Food and Agriculture Organization of the United Nations

ISSN 1020-4695

FAO Pesticide Disposal Series

18

Environmental Management Tool Kit for Obsolete Pesticides

Volume 6

R. Risk reduction strategy design

S. Risk reduction implementation strategy design

T. Development of risk mitigation plans

U. Development of the environmental management plan

FAO Pesticide Disposal Series 18

Environmental Management Tool Kit for Obsolete Pesticides

Volume 6

R. Risk reduction strategy design

S. Risk reduction implementation strategy design

T. Development of risk mitigation plans

U. Development of the environmental management plan

FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS
ROME, 2020

Required citation:
Cobban, R.J., Keith, J. and Thompson, R.H., 2020. *Environmental Management Tool Kit for Obsolete Pesticides.* FAO Pesticide Disposal Series 18. Rome, FAO.

ISBN 978-92-5-132112-6

Cover photo: © FAO/Reeham Ammati

Contents

Foreword

Environmental Management Tool Kit volume 6 is intended to provide practical methods to assist countries in the formulation of strategies for the management of pesticide contaminated land. As risk reduction largely depends on the accuracy of site investigation and associated risk assessment this document is meant to be used in close conjunction with EMTK volume 5, the outputs of which are critical in the design of pesticide contaminated land risk reduction and environmental management plans.

The previous volumes of the FAO EMTK series (volumes 1-4) are designed to assist countries with the risk management of obsolete pesticide stocks. From a wider perspective the approaches used to deal with obsolete stocks and pesticide contaminated land are similar. For both contaminated land and obsolete stocks, the first step requires a preliminary risk assessment to prioritize sites in terms of urgency for risk management and to estimate the absolute risk to human health and wider environment receptors. EMTK 1 explains a system for risk assessment and prioritization of stores containing obsolete stocks (the Pesticides Stock Management System, PSMS) whilst EMTK 5 (risk assessment of pesticide contaminated sites) describes the use of the FAO Rapid Environmental Assessment for contaminated sites to prioritise sites for further investigation and assessment. Due to the nature of contaminated land, additional assessment steps (further described by EMTK 5) are required to understand what is going on below ground and how this affects risk that are not required for obsolete stocks sites where the risks can largely be understood from a single visit to a site.

In terms of risk management and risk reduction EMTK 3 (risk management of obsolete pesticide stocks) and EMTK 6 (risk management of contaminated land) again have many similarities. Both documents discuss methods for the selection of treatment and/or disposal techniques required for the waste encountered. In addition, they have a similar approach to development of strategies needed for carrying out any works (i.e. which organizations will be required for implementation, management and supervision) and the development of plans to assess the risks and put in plan mitigation measures for things that may go wrong whilst the work is in progress.

EMTK volume 4 provides the user with a set of pro-forma systems to mitigate the risks common to most obsolete pesticide safeguarding projects, including contaminated land risk reduction work. Where the risk management of obsolete stocks and contaminated land differ is in the number and types of disposal options and risk reduction techniques that may be called upon. As risk management of contaminated land requires dealing with larger sources, usually at lower concentrations, and the escape of and exposure to contaminants in many different ways there are a much wider range of risk management approaches and techniques that need consideration. Additionally, the risk reduction measures put in place to manage contaminated sites can need monitoring and care long after the completion of projects. In comparison, most obsolete pesticide safeguarding work usually ends with the final disposal of any stock that has been safeguarded.

Acknowledgements

The EMTK series has been designed to help countries address the complex challenges from hazardous waste based on the adaptation of international best practice in chemicals risk management. FAO would like to express their sincere thanks to Dr Kevin Helps (formerly Senior Pesticide Management Officer in the FAO Pesticide Risk Reduction Group) for his vision in developing the EMTK series. For EMTK 5 (and 6) this vision was put into practice thanks to the efforts of a team of technical specialists under the management of Mr Russell Cobban (consultant). A special mention goes to Dr John Keith (Pure Earth) for his technical support, Dr Paul Nathanail (Land quality expert, University of Nottingham), Dr Eva Kohlshmid (Land and Pesticides expert, FAO Consultant) and Mr Bram de Borst (consultant) for providing invaluable peer review of the finalized materials. Furthermore, development and publishing of the documents was funded by the Global Environment Facility (GEF) to which the development team are indebted. for providing invaluable peer review of the finalized materials.

Acronyms

CSM	Conceptual site model
DQRA	Detailed quantitative risk assessment
DSI	Detailed site investigation
EA	Environmental assessment
EMP	Environmental management plan
EMTK	Environmental management tool kit for obsolete pesticides
FAO	Food and Agriculture Organization of the United Nations
GAC	Granular activated carbon
GPS	Global positioning system
GQRA	Generic quantitative risk assessment
HSE	Health, safety and environment
HTI	High temperature incineration
NGO	Non-governmental Organization
PMU	Project management unit
POPs	Persistent organic pollutants
PPE	Personal protective equipment
PRA	Preliminary risk assessment
PSI	Preliminary site investigation
PSMS	Pesticide stock management system
QA/QC	Quality assurance/quality control
REA	Rapid environmental assessment
SC	Steering committee
SL	Screening level
SSAC	Site-specific assessment criteria
S/S	Solidification/stabilization
SWOT	Strengths, weaknesses, opportunities, threats
TOR	Terms of reference
TD	Thermal desorption
UN	United Nations
UNEP	United Nations Environment Programme
WHO	World Health Organization

Introducing EMTK 6

Objectives

The principle objectives of this guideline are:

- to provide users with the background, tools and supporting information to develop effective risk reduction strategies for pesticide contaminated sites;
- to assist users in deciding the types of organizations best suited to carrying out risk reduction projects so that the risk reduction strategy can be implemented out as effectively as possible;
- to assist users, analyse what could go wrong while carrying out projects and to help provide measures to ensure that any problems are minimised;
- to ensure that any techniques or measures used are environmentally sound, socially acceptable and economically viable while being carried out according to international best practice and relevant standards and conventions.

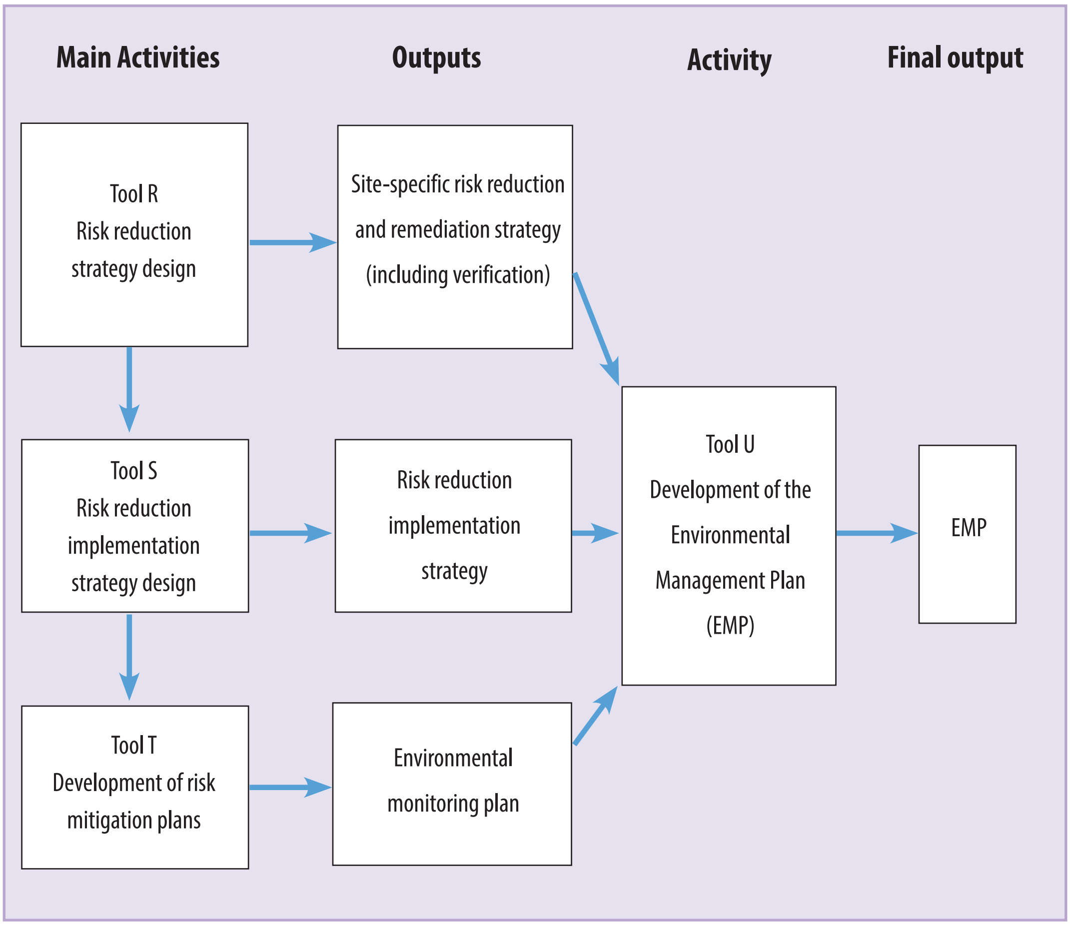
Outputs

The principal output of EMTK 6 is a strategy for dealing with sites containing ground contaminated by pesticides, the Environmental Management Plan.

Audience

- **Officers of the Ministries of Agriculture, Environment and Health** to support them in the development of objective strategies for the risk management of pesticide contaminated sites.
- **Country project managers, project coordinators and PMUs** in charge of the national obsolete pesticide programmes to help them devise and develop Environmental Management Plans for contaminated site risk reduction.
- **Individuals and groups within the private sector** who may be seeking to provide services in support of risk management projects.
- **Key decision-makers** within government who need final recommendations for budgetary and policy decisions.
- **Remediation Project Site Managers and technicians involved with project implementation.**

Presentation of EMTK 6



Tool R: Risk reduction strategy design

Tool R leads readers through the steps required to design a site-specific risk reduction strategy taking into consideration the risk and conditions encountered at each site as set out by the Conceptual Site Model (developed as part of EMTK 5). The tool helps users identify the objectives of risk reduction activities and the standards to which any activities should be completed. Tool R describes how users should select the optimum strategy from amongst a number of alternatives.

Tool S: Risk reduction implementation strategy design

Once the strategy has been chosen Tool S describes how to select organizations to carry out each of the components of implementation, management and supervision. The tool analyses the potential responsibilities of key participants available to countries to consider inputs from government or the national waste or environmental management sectors and the level of input from waste or environmental management contractors and/or consultants.

Tool T: Development of risk mitigation plans

Important in any risk reduction strategy is how to account for events that may go wrong. Tool T helps designers identify actions that could go amiss, how to avoid things going awry and how they can mitigate for each potential event.

Tool U: Development of the Environmental Management Plan

Tool U provides a format for combining and presenting the data and outputs from the previous tools presented in the guideline as a coherent Environmental Management Plan. The format provided allows for the presentation of the various outputs in relation to the broader environmental situation in the country.

Background to EMTK 6

The selection, design and implementation, including verification, of any risk reduction activity critically depends on information collected during the site investigation and risk assessment phases conducted as part of EMTK 5. This enables assessors and designers of risk reduction strategies, at a project level, to decide which sites are most in need of attention and at a site level how different areas of contamination are to be dealt with. The accuracy and sufficiency of the information coming from the risk assessment stage is therefore crucial in determining the most effective methods of risk reduction.

The first stage towards countrywide or regional risk management of pesticide contaminated land requires the identification and prioritization of all sites that are potentially contaminated. It is then necessary to use risk-based assessment to identify if there are unacceptable risks to human health or the environment. Integral to this process is the development use of the Conceptual Site Model (CSM). The CSM should clearly set out contaminant sources, pathways and receptors and any pollutant linkages operating that risk reduction activities will be required to demonstrably break. If unacceptable risks are found the following step is to find the most appropriate methods of reducing or if possible eliminating the risk. This is completed by evaluation of as many alternative methods of risk reduction that are potentially suited to the conditions on-site and the type of contamination encountered as well as national capacity. As site conditions and contamination will vary, more than one method of risk reduction is usually necessary; most sites will require a combination of risk reduction approaches and physical remediation techniques in order to manage the different types of risk involved. During the assessment process it is important to bear in mind that the techniques and approaches considered for risk reduction and/or disposal should be environmentally sound and comply with national and international guidance, standards and legislation. The resulting site-specific risk reduction strategy describes how the different risk reduction activities are to be carried out at each site and according to what standards.

