential of the system in relation to the surrounding environment means that the potential for release of contaminants is reduced. Also, the process can be readily shutdown in a short period of time, further reducing the potential for release in case of an emergency or power failure;
- the process operates at low temperatures increasing safety, reducing energy consumption and reducing the potential for formation of dioxins;
- items of electrical equipment, contaminated with PCB or damaged or corroded waste containers may be fed directly into the ball mill system for destruction;

- the process largely uses well established mineral processing equipment and principles;
- the process by its nature will result in a high degree of mixing of wastes and would tend to break up agglomerated material;
- no gaseous emissions are produced;
- the process is likely to readily treat wastes containing a range of organic contaminants, or mixtures of organic contaminants in one step, reducing waste handling and the associated risk.

CONS

- Disperse wastes (eg contaminated soil) would preferably be concentrated by solvent extraction or a similar process prior to destruction within the ball mill treatment system.

The Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal was adopted in 1989 and entered into force in 1992. Its purpose is to protect human health and the environment from the adverse effects caused by the generation, management and transboundary movements of hazardous and other wastes.

To achieve its purpose the Basel Convention aims at reducing the transboundary movements of hazardous wastes, the prevention and minimization of their generation, the environmentally sound management of such wastes, and the active promotion of the transfer and use of cleaner technologies.

Presently, there are over 150 Parties to the Basel Convention.

In December 1999, the Parties to the Basel Convention adopted the Basel Protocol on Liability and Compensation for Damage resulting from the Transboundary Movements of Hazardous Wastes and Their Disposal.

www.basel.int

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