Once it has been decided which risk reduction measures are to be used and how they are to be carried out, it is then decided which type of organizations should be responsible for each of the different activities of management, implementation and supervision. This may include government, public sector (e.g. regulators) or private sector contractors or a combination of both, and in addition it may be decided to include NGOs/IGOs in the process. At this point, providing funding has been obtained, the risk management plan is executed. Once the active phase of the risk management plan is complete, there is often a need for continued monitoring and oversight at sites to manage residual continuing risks. An environmental monitoring and long-term oversight plan is produced, identifying work to be done, responsibilities and funding sources. The monitoring plan will also detail who is responsible for the monitoring and oversight of each of the risks identified. It is important to put in place institutional controls to deal with situations in the future where the land use may be changed to a more sensitive one.

Tool R

Risk reduction strategy design and analysis of risk reduction techniques

Considerations for strategic risk reduction

Once site investigation and associated risk assessments have been completed, assessors and designers will be able to make a number of decisions at a strategic level. This will include the priority for which sites are required to be dealt with and the urgency with which risk reduction should be carried out. These factors are determined by assessing the numbers of people at risk of unacceptable levels of exposure at each site and the types and quantity of contamination involved.

Outputs from EMTK 5 will also give designers of projects an understanding of where the major sources of contamination are located and what types and quantities of contamination are involved at a countrywide level. This is important as it should have an impact on the types of off-site disposal or treatment facilities that are required to deal with any waste generated during a project. In combination with an assessment of local disposal/treatment capacity and types of domestically generated wastes this will enable stakeholders, including government, industry and donors, to decide the type and location of any future disposal/treatment facilities[1], if required.

Site risk reduction strategy design

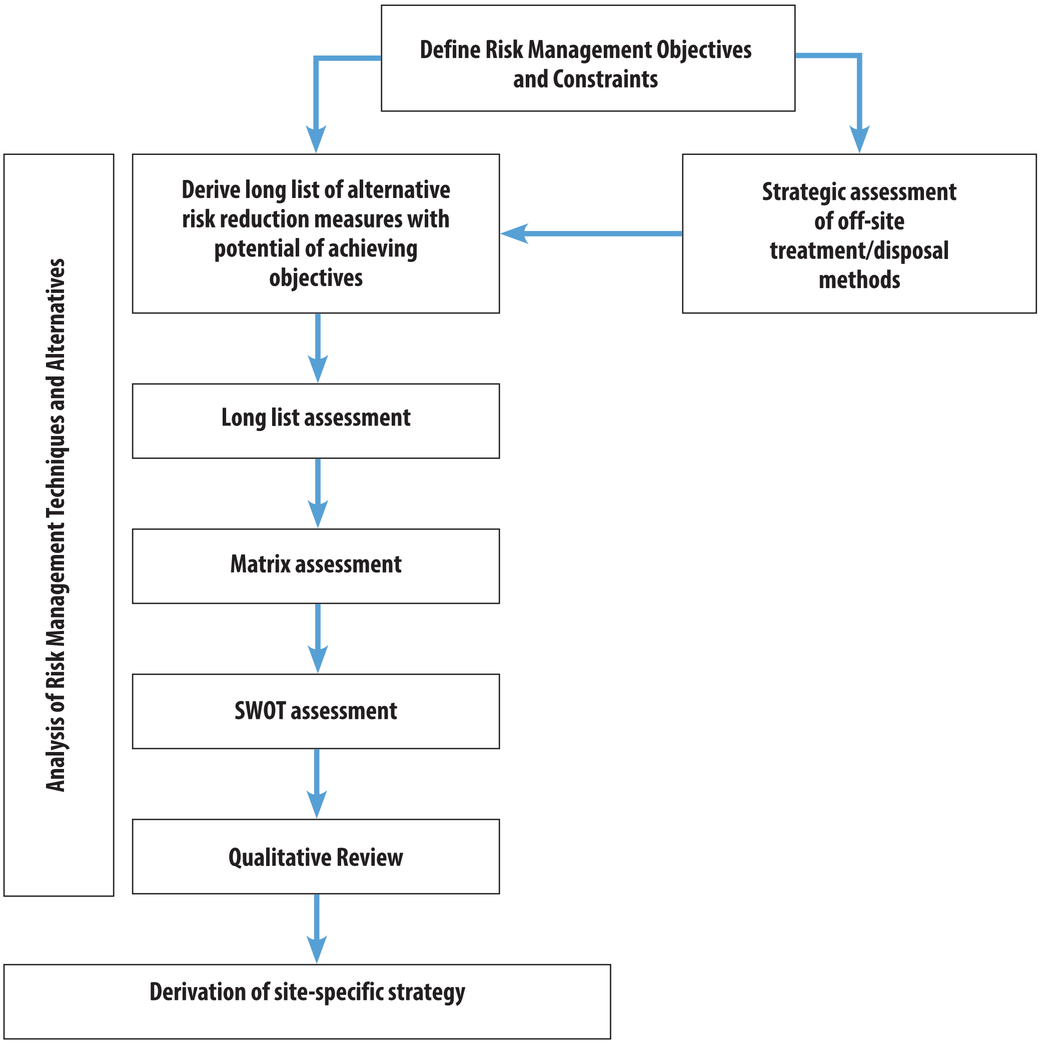
At site level, pesticide contamination is usually the consequence of spills during transport, formulation or use; poor container and stock management resulting in container degradation, spills and releases; or inappropriate pesticide disposal such as burial or dumping. The released quantities may be large or small, and the contamination can vary from being highly concentrated (many thousands of mg/kg) at the area of release to being more diffuse further away. The contaminant profile can range from simple – one or two known pesticides – to being highly complex with many types of pesticides plus other, perhaps unknown, chemicals. In addition to variations in the contamination, the ground on which contamination is found is also highly variable. Consequently, there are a wide range of techniques that have been used to treat land contaminated with pesticides. Each has advantages and disadvantages with respect to cost, social acceptability, environmental impacts, effectiveness, long term management requirements, the contaminants involved and the environmental and geological/hydrogeological circumstances in which they are found. The aim of the following section is to develop a risk reduction strategy that has the potential to address the pollutant linkages identified by the CSM at the site using one or a combination of the techniques available in a country[2].

Definition of site-specific risk reduction objectives and constraints

The detailed site investigation and subsequent risk assessment enable assessors to clearly identify any pollutant linkages operating at a site i.e. what is the contamination, what form is it in, who are the receptors and how is the contamination reaching the receptors. By understanding these

[1] Waste disposal facilities can often include pre treatment or treatment processes to recover or reduce the volume of waste for disposal.
[2] This can include both techniques in country or imported from abroad.

Figure 1
Developing a site-specific risk reduction strategy



relationships, the risk management objectives can be set with a view to demonstrably breaking the source-pathway-receptor linkage. Designers of risk reduction strategies should examine the Conceptual Site Model and define as closely as possible the objectives for any risk reduction measures, in other words specify what has to be done to reduce or eliminate the risk in terms of the pollutant linkages operating. Table 2 below provides several examples of this.

Each site will pose specific constraints on feasible risk reduction technologies. Such constraints may include neighbouring land uses, area available for on-site plant, proximity to off-site disposal/ treatment facilities.

Importance of the Conceptual Site Model in risk reduction

The Conceptual Site Model is an important part of the risk reduction decision making process. The CSM is one of the principal outputs from the risk assessment stage and is a fundamental tool that assists the choice of risk management strategy. Regarding risk reduction, the CSM should set out the following:

- the most relevant and important pollutant linkages that drive the need for remediation;

- the principal geographic, geological and hydrogeological conditions that may affect pollutant transport and the choice of risk management technologies;
- details of the critical receptors affected and their behaviour patterns;
- fundamental information regarding the source(s) including the extent and depth of contamination, physico-chemical characteristics, environmental behaviour and toxicological information;
- the level of risk at the site or in different parts of the site;
- potential risk management solutions.

Following risk assessment, the CSM should contain enough information so that informed decisions about risk reduction can be made i.e. what and where are the sources, what are the types and quantities of contamination, who are the receptors, how is contamination getting to the receptors and any other factors that may have a bearing on potential strategies and risk reduction techniques. By identifying the principal risk-driving pollutant linkages, the focus of the risk reduction process can be directed towards them.

The CSM is also a very effective communication tool as it allows those directly involved with the risk management process to communicate technical issues to stakeholders involved in the project who may not have such a detailed level of technical understanding.

Choice of risk reduction criteria

Once the risk reduction objectives have been determined, site-specific remediation criteria are set. These are the standards against which performance of any risk reduction activities are compared so that compliance can be measured. Risk reduction criteria not only includes the setting of maximum permissible limits for allowed for contaminants (pathway and receptor specific) but could also be the introduction of physical measures or interventions that result in risk reduction.

Maximum permissible limits in FAO risk management projects will normally refer to already published screening levels and drinking water standards identified at the risk assessment stage.

For very large or complex projects the generation of site-specific assessment criteria may be required.

Table 1

Screening levels available for use as risk reduction criteria

Agency	Link to screening levels concerned
United States Environmental Protection Agency Regional Screening Levels	http://epa-prgs.ornl.gov/cgi-bin/chemicals/csl_search
Canadian Council for Ministers of the Environment Environmental Quality Guidelines	http://st-ts.ccme.ca/en/index.html
Netherlands Ministry of Infrastructure and the Environment Soil Remediation Circular 2009	http://rwsenvironment.eu/subjects/soil/legislation-and/soil-remediation/
United Kingdom Environment Agency Soil Guideline Values	https://www.gov.uk/government/publications/land-contamination-soil-guideline-values-sgvs
World Health Organization Drinking Water Quality Guidelines	http://www.who.int/water_sanitation_health/water-quality/guidelines/en/

For a more in-depth discussion of screening levels, readers should refer to Tool Q of EMTK 5.

Table 2

Pollutant linkage, Risk Management Objective and Site-specific Remediation Criteria (showing examples)

Pollutant linkage (from CSM)	Risk Management Objective	Site-specific Remediation Criteria
POPs pesticide spill area in soil in residential area causing direct dermal contact, inhalation and ingestion of contaminated particles by children	Prevent direct exposure by most sensitive residents of contaminated particles and pesticide residues	Reduce or eliminate POPs pesticides to below levels considered acceptable for residential exposure i.e. Residential Soil Screening Level
Pesticide spill leaching into groundwater which is being drawn from wells and then consumed by villagers	Prevent consumption of contaminated well water	Reduce or eliminate pesticide to level considered acceptable for human consumption i.e. WHO drinking water standard
Ingestion of POPs by animal products (poultry, livestock) grazing in pesticide contaminated area	Short term prevention of human consumption of contaminated animal products	Recommend slaughter of all contaminated animals, prevent entry to site of other animals.
Exposure of workers to pesticide residues present in non-residential areas (e.g. farms or industrial areas) where workers are directly exposed or may pick up contamination and carry it home or distribute residues to the surrounding area	Short term prevention of exposure by segregation/isolation or securing the site	Reduce or eliminate POPs pesticides to levels considered acceptable for industrial or agricultural land uses
Exposure, e.g. during bathing or by consuming contaminated fish, to pesticides in pond water or sediment	Prevent exposure by ingestion of contaminated fish and/or exposure by bathing	(i) Reduce or eliminate pesticide concentrations in water to level considered acceptable for consumption i.e. WHO drinking water standard (ii) Reduce sediment level to leachable concentration considered acceptable for consumption i.e. WHO drinking water standard
Exposure of people in residential areas to pesticide residues adsorbed to windblown dusts by ingestion, inhalation and dermal exposure.	Prevent exposure by ingestion, inhalation and dermal to windblown residues	(i) Reduce or eliminate pesticide concentrations in source area to beneath residential exposure levels; or (ii) Isolate contamination so that contaminated dust does not become airborne

Table 2 above provides a format for setting out the relationships between pollutant linkage, risk management objectives and the relevant site-specific remediation criteria. It also includes some obvious examples encountered in the field.

Disposal and treatment standards

A key element in the development of a risk reduction strategy is to determine which contamination can be remediated on-site and which must be removed for off-site treatment or disposal. Any disposal that occurs, either on-site or off-site, must conform to standards set in international chemical conventions such as the Basel Convention (http://www.basel.int/) on transboundary movements of hazardous wastes and their disposal and the Stockholm Convention (http://chm.pops.int/) on protecting human health and the environment from persistent organic pollutants. It is also critical that regarding any other technologies or approaches used that only environmentally sound, socially acceptable and regulatory compliant forms of treatment should be considered. The following principles should be important in any decisions made:

(i) all disposal activities are completed to the same standard irrespective of the location of disposal (international or national disposal options);

FAO compares any national standard for treatment or disposal of hazardous wastes against the relevant standards in the European Union and the United States. The regulations in these two regions are considered as the most comprehensive and meet all requirements as set out in the chemical conventions;

(ii) technologies with a track record of compliance with the standards highlighted in this document should be given preference, so that developing countries are not used as a testing ground for unproven treatment or disposal technologies;

(iii) where feasible the proximity principle should be used i.e. on-site treatment or management is generally preferred as this avoids transport issues such as risk of spills during transport let alone border-crossing approvals. It is also often less expensive, more socially acceptable and environmentally beneficial and confines the work to the contaminated site.

Which disposal standards to use?

Considering that the basic starting point underlying disposal standards are the Basel and Stockholm Conventions, there are several other well-developed systems of legislation and regulation for effective management of hazardous waste treatment and disposal operations worldwide in addition, including those used by the European Union (EU) and United States Environmental Protection Agency (US-EPA). A striking feature of these systems is that they identify and address the same key issues in a broadly similar manner and there is general agreement on the issues that need to be addressed to develop soundly based, effective and environmentally protective regulatory systems for hazardous waste treatment and disposal. A review conducted under a previous FAO project, the African Stockpiles Project (ASP), concluded that of these, the European Union (EU) system is most the most effective comparator for systematic and coherent regulations on waste treatment and disposal as it is very comprehensive and sets high standards of environmental protection. Some of the key points regarding hazardous waste management and disposal in relation to international standards are presented in the following dialogue boxes.

BOX 1
Stockholm and Basel Conventions: key points for hazardous waste management and disposal

- All hazardous wastes arising from pesticides disposal projects should be subject to environmentally sound management (ESM) as defined by the Basel Convention.
- The Basel Convention states that hazardous wastes and other wastes should, as far as is compatible with environmentally sound and efficient management, be disposed of in the state where they were generated, so solutions in the country of origin would be preferred when they are environmentally sound.
- Article 6 of the Stockholm Convention highlights that any waste or stockpile consisting of POPs at concentrations greater than 50 mg/kg (ppm) should be treated to destroy or irreversibly transform the POP content (unless other environmentally sound management is the environmentally preferred option). Guidance on ESM of POP wastes is provided by the [*]Technical Guidelines from the Basel Convention.
- Contaminated soils with concentrations of POPs greater than 50 mg/kg that remain undisturbed *in situ* and have not been placed in stockpiles are not currently considered subject to the Stockholm or Basel Conventions.
- Any trans-boundary movements of waste must be in accordance with the requirements of the Basel Convention.
- Attention must be paid to avoidance of unintentionally produced POPs. For pesticides wastes this means care should be taken over disposal and treatment processes that may produce dioxins and furans.
- Effective public awareness and participation in decision making is a core principle.

* Conference of the Parties to the Basel Convention, 2017.

Strategic assessment of contaminated sites

Together with the consideration of existing capacity, a strategic assessment of contaminated sites in a country may affect the selection of treatment and disposal technologies at a site level. The overall type and quantity and regional distribution of contaminated soils, as well as other hazardous wastes including obsolete pesticide stocks, will influence the economic feasibility and availability of particular types of disposal and treatment technologies at a countrywide or regional level. For example, the use of a technique such as ex-situ thermal desorption may not be justified for one site only, but may be feasible if, say, a further 10 sites were also suitable for the same technique or equipment. Similarly, developing the expertise and capacity for long term management of *in situ* bioremediation methods may not be feasible for a single site but may be the best option if there are multiple sites with relatively low pesticide contamination in soils or groundwater.

The following table, Table 3, presents a format for a preliminary analysis of disposal options. It should be completed in consultation with representatives from the Ministry of Environment or national regulators responsible for waste management issues.

BOX 2
Key points related to international standards

The following are the main ways in which pesticide disposal projects, including those involving contaminated soils, in any country can use available standards to deal with waste treatment and disposal:Repackaging and export of wastes to an established treatment or disposal facility in a highly regulated environment (most likely, but not necessarily, Europe):

1. treatment in an existing facility which could be modified for the purpose and is designed to operate in the long term (on other wastes) – in the country of origin or abroad (for example a regional facility);
2. treatment in a newly developed facility (as a hazardous waste management facility – i.e. that would continue processing other wastes after stockpiles were treated), in the country of origin or abroad;
3. a special project – development of a dedicated facility or modification to an existing facility with the sole purpose of treating the pesticide stockpile with no expectation of continued operation;
4. a country will need to draw on the relevant parts of the EU (or other) system for their specific circumstances, wastes and options for treatment and disposal;
5. in addition to the regulatory standards, it is essential that the necessary infrastructure, skills, capacity and support is in place to enable a facility to operate reliably and successfully.

To complete the table, the following issues should be considered:

- a review of current waste management practices for each waste stream to establish the baseline of current treatment and disposal capacity nationally;
- based on EMTK 2, Tool F, a review of the proximity of the treatment/disposal facilities to the sites as well as how transport of any contaminated soils may be undertaken;
- an assessment of any existing facilities in terms of their current operating permit or license. Details such as issue and expiry dates, licensing authority, non-compliance with license and operating standards used, volume or concentration limits on wastes that can be accepted.

Table 3
Preliminary strategic review of disposal options

	Pesticide waste (high concentration)	Contaminated soils (low concentration)
Amount and type of waste or soil contamination (taken from risk assessments)		
Number of affected locations nationally or regionally		
Existence of national disposal capacity		
Existence of expertise and equipment for on-site management methods		
Proximity to facility locations		
License and operating standards		
Treatment standards/objectives		

Risk reduction approaches and techniques

As there are many published texts that provide in depth reviews and technical descriptions of the various technologies currently operating in the market place, this document will not present a detailed review of existing disposal or treatment technologies. The following is intended to give readers insight into those technologies and risk reduction approaches that are more likely to be successful for pesticide contaminated sites under the conditions encountered in low to middle income countries.

Existing sources of information regarding risk reduction techniques and approaches include:

• FAO Environmental Management Tool Kit volume 3, Annex 4[3].

This document reviews the suitability of various technologies for each of the major waste streams common to obsolete pesticides and soils contaminated with obsolete pesticides. It also sets out a decision-making process by which the user can assess the suitability of a specific technology to treat a variety of pesticide and other wastes. The process is designed to assist the user in determining if a specific technology has a proven track record in treating a particular type of pesticide waste or associated waste. This will also help to assess disposal options proposed by waste management contractors.

• The Federal Remediation Technologies Round Table[4].

This is a website dedicated to remediation technologies. It includes detailed information about each technology, alternative methods for the assessment of each and also pricing information for the different technologies available. It can be found at the following link: http://www.frtr.gov/ .

• The Basel Convention General Technical Guidelines[5].

The Basel Convention General Technical guidelines section IV.G describes in detail a number of techniques appropriate for dealing with POPs chemicals.

---

3 http://www.fao.org/3/a-i2216e.pdf
4 Federal Remediation Technologies Round Table.
5 http://www.basel.int/Portals/4/Basel%20Convention/docs/pub/techguid/tg-POPs.pdf

Background to the types of risk reduction approaches and techniques

There are three main ways to reduce or control unacceptable risks in land contamination applications:

- remove or treat the source of pollutant(s);
- remove or modify the pathway(s);
- remove or modify the behaviour of receptor(s).

Within each of these categories, there may be different technical and non-technical risk management options. For example, it is possible to remove or treat the source of a pollutant using a variety of engineering, physical, chemical or biological means.

Source Management

Contamination on sites arises from either a specific "point source" or from more diffuse contamination. Pesticide contamination is frequently encountered as a point source caused by poor storage of obsolete stocks, pesticide spillage during formulation or mixing or from the burial of obsolete pesticides. Pesticide contamination from poorly controlled use would be considered diffuse contamination.

Diffuse contamination is spread over a wider area. In this situation, there is normally a much larger quantity of contaminated soil or groundwater than from a "point source" and the contamination is considerably harder to treat, particularly where the contamination of groundwater is involved. Regarding pesticide contaminated sites, diffuse contamination may be caused by, for example:

- over application of pesticides over a wide area for a period of many years;
- contamination that has originated from locations of point contamination say, from a pesticide storage or spillage site. However, over a long period of time, low rates of degradation of some pesticides allows residues spread over a much wider area. This is particularly relevant to POPs pesticides which have half-lives (DT 50 values) in the field in the order of decades.

Many pesticide contamination sites will have both "point" source and "diffuse" contamination characteristics. For example, a site could have a small area where spills or disposal occurred, and a much larger area where low concentration soil contamination is present due to spread from the "point source" area over time. Consequently, the risk management strategies will have to reflect this.

The treatments and technologies for source management outlined above can either be:

- *Ex situ* methods whereby the contaminated soil is excavated for treatment. Treatment can take place on-site or material can be taken away for off-site treatment; or
- *In situ* methods whereby contamination is treated in the ground.

Potential source management options most commonly include:

- <u>High temperature incineration</u> (HTI) – HTI at an internationally located facility is normally conducted only for very acute situations where there are no possible alternatives.
- <u>Thermal desorption</u> (TD) – this can be in situ or *ex situ* (on-site or off-site).
- Sequestration through <u>solidification/stabilization (S/S)</u> – this can be in situ or *ex situ* (on site or off-site).
- Sequestration or long-term storage through <u>specially engineered landfill</u> or <u>underground deposition</u>.
- <u>Bioremediation</u> with and without commercial amendments;
  - Landfarming-soil is spread out to a shallow depth 0.2 m-0.5 m and tilled with nutrients and other amendments to encourage biodegradation;

- Windrowing – soil is placed in longitudinal piles 1.5 m to 2.0 m high and tilled;
- Soil washing to reduce the volume of material needing further treatment or disposal;
- Phytoremediation.

Pathway Management

Pathway management encompasses a variety of in situ techniques that are used to interrupt contaminant transport from the source to receptor. Pathway management can involve:

- capping or blocking of water wells used for consumption;

A well used for agricultural irrigation capped with concrete

- groundwater containment and control techniques such the introduction of slurry walls, sheet piling or groundwater filters;
- capping or covering contaminated soils with geotechnical membrane, clean soils, asphalt or concrete etc.;
- increasing the sorption capacity of soils through the addition of granular activated carbon (GAC), granulated charcoal or increasing the proportion of organic matter.

Enrichment of the soil in a final depot with charcoal (Molodo, Mali)

The use of GAC or charcoal can also be used for pre-treatment of soils required for deposition in landfill or containment cells to reduce the capacity for leaching of organic compounds (as illustrated by the following photograph which shows the mixing of GAC with soils in Mali to restrict the mobility of POP pesticides).

- Improving drainage to control surface water run-off and soil erosion by run-off.
- Using vegetative buffering to control wind erosion and surface water run-off.

Vegetative buffering used to control surface water run-off from a site

Receptor Management

Receptor management is the introduction of methods or measures that will result in the reduction of exposure to persons and/or animals near the contaminated area. These include:

- change of land use to exclude sensitive receptors. Most commonly this would be to change a residential area contaminated with pesticide to an industrial land or semi-industrial use. As this is a very sensitive issue this measure should be considered only as a last resort. As additional measures to ensure that displaced residents are adequately compensated and provided with suitable alternative accommodation should also be introduced.

A change of land-use in order to manage risks requires commitment from various parties to ensure that the change will be permanent:

- improvement of public awareness through community meetings, publicity campaigns and seminars;
- education of children to improve understanding of pesticide related issues, including contaminated land, via the school curriculum;
- local bans on grazing of animals and consumption of potentially contaminated animal products;
- local bans on hunting and fishing in contaminated areas;
- site zoning and access control using signs and fencing;
- awareness of the value of protective equipment, personal hygiene and going home from work with clean clothes/hands/shoes; and
- encouraging improvement in the general level of sanitation and cleanliness.

Process based remediation of contaminated soils and ground water

In OECD countries market-driven pressure in combination with legislation and government incentives have facilitated the redevelopment of many contaminated sites. In these countries market pressure has also allowed the development and use of many process-based solutions to solve contaminated land problems. Process based solutions normally involve a high degree of technical input at the design stage, the use of hi-tech equipment and continual operational control and monitoring during the implementation phase.

While it is relatively easy to use more advanced technologies in OECD countries, the budgets available for FAO projects and the practicalities of their implementation can be a considerable barrier to their successful use in low to middle income countries. Frequently these techniques require equipment not locally available, long term maintenance, a constant power supply and regular monitoring to ensure success. Where possible, FAO projects should try to focus on the use of low technology, extensive approaches using resources and equipment already available in country. Such approaches will likely be in situ, make use of manual or low capacity machinery, benefit from access to solar or other renewable energy sources, will be most effective if risk assessments are able to narrow down the scale of remediation needed.

Use of the Conceptual Site Model to help determine the risk reduction strategy

In general terms, as the level of risk increases at a site more intensive forms of risk reduction will be necessary. In situations where there is low risk, for example where there is a breach of screening levels in a remote location, it may be sufficient to simply use receptor control techniques. In this situation, it may be permissible to segregate the area using fencing and erect signs to warn people of the dangers of the contamination. As the level of risk rises, say, as the concentration of contamination or the numbers of people passing by or living near the contamination increases, additional pathway management measures may have to be introduced. For example, the soils may have to be covered with a geotechnical fabric and clean soils. In high risk situations, where exposure to contamination is very high (such as people living in a contaminated area), removal of the source may well be required.

Table 5 below illustrates the categorization of risk management technique or approach which can be made about the general level of risk.

When designing risk management strategies, it is very difficult to define where the divisions between low, medium and high-risk levels can be introduced let alone under what circumstances different techniques/approaches become appropriate for use. The single level that can be set is the risk reduction criteria that specifies when risk management should commence. The other divisions are much more diffuse and are open to interpretation. These levels are determined by a combination of examination of the CSM, project experience and a knowledge of the performance that the different techniques can provide.

Table 4

General risk category versus risk reduction technology/approach

<table>
<tr><th>Risk level</th><th>Risk Management technique or approach</th></tr>
<tr><td>High risk</td><td>Source management of soils by excavation then disposal
Thermal treatment (normally only used in high risk scenarios)
Thermal desorption
High temperature incineration in rotary or cement kiln
Bio remediation of biodegradable contaminants (i.e. non-organochlorine pesticides)
Land farming
Windrows
Covered windrows (where there is a risk of volatile chemicals)
Sequestration
Stabilization (pre-treatment) of metal contaminated soils using alkaline material e.g. cement followed by disposal to landfill
For large quantities of contaminated soils other techniques may become viable:
In situ thermal techniques
Thermal desorption
Soil washing</td></tr>
<tr><td>Medium risk</td><td>Receptor management
Change of land use from more sensitive to less sensitive (mainly to an industrial area), therefore exclusion of identified receptors
Source management of soils by excavation then disposal
Sequestration
Disposal to landfill and pre-treating by:
Stabilization using alkaline material e.g. cement or lime (metal contaminated soils)
Addition of granular activated carbon or crushed charcoal or biochar to improve adsorption characteristics
Excavation for ex situ or even off-site Bioremediation (as above)
Source management of soils using in situ techniques
Bioremediation (as above)
Stabilization using cement (metal contaminated soils)
Addition of granular activated carbon or crushed charcoal to improve adsorption characteristics (organic contaminants, largely organochlorines)
Pathway management of contaminated soils
Installation of capping using geotechnical fabric, clean soil, asphalt and/or concrete
Pathway management of groundwater
Installation of slurry walls
Installation of sheet piling
Installation of permeable barriers
Replacement of drinking water wells</td></tr>
<tr><td>Low risk</td><td>Receptor management
Use of signs to warn people (bearing in mind language and appropriate symbology)
Fencing to maintain segregation from the wider population and animals from contaminated areas
Education of school children and local population
Use of security firms to prevent entry
Pathway management
Banning of consumption of contaminated meat or animals
Improvement of drainage (use of vegetative barriers and physical barriers such as ditches etc.)
Implementation of wind erosion controls drainage (use of vegetative barriers and physical barriers such as screens etc.)
Source management
Improvement of soil quality to improve degradative (also adsorption) properties, for example addition of mineral fertilizers or manure
Phytoremediation (note that this technology is a very long-term option and requires research and development)</td></tr>
</table>

Setting levels of contamination at which different forms of disposal or treatment may be introduced

POPs contaminated soils

Contaminated soils identified as containing POPs chemicals fall under the Basel and Stockholm Convention Guidance. The Low POPs limit under this guidance sets out that any POPs species over 50 ppm must be subject to destruction or irreversible transformation. Due to the high chemical stability of organochlorine chemicals, the proven technologies that have this capability are restricted to thermal technologies such as high temperature incineration (either by dedicated hazardous waste rotary kiln or cement kiln technology). Other process-based techniques, bioremediation technologies and amendments available on the market are currently not proven and are largely experimental at the project level where significant quantities of contaminated soils are involved. Unfortunately, the costs required to implement thermal treatment for all POPs contaminated soils of each POPs species above 50 ppm are prohibitive. It is unlikely that projects will be able to afford this type of treatment except in cases where soils are very highly contaminated and where the risk of exposure is high. In practise, risk assessment is crucial in establishing the risk presented by a site; only those sites which are classified as high risk will justify the level of expenditure necessary for thermal treatment, whether on-site or off-site.

In terms of waste management, the critical decisions for a project are to determine at what concentration of contamination risk reduction measures are required and also at which concentrations different forms of disposal or treatment will be necessary above this level. For POPs contaminated soils there will generally be three categories of soils affecting the type of disposal or treatment:

1. Soils containing concentrations of POPs above human health criteria but below 50 ppm

As these soils breach screening levels, they are determined to be a risk to human health therefore risk management is required. Where the likelihood of exposure is low the soils will be suitable for site-based risk reduction such as capping with geotechnical fabric, clean soils or concrete and over the longer term may be suitable for phytoremediation. Where the likelihood of exposure is higher soils should be removed from the zone of exposure and then placed in some form of engineered landscaping such as berms or banks covered with a heavy-duty geotextile and then clean soil.

2. Concentration of POPs above the 50 ppm low POPs limit

These soils are above the 50 ppm low POPs limit and therefore require risk management according to the Stockholm and Basel Conventions. As referred to above, the relatively low concentration and large quantities of this type of soil mean that the use of thermal treatment to destroy or irreversibly transform contaminants would prove very costly indeed.

Volumes of soil requiring treatment can be reduced considering the following:

- the Basel and Stockholm guidance requires that soils considered part of a "stockpile" only should be treated as low POPs waste. This means that soils encountered *in situ* that are identified as above 50 ppm are not subject to the guidelines;
- the guidelines recognise that soils above the 50 ppm low POPs limit may be placed into some form of dedicated engineered structure such as a specially engineered hazardous waste landfill for temporary storage.

Bearing these points in mind, readers should take care to understand the exact circumstances of the CSM and the effects of POPs chemicals on human health and the environment in each case. Where the human health limit is exceeded but exposure is deemed to be low it is permissible that POPs contaminated soils above the 50ppm limit are left *in situ*. However, it is recommended that the potential for exposure is further reduced using site-based risk reduction such as capping and/or isolation. Where the CSM shows that exposure is high and human health screening levels are breached the soils should be removed.

3. Concentration of POPs requiring destruction or irreversible transformation

As the only practical alternative to thermal treatment is sequestration by landfill, controlled stockpile or underground disposal, the level at which thermal treatment should apply should be when the concentration of contamination becomes high enough that sequestration by these methods cannot be considered a viable alternative. One method of determining this level is by leachate testing i.e. determining the concentration of contaminant in soils, that when subjected to leachate testing, shows concentration of POPs in leachate above guideline levels in water, soils should then be sent for thermal treatment. The exact form of the leachate test is normally part of national waste management testing and guidance.

Other types of contamination in soils

Levels of contamination at which different forms of treatment should be used are normally determined by the effectiveness of the types of treatment selected.

In FAO projects, the initial threshold for risk management will be the human health screening level. The upper level for proceeding to the next level of treatment should be determined by the capacity of the treatment to deal with the type of contamination concerned.

Treatment	Suggested level of introduction
Bioremediation	Upper level determined by effectiveness of treatment. Determined by field trials or available experimental data
Stabilization/solidification	Leachate testing
Capping	Leachate testing
Sequestration (landfill, above ground stockpile)	Leachate testing
Thermal treatment	Level at which thermal treatment is required is determined by the level at which other treatments are not effective

Assessment of risk reduction alternatives

Once a site has been characterized and risk reduction needs have been defined, an evaluation must be completed of risk management alternatives. In general, there are four steps in this evaluation process:

- *development of a long list of potential remedial techniques and risk reduction approaches;*
- *long list assessment to shortlist 3-5 reasonable options;*
- *matrix assessment;*
- *analysis by SWOT;*
- *qualitative Review.*

However, the analysis sometimes can be abbreviated, particularly for smaller sites, or where sites with similar conceptual site models have already been evaluated and the learning from this previous work can be used. The intent is to most efficiently evaluate risk management alternatives considering all feasible options, while moving to focus as quickly as possible to the most viable options in order to identify a preferred option.

The combination of technologies is becoming increasingly common as a way to improve remediation effectiveness. Techniques may be thought of as pre-treatment, treatment and post treatment. For example, heating the ground to improve contaminant mobility (pre-treatment) by thermal desorption can be followed by physical recovery of the contaminant (treatment) and its off-site destruction (post treatment) by high temperature incineration.

It is acknowledged that both matrix and SWOT are subjective forms of analysis that can be manipulated to derive a predetermined outcome. In any event, more complex forms of analysis such as the use of modelling to estimate the effectiveness of various strategies can be difficult to implement without additional expert intervention and effort but may not improve the result. What is important is that matrix and SWOT analysis provide simple and clear methods by which the developers of a strategy can present and justify their choices for risk management. The use of the matrix methodology can be more objective by the introduction of verified data (for example quoted costs per tonne for the technology in question or toxicity equivalents of emissions).

Development of long list of techniques

This preliminary stage involves generating a list of all the potential remedial techniques and risk reduction approaches that could possibly be of some benefit to risk reduction and that are available or could realistically be made available in country.

Long list assessment

The long list is then broadly assessed as to whether the approach or technology is feasible or not given the Conceptual Site Model. Specifically, this initial assessment should evaluate the following:

- is the technique or approach technically able to deal with the contaminants of concern identified to meet risk management objectives or acceptable standards?
- can the technique or approach be applied in the specific ground conditions?
- does the approach or technology comply with international guidelines and conventions?
- is it readily available to the site or will high transportation costs or mobilization costs prove to be prohibitive to its use?
- can the technique or approach achieve all the objectives within all the site-specific constraints?

Any approach or technology not technically feasible, not meeting international guidelines and conventions, or not viable due to obviously high transport or mobilization costs should be excluded from the list.

An example of long list assessment in given in Annex 1.

Matrix assessment

The next step is the screening of the remaining list by a more in-depth matrix analysis whereby each technique is scored according to a number of factors:

- long term reliability – Whether the approach is reliable in the long term;
- implementation risk – What are risks while the technique/approach is being put in place?
- cost for implementation – Where costings are involved a budget should be drawn up for each option that includes all foreseeable costs. For example, operational cost, costs for testing and monitoring (during and post project), costs for infrastructure etc.;
- compliance to the waste hierarchy – Does the method destruct, degrade, transform, neutralize contaminants or does it dispose, sequester or immobilise the contaminants?

- proximity – Can the method be used on-site or is it available locally? Is it only available at national, regional or international level?
- is the technology acceptable to key stakeholders, particularly regulatory agencies and local governments?
- long term management requirements, including cost and institutional requirements, after work is complete – e.g. security, monitoring, land use restrictions, etc. Can the project or the government involved commit to long term care?
- emissions data;
- potential to improve in-country waste management capacity (both infrastructure and skills);
- implementation time required.

Weightings should be applied to each of the above factors, and scores applied to each viable technology or approach. The techniques are then ranked with respect to the product of the scores.

In a project where the conditions of implementation are similar at different sites, only one assessment may be required. On the other hand, where conditions are markedly different more than one assessment will be needed. Often several technologies or approaches may be needed at a single site. Different methods may be needed when:

- there are both high concentration pesticide wastes and lower level contaminated soils at a site;
- there are different pesticides to be managed in specific areas of a site and they are amenable to different treatment technologies.

In this situation, several different matrix analyses may be necessary for the different areas.

An example of matrix assessment is given in Annex 2.

If after the matrix analysis there is not a clear choice or choices for the risk reduction/management method, a SWOT (strengths, weaknesses, opportunities and threats) analysis should be completed for the remaining methods.

Analysis by SWOT

Unlike the preliminary screening steps, the SWOT screening step attempts to incorporate the country and site-specific context, including local perceptions and values, resources available, and compatibility with existing national policies, goals and prior practices, etc. The SWOT screening includes assessing each potential technique for the following factors:

(i) sustainability of the techniques;

(ii) the Waste management hierarchy;

(iii) the effort to move away from the use of energy intensive techniques;

(iv) promotion of the use of on-site treatments;

(v) site-specific factors that may preclude the use of some techniques or enhance the use of others. Examples might include lack of water that precludes bioremediation methods; proximity of sensitive receptors (schools, residential areas) that precludes use of treatment methods that may create dust, odours or fumes; access challenges that limit use of heavy equipment; etc.

An example of SWOT analysis is given in Annex 3.

Qualitative review

The qualitative review is an analysis of the potential alternative combinations of techniques suitable for each area of the site and the primary reasons for their selection (or not being selected). It also briefly examines the risks of implementing each strategy and activities or actions necessary to mitigate the risks. The qualitative review should also explain any changes in strategy due to the impact of national or regional availability of treatment methods. The format for the table is the following:

An example of a qualitative review is set out in Annex 4.

The site-specific risk reduction strategy

After evaluation of risk reduction alternatives, the final strategy selected should be described in some detail. This includes how and where different risk management approaches will be used on the site, in addition to details of any final on-site or off-site disposal options selected. The risk management strategy should also state the standards to which any risk management activities are conducted, and remediation targets. This information provides the detailed specification for tendering that enables contactors, and/or other providers, to design services for implementation of the risk management activity.

The risk management strategy should contain:

- a detailed reasoning for the final selection of the risk management techniques or approaches used in each area on-site;
- the type, quantity and location of contaminated ground in each area of the site to be remediated (including maps);

- details of specific disposal or treatment techniques to be used, either on-site or off site, and how this is to be conducted. Specific off-site disposal facilities should be identified. This should take into consideration the countrywide or regional activities that are occurring at other sites at the same time;
- the standards to which any remediation is to be conducted including the use of any groundwater and soil remediation criteria;
- details of any specific monitoring to be conducted, including the parameters for monitoring at the end of the work to measure success, and post-work monitoring needs. This always includes soil sampling and analysis to be done at the end of the work to validate that it has been successful. Other monitoring may also be done, for example: the use and/or installation of water monitoring wells including the number, type and location of the wells and the parameters for groundwater monitoring, the frequency of monitoring and for how long monitoring is to continue.

At this point it is very useful to use a drawing to set out specifically where risk management activities are to be carried out on the site.

Tool S

Risk management plan implementation

Once the Risk Management Strategy of the site has been confirmed, consideration should be given to the types of organization to implement it. A framework should be developed that sets out which organizations will be responsible for the key areas of management, implementation, validation and supervision of the various risk reduction activities.

During the implementation phase of risk reduction, the preferred option is often for all activities to be completed by specialist contractors. Whilst this option appears the easiest strategy and offers some clear advantages, it is not always feasible, desirable or economically justified. It is important to consider national competencies and to explore ways in which they may be developed during the implementation of a project. In general terms the following options as to who will make the major contribution towards implementation are considered for most projects:

Option 1: 100 percent international contractor implementation.

Option 2: 100 percent government self-implementation.

Option 3: Government as the lead implementer, with use of international consultants for special expertise and national contractors as needed.

Option 4: international contractor implementation in partnership with government.

Option 5: international contractor implementation with sub-contracting to a national contractor.

Option 6: National contractor with use of international consultants for special expertise areas.

The level of contractor and government involvement can vary greatly in each of these areas, so any strategy should clarify who is responsible for the management, supervision and implementation of the project. This will have a direct impact on the scope of services included in any tender for services required for risk reduction. The challenge is on deciding which combination of options is best suited to the scope of their project as defined by the risk management strategy. It is likely that a combination of options may be appropriate for larger or high-risk sites where there may be a number of different activities or risk reduction strategies occurring according to the problems encountered in each zone. As the situations in medium and lower risk sites become simpler, is it probable that national contractors and government will take a more leading role in implementation.

This process of defining who is responsible for each set of activities can be completed as a national coordination workshop involving a mixed group of stakeholders. In workshops provided by FAO, the PMUs and other stakeholders are requested to complete a SWOT analysis[6] for each option above based on their current understanding of the project in their country and competencies available in country. Participants are also invited to provide additional options which are then also subjected to the SWOT analysis. When analysing each option, it is important that the core issues of risk, cost, time and capacity development/skills transferred are considered alongside the risks associated with each option.

6 Photograph reproduced from (Harmesan, 2010).

BOX 3

Involvement of government in pesticide contaminated land risk management

A decision needs to be reached as to the extent of involvement the government can commit to and to which department would be most appropriate. This decision is almost always made by the government, not donors, contractors or consultants. In some instances, involvement will be limited to developing the terms of reference (TOR) for national and international contractors to complete risk management activities. Alternatively, government may wish to use the project as an opportunity to develop national chemicals management capacity at managerial, supervisory and implementation levels. In addition to the policy issues it is also important to consider the scope of the project. Initially projects often involve risk management of high priority or complex sites that are high risk. In this instance there may be a lack of national contractor capacity to do the work and outside input by an international or regional contractor will be inevitable. However, as clean-up work continues, projects may involve the risk management of large numbers of lower risk contaminated sites scattered in numerous locations over a wide geographical area that require increased levels of government or national contractor inputs, as hiring of international contractors will be too costly. However, in many instances, there is a lack of national contractor capacity. Thus, it is left to government to provide the personnel, which are then trained to develop the necessary level of competence by a consultant, disposal contractor or FAO. Such skills transfer typically involves supervised work at high risk locations with increasing levels of responsibility transferred to national staff over time, based on continuous assessment of the individual staff member.

BOX 4

Involvement of national contractors in risk management

The use of national contractors working in partnership with experienced international companies has been successful in several projects completed to-date. The decision to use a national contractor can either be the result of a local tender/procurement process or can be the result of an international contractor appointing a local partner to assist in implementation. In both cases it is critical that there is a full assessment of the capacity of any national contractor to ensure that they are competent to complete all activities assigned to them under a safeguarding contract. It may be possible to develop the competence of the local contractor for implementation of future projects through a skills transfer plan. This would also develop local capacity in the private sector which would assist in the overall development of in country chemicals management capacity. A further factor to consider is liability and insurance coverage. All local contractor inputs will require similar levels of insurance coverage as for international contractors. In the case when more than one contractor is involved in the project, seamless insurance coverage must be assured, perhaps through back to back contracts and sub contracts.

The implementation strategy for each site will vary according to the risk at the site, risk management methods and technologies to be used and the development of competence gained in government or the national contractor sector through skills transfer and working in cooperation with specialist international contractors. Even so, this approach of progressive skills transfer and capacity development will not be suitable for all risk management projects. There will remain instances where the safest, simplest and most cost-effective solution will be to contract a specialist waste management company to complete all activities.

The decision to opt for one of the solutions outlined above will be driven by several key factors including:

- scope of the project;
- competence of national staff;
- available budget;
- materials and equipment supply; and
- liability insurance.

FAO provides support to countries in the selection of the most appropriate option for risk management implementation. This process considers issues such as:

- the time frame for implementation of each option;
- the cost implications of each option;
- the scope of work as set out risk management strategy;
- defining who is responsible for management, supervision and implementation of different activities;
- establishing who will be responsible for the procurement and supply of all equipment inputs and services;
- assessment of local capacity in government and the private sector; and
- assessment of the potential for capacity development in government and the private sector.

Tool T

Evaluation of what could go wrong during project planning and implementation and the development of mitigation measures

Once the final risk management strategy has been determined and the types of organization that will carry out the various activities have been decided, a more detailed analysis of the risks associated with project implementation is made. The analysis should also consider how these risks are to be mitigated. In simple terms, this is to define all possible things that may cause the remedial works to fail, exceed budget or overrun and what should be done to prevent this happening. All types of risks should be considered. A project risk register might include:

- health hazards to workers and people living in the area;
- inadequate pay agreement with workers;
- poor organization and communications within the project team;
- inadequate budget, either due to funding limits or cost uncertainties;
- lack of local resources (materials, equipment and labour);
- infrastructure problems, such as power failure, unsuitable roads or bridges;
- failure to get all required government approvals and support, despite previous support;
- disposal facility problems, such as not accepting waste (despite prior approvals) or shutdown;
- failure of on-site technologies to adequately reduce risk (a particular concern for bioremediation approaches);
- protests or delays caused by communities or stakeholders not satisfied with the plan (often related to community and stakeholder communications);
- unseasonal or extreme poor weather;
- discovery of more contamination or geological conditions not anticipated despite high quality detailed investigations; and
- dust, water contamination or environmental damage during the work.

The information from a project risk evaluation will contribute to the generation of more accurate, complete tenders; help organizations involved with implementation (international and local contractors or government) to write accurate plans for health and safety, community/stakeholder relationships; and project execution. It will also allow contractors to plan and prepare more complete proposals, and allow those involved with tender analysis to do this more effectively. It is recommended that a project risk management strategy analysis should be completed for every site where risk management is to be conducted. Table 5 below provides a format for presentation of the risk evaluation and some examples of each category.

Table 5

Risk Mitigation (showing examples)

	Risks	Mitigation measure(s)	Institutional Responsibilities (incl. enforcement and coordination)
Health and safety	Exposure to extreme temperatures -40 °C to +50 °C	Arrange project outside mid-summer and winter, if this is unavoidable change in working hours to suit operations.	Steering committee (SC), Project Management Unit (PMU)
	Worker abduction/ attack	Training in use of UN security procedures, use of radios for communications, guard in separate vehicle to accompany workers on-site and to and from hotel	Steering committee, PMU
	Accidents using mechanical equipment	Writing and implementation of HSE plan & SOPs Health monitoring, use of PPE, operation according to HSE Plan & SOPs. Operation and maintenance of mechanical equipment according to manufacturer's instructions	Contractor to write HSE Plan, third party to supervise
	Exposure to toxic pesticide residues by workers	Writing and implementation of HSE plan & SOPs Health monitoring, use of PPE.	Contractor to write HSE Plan, third party to supervise
	Malaria	Provision of mosquito nets and insect repellent	PMU, supervising consultant
Environmental	Cross contamination	Writing and implementation of HSE plan, SOPs Use of site zoning Duty of waste management care-use of materials movement log	Contractor-third party to supervise
	Flooding of roads and working area	Work outside rainy season, upgrade of road	Steering committee, PMU. Tender to specify working time
	Remediation treatment failure	Inclusion of penalty clause in contract documents Bench phase testing of bioremediation and stabilisation Validation testing of site to prove treatment completion by third party	Steering committee, PMU
Equipment	Equipment failure, theft, vandalism	Use of inspection and maintenance regime according to manufacturer's instructions Erection of security fencing before works start, use of 24hr guard	Contractor-third party to supervise Contractor-PMU to check
Project management	Poor communication	Regular recorded meetings at management and site level Weekly toolbox talks with workforce Guarantee by government of provision of mobile phone, radio and/or satellite communications	Steering committee, PMU
	Poor worker relations	Realistic pay agreement before works start Agreement of project working times and holidays before works start	Steering committee, PMU
		Regular site briefings using FAO format	Contractor or supervising consultant

	Risks	Mitigation measure(s)	Institutional Responsibilities (incl. enforcement and coordination)
Consultation	Non-cooperation from key stakeholders, local people, vandalism, theft	Regular meetings at site level with local people, meetings at district level and central govt. level	SC and PMU to arrange
Sustainability	Failure to provide government employees training for long term monitoring/ care leading to infrastructure breakdown of project equipment.	Training for long term care to be provided by project. Government to give long term commit to the EMP before works start, this to include institutional responsibility (i.e. maintaining the same individuals responsible and same organization/department).	Steering committee, PMU
Budget	Inadequate provision of funds for long term monitoring leading to infrastructure breakdown and re-release of contamination into the environment	Binding FAO/Government commitment to financial long term provision for project after care and monitoring	FAO Technical Officer-Head of Department of the Environment

The environmental monitoring plan

The development of a comprehensive environmental monitoring plan is a critical aspect of preparation for carrying out the implementation phase of the project. The purposes of the plan are to assure that work is done in a way that conforms to tender specifications, protects the health of project workers, visitors and people living in the area, and protects the environment. It assures that as remediation work is done, which often involves disturbing and moving pesticide contaminated soils and materials, the project will not result in a worsening of the baseline situation. Indicators for the environmental monitoring plan are derived from the risk analysis conducted during development of the remediation strategy, these may include:

- specific documentation regarding execution of the HSE plan, specific Standard Operating Procedures and project specifications;
- regular inspection of the site while work is in progress by knowledgeable persons with authority to note and raise concerns, with records of inspections kept;
- reporting on spills, leakages, accidents or injuries during the project;
- validation testing of any works completed including testing of soil and water;
- determination of the amount of each waste stream processed by the allotted treatment or disposal technology;
- health surveillance data for project workers and air quality monitoring at locations where work has been completed;
- continued engagement with stakeholders to learn of any concerns during project execution.

The project monitoring plan must include identification of who will do the monitoring, at what stages of the project, how often (e.g. weekly during the work, monthly, once, etc.) and how any problems found will be raised to the project managers or authorities to assure corrective actions are taken. For environmental sampling and analysis work, the plan should identify who will do this, whether analysis will be using field methods or laboratories, the laboratories planned for use, and quality control procedures (typically referencing a QA/QC appendix). The cost for monitoring must be factored into the overall project budget. By setting clear indicators, assurance is provided that the project complies with international best practice for implementation of waste management projects. The implementation of the monitoring plan needs to include supervision missions and audits from a number of key players. These may include FAO and other development partners, as well as independent monitoring by local or international NGO groups.

Table 6 below provides an example format for the presentation of the environmental monitoring plan.

Table 6

Environmental monitoring plan (showing examples)

Zone and risk management measure	Mitigation measures	Parameters to be measured	Location	Data and/or measurements (incl. methods and equipment)	Frequency of measurement	Responsibility for M&E (incl. review and reporting)	Cost (equipment and labour)
Excavation of highly contaminated soils for placement into big bags-Flexible Intermediate Bulk Container (FIBC)	Work to be conducted outside mid-summer and winter	Check the tender project programme to see the work is planned outside these times	Tender	Once	Once	Technical advisor	
	Equipment to be correct specification	FIBC specification	Tender	Inspection on-site	Check tender once, check every FIBC	Contractor/third party	
	Writing of HSE Plan& SOPs,	Tender document, SOPs, Site Zoning Plan & Implementation	Tender	Tender review	Once	Technical advisor	
	Implementation of SOPs & HSE plan	Site methods	On-site	Visual check	Continual	Third party	
	Health monitoring	Blood testing of people working on-site	Hospital	Before, during and post project	Three times	Project manager	
	Duty of waste management care-use of materials movement log	Type and quantity of waste moved, also check labelling to IMDG / ADR regulations	On-site material movement log to be kept	Type and quantity of waste moved	Continual	Technical advisor	
	Soil validation testing	Concentration of COCs	sides and base of excavation	Soil composite sampling Lindane Atrazine	1 per 10 m or 50 m^2	Contractor/third party	
	Ground water monitoring	Concentration of COCs	One MW up stream, two downstream	Lindane & Atrazine	1 sample to be taken from each well for 3 rounds, one month apart	Third party	
	General supervision of works	Adherence to HSE Plan, Site Zoning etc.	On-site	Contractor behaviour	Continual	Third party	
	Separate armed guard	Presence/absence	On-site		Continual	PMU	
	UN security procedure training	UN Security Advanced Field Cert.	On-line	Check pass/fail	Once	Third party	

Tool U

Environmental management plan (EMP) report

The environmental management plan report is the principal tool used to present the project to stakeholders (national and regional authorities, donors, local communities, IGOs, NGOs etc.) for approval and support for the implementation phase of any risk reduction activities. The report serves as the principal justification of the site-specific implementation of risk reduction and provides the technical basis for the tendering of any risk reduction services. The document also specifies what risk reduction activities are to be carried out, how they are to be carried out and who will be responsible for components of the work including management, implementation and supervision. The document also provides information critical for the development of other documents required for the successful completion of the project including the Health Safety & Environment (HSE) Plan and information for assembling the Monitoring and Evaluation of any works.

Once the report is finalized there should be an opportunity for it to be presented to stakeholders so that their comments can be taken into consideration and any changes suggested written into the document. For FAO projects, official endorsement from government ministries will be required before any risk reduction activities can go ahead.

Document Structure of the EMP Report

For reasons of economy of scale and ease of management and regulation many projects involve dealing with multiple sites at the same time in the same region or country, consequently the format of EMPs will have to reflect this. To put risk management plans in context, the EMP report should contain information relevant at a strategic level as well as at the site level. It is suggested that background and baseline information should be incorporated into a 'core' document used for multiple sites in any one project. Sections dealing with environmental impacts, the analysis of alternatives and site-specific risk reduction strategy are generally site-specific and will need their own sections. Later sections that describe project implementation, risk mitigation, the environmental monitoring plan and training are generally project specific and will need to refer to all sites being dealt with.

Below is an outline of what should be included in the EMP Report. The report must be reasonably comprehensive, keeping in mind that this document will be distributed widely to parties interested in the project, including to governments, communities, donors/funders, contractors, and others.

Section 1: Country setting

Brief data concerning sensitive geographical areas relating to the specific sites to be dealt with by the project should be presented, such as:

- population centres (with size);
- world and National Heritage sites;
- national parks;
- wetlands;

- areas of importance with regard to biodiversity (both fauna and flora);
- sensitive areas due to topography;
- distribution of major hospitals and clinics, with their capacity to deal with poisoning; and
- any other "special" areas.

Section 2: Policy, legal and institutional framework

Much of this data may have been detailed in an operational manual of the country project. The project management unit (PMU) should compile a complete set of all relevant government policies, decrees and regulations that could potentially impact on the implementation of the obsolete pesticides safeguarding project. Areas of focus should include:

- national pesticide legislation and regulations;
- national waste management legislation;
- regulations governing national transport of hazardous goods;
- environmental assessment impact regulations;
- any legislation particular to contaminated land and its regulation; and
- national labour regulations.

In accordance with the legislative and regulatory frameworks, the text should note that the EA component of the work is being prepared in strict compliance with requirements of the country environmental regulations regarding environmental assessment. In cases where national disposal facilities are being considered, the review should also include issues related to environmental impact assessment studies, permitting regimes, monitoring of operations, etc. Donor EA requirements may also need to be accounted for under this section.

In addition, the section should explain the relevance of the three Chemical Conventions (Basel, Rotterdam and Stockholm) to the proposed works. This should include a statement indicating that the risk management process will assist the country in facilitating its obligations to remove agricultural POPs as required under the Stockholm Convention.

In terms of the institutional arrangements for implementation of the project, the section should also define the responsibilities for risk mitigation and monitoring along with arrangements for information flow, especially for coordination between agencies responsible for mitigation. This is especially important since projects usually require cross-sector and cross-institutional integration. The EA should outline the key responsibilities for the mitigating and monitoring measures, of implementation, training, financing, and reporting. Institutional arrangements should be proposed that will maintain support for agreed enforcement measures for environmental protection.

Section 3: Baseline data

The section should include:

- a summary of any previous relevant waste management and pesticide disposal initiatives via government or other internationally resourced projects;
- a summary of known pesticide contaminated sites and a map showing where the sites are (REA report);
- a description of how and why the top sites have been prioritized and have been put forward for further assessment and potential risk management, and specifically how the sites proposed for work fit in the prioritization;
- a summary of national capacity to complete risk management, considering potential contributions from national industry and government bodies (see Table 3); and
- an assessment of current disposal and treatment capacity in the country, to determine the potential for in-country off-site disposal or treatment of pesticide wastes and contaminated soils.

Section 4: Environmental impacts

This section contains information specific to each site being considered under the project. It should summarize, and reference important information derived from the Detailed Site Investigations and associated risk assessment. This is critical to development of the Environmental Management Plan.

For each site, the report should state:

- a summary of the conceptual site model clearly setting out sources, pathways and receptors and any pollutant linkages that need to be dealt with by risk reduction; and
- the quantity and type of contamination at the site and where it is located.

Section 5: Analysis of alternatives

This section is composed of two parts, firstly the analysis of potential risk reduction techniques and approaches and secondly the analysis of the principle contributors (contractor, government, NGO or IGO) who will be involved with implementation of risk reduction measures:

- product of the long list selection and reasons for selection of techniques or approaches (the annexes should contain the full list of potential alternatives and the reasons for non-selection);
- a summary of the matrix assessment, (again the details do not necessarily need to be included in the main document);
- the SWOT analysis of the techniques and approaches to be used for each zone or area of the site; and
- the qualitative review.

Section 6: The risk reduction strategy

This section should set out, in detail, the proposed risk reduction strategy with respect to the activities happening in different areas or zones of each site. It also should be made clear why the final options have been selected. If off-site disposal of waste or contaminated soil is planned, the proposed off-site facility should be identified, referencing national disposal facilities available as identified in the baseline study. At this point the document should consider changes in site-based risk reduction due to wider influence of risk management at a countrywide or regional level. Documentation that off-site treatment or disposal facilities planned for use can and will accept the waste should be provided in an appendix. This section should also specify the remediation criteria against which any risk reduction can be measured and also any monitoring that is proposed.

Section 7: Risk management plan implementation strategy

In this section, there should be a statement of who will be responsible for implementation of the different aspects of the project in terms of management, implementation and supervision-i.e. the proposed project management structure. A diagram of the project management structure is often helpful. This section should also provide a draft schedule showing key activities, durations for the activities, and inter-linkages and sequencing of activities. Typically, this is done using a Gantt chart or similar tools. The laboratories to be used for environmental monitoring work should be identified. Finally, regulatory agencies who will oversee or be involved with the work should be identified and their role described.

Section 8: Environmental monitoring plan

This section should specify the products of the risk analysis as specified in for carrying out the project successfully. It should specify what risks may threaten the project, both in terms of threats to human health and the environment but also to other aspects of the project, such as sustainability, project management and financing. The environmental monitoring plan should then specify the mitigation measures proposed for the risks that have been identified and what monitoring will be key to ensuring that the risk is minimised.

Section 9: Post-work monitoring and care

Bearing in mind that longevity of any intended risk reduction measure should be a key consideration in its selection, the Environmental Management Plan needs to consider the long-term monitoring and care of measures that may go beyond the lifespan of the project.

Considerations for each activity should be requirements for:

- post project inspection and maintenance;
- long term environmental monitoring and sampling;
- the security of any infrastructure; and
- legal restrictions regarding future land use type and how this status should be maintained in law.

This part of the plan should specify the frequency of any activities that are required, who will be responsible for work and its supervision and how it will be funded. If such post work monitoring will be necessary over an extended period, the document will need to state how work will be assured from an institutional management and funding perspective. Like the Environmental Monitoring Plan it may be useful to present this in a tabular format, for example:

Risk management measure	Parameters to be measured	Location	Data and/or measurements (incl. methods and equipment)	Frequency of measurement	Institutional responsibility for implementation and supervision	Cost (equipment and labour)

Section 10: Training requirements for environmental and social management

Any training requirements associated with implementing the risk management strategy and the monitoring plans should be presented in detail, including associated costs. In addition, the overall institutional capacity for environmental management should be evaluated and components identified for a broader programme of institutional strengthening (e.g. the development of laboratory facilities and training for pesticide trace/residue analysis.)

Annexes to the Environmental Management Plan

Annexes to the document should contain all the required supporting information and should include:

- the long list of risk management techniques and approaches with reasons for selection or non-selection;
- matrix analysis of risk management techniques and approaches;
- SWOT analysis of risk management alternative techniques and approaches;
- SWOT analysis of project implementation alternatives;
- HSE plans for risk reduction activities; and
- QA/QC Plans for risk reduction activities.

Works cited

C. Paul Nathanail, R. P. 2004. *Reclamation of Contaminated Land*. Wiley and Sons.

Conference of the Parties to the Basel Convention. 2017, May. *General technical guidelines on the environmentally sound management of wastes consisting of, containing or contaminated with persistent organic pollutants*.

Federal Remediation Technologies Round Table. (n.d.). Federal Remediation Technologies Roundtable (FRTR). From Federal Remediation Technologies Roundtable (FRTR): https://frtr.gov/default.htm

Food and Agriculture Organization of the United Nations. 2011. *Environmental Management Tool Kit Volume 3 (EMTK3)*. http://www.fao.org/3/a-i2216e.pdf

Food and Agriculture Organization of the United Nations. 2011. *Environmental Management Tool Kit Volume 4 (EMTK4)*. http://www.fao.org/3/a-i2022e.pdf

Food and Agriculture Organization of the United Nations. 2009. *Environmental Management Tool Kit for Obsolete Pesticides Volume 1 (EMTK1)*. http://www.fao.org/tempref/docrep/fao/011/i0473e/i0473e.pdf.

Food And Agriculture Organization of The United Nations. 2009. *Environmental Management Tool Kit for Obsolete Pesticides Volume 2 (EMTK2)*. From http://www.fao.org/3/i0474e/i0474e.pdf

Harmesan, J. 2010. *An African Approach to Risk Reduction of Soil Contaminated by Obsolete Pesticides.* United Nations Food and Agriculture Organization.

Hatfield Consultants. (n.d.). *Risk Management*. (Hatfield Consultants) From Persistent Organic Pollutants Tool Kit: http://www.popstoolkit.com/riskmanagement.aspx

International Standards Organization (ISO). 2017, December. *Geotechnical investigation and testing - Identification and classification of soil - Part 1: Identification and description*.

International Standards Organization (ISO). 2017. *Sustainable remediation.*

Netherlands Ministry of Infrastructure and Water Management. 2003, June. *Rijksinstituut voor Volksgezondheid en Milieu; Netherlands Soil Protection Guidelines for Industrial Activities*.

UK Environment Agency. 2004. *Model Procedures for the Management of Land Contamination.* UK EA.

Annexes

ANNEX 1

Overview of disposal/treatment methods for contaminated soil and groundwater

Soil remediation

High temperature incineration-HTI

The most common form of high temperature incineration is *ex situ* rotary kiln HTI. This normally involves placement of soils in a rotating kiln at temperatures of between 1 000-1 200 °C. Exhaust gases from the plant are then cooled very quickly to prevent gaseous reformation of unintended chemicals and then sent through a gas cleaning/scrubbing plant. The inert solid "clinker" remaining at the end of the process can then be recycled or sent for landfill, depending on the iron content it contains and the contents of contaminants remaining from the incineration process.

Material destined for HTI is usually dealt with by packaging into UN containers and then transportation off-site to a dedicated facility overseas (usually but not always in Europe). There are also mobile HTI plants that can be transported for use on-site. However, due to logistical difficulties of setting up a mobile plant, high mobilisation costs and regulatory problems it is very rare that mobile incinerators are used.

Pros: Off-site HTI is the most common form of treatment for highly toxic, high risk situations. It is also one of the most straightforward solutions to implement. HTI can deal with most contaminants in contaminated soil (except for high concentrations of heavy metals). HTI allows almost total destruction of organic contaminants and collection of inorganic contaminants in the clinker/slag produced during incineration.

Cons: HTI is the costliest type of solution, budgetary figures are in the region of USD 2 500-USD 3 500 per tonne for safeguarding and disposal. HTI is an energy intensive form of treatment even when the transportation element is not taken into consideration and is therefore low down on the disposal hierarchy because of this. Export and transportation are both high risk activities and bureaucratic to implement. Exportation requires strict compliance with guidelines set down in the Basel and Stockholm conventions as well as national legislation and takes many months to arrange.

Thermal desorption-TD

TD involves the heating of contaminated soils to 300-400 °C which causes organic compounds, including most pesticides (and any mercury) to volatilise. The vapours are then burned directly or condensed and then collected followed by disposal or destruction. Most TD plants do not have the mercury filtration capability in the plant exhaust treatment and therefore the mercury content of the incoming soils must be low enough to ensure off gases comply with air quality standards.

Pros: Thermal desorption (TD) is much less energy intensive than HTI and is therefore very much cheaper for the basic cost of treatment (USD 200 per tonne). If *in situ* or mobile TD is used, then it can be used directly on-site and therefore fits well with the proximity principle.

Cons: To date *in situ* and mobile forms of TD have largely been used in Europe and North America. High mobilization costs for both the *in situ* and mobile forms markedly increase the basic costs of treatment and therefore TD is only effective for large quantities of contaminated soils >5 000 tonnes. Due to the corrosive nature of the exhaust gases produced, TD is limited to dealing with levels no higher than 10 000 ppm of organochlorine contaminated soils. Although TD has the capability to deal with some level of mercury contamination when its exhaust system is adapted, it is not generally able to deal with heavy metals.

Solidification and stabilization (S/S)

These techniques normally involve mixing soils with lime or some other alkaline material such as cement and/or clays such as bentonite. Sometime this can involve co-disposal with alkaline waste such as ash from incineration plants or slag from blast furnaces. Confirmatory testing involves leachate testing.

Pros: Treatment can be easily implemented using agricultural/construction machinery and is very cheap. The addition of lime or cement forms highly insoluble precipitates with many metals so that it can be suitable for treating soils contaminated with heavy metals such as Arsenic. The mixing of lime with soils can be useful for reducing the high moisture content that other forms of treatment are not able to deal with

Cons: S/S has demonstrated success in dealing with organic contaminants including pesticides. However, the performance of stabilisation is influenced by the contaminant mixture and bench tests or treatability studies are valuable in deciding whether or not the site-specific mixture of contaminants can be stabilised. Will not deal with volatile substances which may be amenable to sorption on activated carbon or organophilic clays.

Sequestration by landfill

Pros: Landfill can be a very cheap form of disposal (costs may be as low as USD 19/tonne) and is suitable for large quantities of soils. It can be combined with other forms of treatment such as S/S to improve sequestration and behaviour of the contaminants involved. The relative ease of using civil engineering techniques involved mean that construction of landfills on or close to site is both cheap and easy to implement as long as local laws and conditions allow.

Cons: Landfill is low down on the waste hierarchy as the contaminants remain in their original form. Once landfilled there is limited control on how contaminants behave. Landfills have a limited life span and require continual monitoring and control to ensure their integrity. Landfill, particularly of pesticides, is not suitable in areas where groundwater resources are important for potable or even industrial use.

Sequestration by deposition in an underground mine (usually salt mines)

The relatively stable conditions in these mines, structurally and chemically and because the temperature of the mines remain constant, and also due to the absence of groundwater allows the deposition of many types of waste. This type of solution is suitable for situations where contaminated soils contain high levels of non-degradable substances, such as heavy metal containing pesticides (e.g. Arsenic or Mercury) where risk assessment dictates their removal is necessary from site.

Pros: As for regular landfill, the non-thermal nature of this type of sequestration means that the price of disposal is relatively low. There is more control of where the waste is deposited as opposed to conventional landfill where wastes are generally mixed together.

Cons: As there are relatively few facilities worldwide where this type of disposal is feasible, almost always the waste will have to be transported internationally. As for other forms of sequestration the waste does not change chemically and therefore retains its original characteristics.

Bioremediation

Bioremediation involves the use of microorganisms, by taking advantage of natural or augmented microflora, to increase the rate of degradation of contaminants. Bioremediation also involves improving the soil conditions using moisture, organic material and fertilizer to maximize degradation.

Landfarming involves excavating the contaminated soil and spreading it on top of soil and periodically turning it over (tilled) to aerate the mixture thereby stimulating biodegradation.

Windrows involve excavating the contaminated soil and placing it in long stockpiles that are periodically turned over (tilled) to aerate the mixture thereby stimulating biodegradation.

Pros: Under optimum conditions and with an appropriate substrate, concentrations of contaminants can be reduced to negligible levels in relatively short lengths of time. Treatment can be very cheap and easy to implement with commonly used agricultural methods for large quantities of contaminated soils. As bioremediation is a low[7] energy demanding technique and can be implemented at the site of interest it is very high on the waste treatment hierarchy and is often one of the most sustainable remediation options.

Cons: It is not suitable for inorganic contaminants and can be difficult when highly recalcitrant organic compounds such as organochlorines (including POPs chemicals) are involved. Bioremediation techniques can take a long time for them to be effective (treatment time may be in excess of 1-2 years), the length of which may be longer than the project duration. Bioremediation can be affected strongly by weather conditions either being too hot, too cold or too wet. *Ex situ* bioremediation involving handling large quantities of soil and requires a comprehensive materials management plan including a system to prevent contamination of the surrounding environment.

Soil washing

Soil is excavated and then passed through a rotating drum with water. Clean coarse particles are separated from contaminated fines thereby reducing the volume of waste needing further treatment or destined for disposal.

Soil washing exploits the adsorption of contaminants primarily onto the finer soil fraction, the silt and clay. Soil washing allows for the larger particles of sand, gravel and cobbles to be physically removed from the soil by conventional stone separation techniques used in the aggregate industry. The grave and stone component is then washed with water, and rarely with detergents and even solvents, to remove any finer particles and contaminants still attached. Once cleaned the washed components can then be used either at the site of origin or elsewhere. The fine soil component and dirty washings then require alternative disposal or further treatment. Soil washing is not suitable for soils with high clay or silt content. Soil washing plant are largely mobile. Soil washing is a technique that requires soils to have no more than about 15 percent of contaminated fines for it to become economically viable.

Phytoremediation

Phytoremediation involves the use of plants to enhance the degradation of or to extract organic contaminants or toxic metals. Although there are accounts of the successful use of phytoremediation to treat waste water, such as the use of reed beds, the number of reported projects where it has been used effectively for the treatment of contaminated soils is limited. There are also a number of research studies demonstrating its effectiveness for the treatment of heavy metals and trace level contamination by organic contaminants, however these are yet to be translated into project scale activities for risk reduction. One benefit of phytoremediation, in addition to any source reduction it may achieve, is that the plants also contribute to pathway management techniques such as reduction in surface water and wind erosion.

Pros: Low intensity technology, cheap

Cons: Currently largely experimental, longer term treatment periods required (>2 yrs), phytoremediation is not recognised by all agencies due to its experimental status. The plants

[7] Cf ISO 18504:2017 Sustainable Remediation

used are highly specific to the treatment required and levels of contamination may be toxic to the plants themselves. In many cases contaminants are accumulated into the plant materials which then require further waste management treatment. Additionally, root zone mobilisation of contaminants may result in spreading of contamination.

Capping or covering of contaminated soils

In low to medium risk situations and where the risk of exposure to groundwater is low, the use of a cap to cover the source and limit exposure at the surface of contamination can be effective. Caps in use include covering areas with geotechnical fabric or membrane and then covering with clean soil, covering with concrete or with asphalt. Such techniques can also reduce the infiltration of rainwater and hence protect groundwater.

Groundwater containment and control techniques

There are many different types of groundwater containment and control that vary from process orientated pump and treat systems to simpler forms of containment.

Installation of slurry wall

A slurry wall is a trench that has been excavated and filled with a mixture of cement and bentonite (a swelling clay) and water to form a slurry. When set, the mixture forms a dense very low permeability barrier through which groundwater is able to pass only very slowly, the permeability of the wall can be further decreased by insertion of an impermeable membrane into the wall's centre prior to it setting. Slurry walls can be used to contain a source where there is a risk to groundwater. They are more effective in situations where there is a defined source.

Sheet pile wall

Sheet piling can be used in a similar fashion to a slurry wall. The prefabricated sheet pile sections (long sheets of steel up to 7 m or 8 m in length) are driven or vibrated into the ground and then connected to form a barrier around the contamination so that it does not come into contact with groundwater. Rubber gaskets can be fitted to the piles to improve the impermeable nature of the wall.

Permeable reactive barrier

Where there is a risk to groundwater an alternative to the sheet pile wall is to filter contaminants flowing groundwater. Sheet piles or a slurry wall can be installed to direct groundwater flow through a filter or treatment zone composed of materials that are effective for the particular type of contamination. For example, granular activated carbon can be used to filter out organic contaminants or zero valent iron can be used to treat chlorinated hydrocarbons dissolved in groundwater.

Monitored Natural Attenuation (MNA)

MNA involves monitoring the rate at which natural subsurface processes – such as biodegradation, adsorption, oxidation, and reduction – are reducing contaminant concentrations to acceptable levels and maintaining or reducing the footprint of the plume of dissolved phase contaminant.

ANNEX 2

Example long list assessment

Possible methods of source management	Strategy	Relevance to pollutant linkage	Reason for inclusion or removal	Include/ remove
Ex situ Solidification or stabilization	Excavation then Stabilization using granular activated carbon or crushed charcoal	Eliminate movement of contaminants from source	Economic local solution	Include
~~In situ chemical oxidation~~	Neutralization of contaminant/volume reduction of contaminant	Minimise contaminant at source to beneath screening levels	No local contractors, dangerous to implement, unwanted by products	Remove
In situ solidification	Mixing of cement *in situ*	Eliminate movement of contaminants from source	Local contractors with specialist plant available, economic for limited quantities, treatability study needed	Include
~~Removal of contamination by bioremediation~~	Destruction of contaminant/ volume reduction of contaminated ground	Minimise contaminant at source to beneath screening levels	Possible to reduce quantity of contamination economically	Remove
~~Excavation then soil washing~~	Excavation, treatment, replacement and disposal of fines	Minimise contaminant at source to beneath screening levels	High clay and silt content renders soil washing uneconomic	Remove
~~Phytoremediation~~	Neutralization of contaminant/volume reduction of contaminant	Minimise contaminant at source to beneath screening levels	Unproven. Long term method, partial treatment only. Leaves contamination in the ground, not secure	Remove
~~Monitored Natural Attenuation~~	Neutralization of contaminant/volume reduction of contaminant	Minimise contaminant at source to beneath screening levels	Not suitable for higher areas of POPs contamination. Leaves contamination in the ground	
~~Volatilization and monitoring~~	Neutralization of contaminant/volume reduction of contaminant	Minimise contaminant at source to beneath screening levels	Not suitable for higher areas of POPs contamination. Leaves contamination in the ground	
Excavation and landfill	Excavation, local transport and disposal	Source removal	Rapid, transfer of liability, local solution, non thermal	
Excavation and treatment via thermal method (thermal desorption or incineration)	Excavation, international transport and disposal	Minimise contaminant at source to beneath screening levels	Total destruction of highly concentrated pesticides where necessary	
~~Excavation and treatment via mobile thermal method (thermal desorption or incineration)~~	Excavation and disposal on-site	Source removal	Too expensive for small quantity, no local contractors not enough soil to justify method	
~~Excavation and mobile ball milling~~	Excavation and disposal on-site	Source removal	Not proven	
Excavation and long term storage in underground mine	Excavation, international transport and disposal	Source removal	Economic, removal of liability	

~~In-situ treatments including Soil Vapour Extraction, air sparging, bio sparging~~	Neutralization of contaminant/volume reduction of contaminant	Minimise contaminant at source to beneath screening levels	Difficult to implement in heavy soils, contaminants not suitable, high technology, expensive for relatively small volumes, not suitable for non volatile compounds. Not suitable for POPs chemicals	
~~Long term storage in local or on-site concrete sarcophagus~~	Excavation then sealing in sarcophagus	Remove source	Concrete subject to degradation and leaching of contaminants in the long term This method in contravention to Stockholm Convention; Liability remains. Security issues in the longer term	
Pathway management				
~~Capping of wells~~	Cap/cover	Remove ingestion of contaminated water exposure pathway	Not relevant	
~~Capping or covering contaminated soils with clean soils, asphalt etc.~~	Cap/cover	Remove wind dispersal pathway	POPs present that require neutralisation/destruction	
~~Using vegetation, wind fences and dust suppressants to control dust levels.~~	Dust control	Reduce/minimise wind dispersal pathway	POPs present that require neutralisation/destruction	
~~Installation of impermeable barrier around the site~~	Segregation	Remove infiltration of contamination pathway	Difficult to implement, not secure, does not effectively deal with POPs	
~~Installation of permeable reactive barrier~~	Filtration of contaminated ground waters	Remove infiltration of contamination pathway	Difficult to implement, not secure, does not effectively deal with POPs	
~~The use of personal protective equipment;~~	Direct control of exposure pathway	Minimise inhalation, dermal and ingestion exposure pathways	Not long term solution	
~~Local bans on hunting/ fishing;~~	Receptor management	Remove ingestion of contaminated foods pathway	Not long term solution	
~~Ban consumption of foods from fields surrounding village~~	Receptor management	Remove ingestion of contaminated foods pathway	Difficult to implement/not really relevant	
Receptor management				
~~Change of land use and use of industrial screening levels~~			Change of land use not feasible or relevant in the situation	
~~Site segregation or zoning~~	Site management		Security breaches difficult to stop without great expense	
~~Access restriction~~	Site management		Security breaches difficult to stop without great expense	
~~Public awareness information and education - school curriculum;~~	Receptor management		Difficult to implement so that it is 100 percent effective	

Note: Possible methods that have been ~~struck~~ *out in the table do not proceed further in the assessment for the reason stated.*

ANNEX 3

Example matrix assessment

No.	Method	Effectiveness	Applicability	Long term reliability	Ease of implementation	Implementation Risk (10 is safest)	Cost for implementation (NB 10 is cheapest)	Cost for O and M (10 is cheapest)	Waste Hierachy	Ranking score
1	Excavation and stabilization using charcoal or GAC followed by disposal to landfill	7	8	5	7	6	8	7	1	658 560
5	Excavation and disposal in on-site landfill	6	5	4	8	5	10	6	1	288 000
2	Excavation, export and treatment via off-site thermal desorption	9	2	10	4	7	4	9	1	181 440
3	Excavation, export and treatment via off-site high temperature incineration	10	2	10	3	8	3	10	1	144 000
4	Excavation and transport for disposal in underground mine	8	2	8	6	6	5	6	1	138 240
6	*Ex situ* Bioremediation	3	4	3	7	4	7	5	1	35 280

Effectiveness – in isolation, how well will the treatment deal with the contamination? (on a scale of 1 to 10).

Applicability – in relation to the site how relevant is the approach or treatment to reducing the site-specific risk? (on a scale of 1 to 10).

Ease of implementation – how easy will the technique or approach be to apply to the situation on site? (on a scale of 1 to 10).

Implementation risk – when carrying out the technique or approach what is the general level of risk involved to human health and the environment? (on a scale of 1 to 10).

Cost for implementation – when a budget is developed for implementing each technique or approach for implementation how does it rank against the other options? (on a scale of 1 to 10).

Cost for operation, maintenance and monitoring-post implementation? – when a budget is developed for each technique or approach for the techniques operation, maintenance and monitoring – after the project is finished, how does it rank against the other options? (on a scale of 1 to 10).

Waste hierarchy – how does the technology or approach perform according to the waste hierarchy?

Ranking score – The scores are simply multiplied together to give an overall product which is then compared.

ANNEX 4

Example SWOT assessment

Possible methods of source management	Strengths	Weaknesses	Opportunities	Threats
Ex situ solidification or stabilization using cement	Relatively cheap compared to other methods, technology readily available, transfer of liability to third party. Suitable for lowering Arsenic mobility	Long term performance not established, not suitable for highly contaminated soils particularly soils contaminated with organic materials including POPs.	Local contactors possible and use of local site. Can be used as pre-treatment	Possibly contravenes Stockholm convention; very low on waste hierarchy
Excavation and landfill	Liability removed, excavation is cheap	Disposal to landfill requires secondary treatment of soils above 50 ppm to render POPs inert (Stockholm Convention)	Local contractors and technical input possible	Problem transferred to alternative location, resistance from stakeholders, long term monitoring required
Excavation and transport for long term underground storage	Relatively cheap compared to other methods, total source and liability removal	Requires international transportation, low down on waste hierarchy; needs accessible mine	Could be used to reclaim abandoned mines	Problem transferred to alternative location, resistance from locals near mine
Excavation and treatment via thermal desorption or incineration	Liability totally removed, total destruction	Very expensive; not enough waste to justify method. Transportation difficult and dangerous.	Best method of complying with Stockholm Convention	Foreign contractor required
Bioremediation (landfarming or windrowing)	Relatively cheap compared to other methods, low level of technology, sustainable	Not suitable for highly contaminated soils, increases amount of contaminated materials. Difficult to treat with POPs	Local contactors possible and use of local site materials. Sustainable methodology	Long term liability remains.

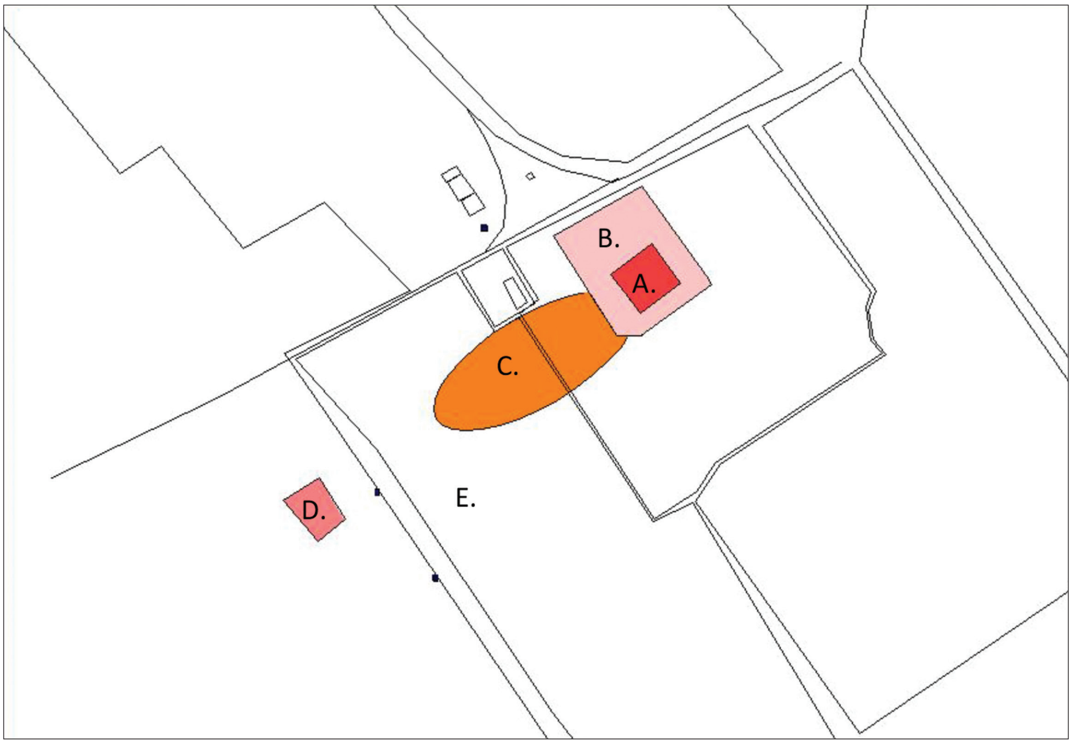
ANNEX 5

Example of qualitative review of risk reduction measures-a case study

A detailed site investigation and risk assessment was conducted in an Eastern European country. The site investigation showed that there were 5 areas of concern on the site that needed to be dealt with:

A. grossly contaminated soil (>60,000 ppm), including POPs and other agricultural products, in a hotspot area that breach human health criteria and the Stockholm Convention level for "Low Level POPs" of 50 mg/kg;
B. soils on-site, outside the hotspot that breach human health criteria but not the Stockholm Convention level for "Low Level POPs";
C. diffusely contaminated soils in a down wind direction (within 100 m of the site) that marginally breach soil screening levels for agricultural workers;
D. contaminated soils breaching human health screening levels and the Stockholm Convention level for "Low Level POPs" in the farmyard within 250 m of the site;
E. contaminated water in perched groundwater in the lowland area used for drinking water. Analysis shows contamination is present in water but beneath screening levels. However as there are other wells further away that do not show contamination it has been decided to block this well.

Figure 5
Site drawing showing principal source areas for use in an example qualitative review



The following tables are an example of a qualitative review of risk reduction measures selected for each area of the site.

FAO category	Alternatives considered	Remedial strategy	Risk analysis	Risk mitigation
Area A and Area D. High risk	Excavation, packaging of soil into UN containers, shipment to thermal desorption plant followed by incineration of vaporized concentrate Selected - Low down on EU waste management hierarchy, high transport costs	Source Management	Secondary contamination of area during excavation	Zoning of site excavation into high, medium and low risk, emission controls, dust control measures, introduction of specific standard operating procedures, use of dedicated haul routes
			Project going over budget & overtime	Careful cost control, use of dedicated project management team and system
			Mechanical hazards affecting workers during excavation	Use of HSE plan; direct supervision of work, use of risk assessment and standard operating procedures, use of skilled drivers and certified plant only. Membership of drivers to assurance scheme.
			Exposure hazards of operators during implementation	Health monitoring including blood testing (before, during and after), use of PPE, environmental monitoring.
			Incomplete excavation leaving contaminated material	Use of specialist contractor with experience, contract specifying clean-up criteria, clear lines of contractual responsibility and liability. Testing of remaining soils according to environmental monitoring plan.
			Road traffic accident	Development and introduction of transport plan inc. driver certification/ADR audit/Use of certified haulier
			Uncontrolled emissions to the environment	Introduction and adherence to environmental monitoring plan.
	In-situ thermal desorption Not Selected - easier to control emissions, reduced to air. Not able to deal with contaminants of more than 20 000 ppm. Not able to deal with metals (arsenic and possibly mercury)	Source management *In situ* thermal desorption	Secondary contamination of surrounding area	Emission controls and monitoring Third party audit of operations Use of HSE plan including risk assessment of all operations, introduction of specific standard operating procedures for all methods to be used Use of PPE Use of specialist contractor with experience, contract specifying clean-up criteria, clear lines of contractual responsibility and liability
			Mechanical hazards affecting workers during implementation	Use of HSE plan; direct supervision of work, use of risk assessment and standard operating procedures, use of skilled drivers and certified plant only. Membership of drivers to assurance scheme.
			Tampering / vandalism	Secure site using fencing and barriers, use of security company to protect equipment. Communications programme with local community to prevent incidents.
			Exposure hazards of operators during implementation	Health monitoring including blood testing (before, during and after), use of PPE, environmental monitoring. Use of trained engineers only, use of HSE and operating system. Environmental monitoring.

	Excavation and treatment by mobile TD plant <u>Not Selected</u> Higher risk of mechanical hazards, possibility of emissions to air, possibility of dioxin/ furan production as a result of incomplete combustion and inefficient filtration	Source management Excavation and loading into *Ex situ*/on-site mobile thermal desorption plant, replacement of soils into former hotspot	Secondary contamination of surrounding area during loading of plant Nuisance to neighbours (smell, dust) Uncontrolled environmental emissions	Emission controls, use of filtration plant and monitoring Use of HSE plan Health monitoring Use of PPE Use of specialist contractor with experience, contract specifying clean-up criteria, clear lines of contractual responsibility and liability Careful cost control, use of dedicated project management team and system Site security and segregation Community liaison programme, regular meetings with community leaders Introduction and adherence to environmental monitoring plan. Third party monitoring
	Excavation, packaging of soil into UN containers, shipment to foreign thermal facility (thermal desorption or high temperature incineration) <u>Not selected</u> as high costs, resistance from stakeholders to send waste abroad and bureaucratic difficulty in sending waste abroad.	Source Management *Ex situ* Thermal desorption (off-site) Loading of soils into UN certified FIBCs, transportation to foreign plant treatment.	Secondary contamination of area during excavation Mechanical hazards affecting workers during excavation Exposure hazards of operators during implementation Treatment not effective during project time scale Project going over budget and overtime Incomplete excavation leaving contaminated material Road traffic accident	Sheeting of area during excavation, dust control measures Use of HSE plan Health monitoring Use of PPE Use of specialist contractor with experience, contract specifying clean-up criteria, clear lines of contractual responsibility and liability Careful cost control, use of dedicated project management team and system Validation testing of excavation to ensure levels are below remediation criteria Driver certification/ADR audit/Use of certified haulier Basel notification

FAO category	Alternatives considered	Remedial strategy	Risk analysis	Risk mitigation
Area B: Medium risk	Pathway interruption by capping using a geotextile membrane, ban consumption of crops from fields in the vicinity Selected: Selected as second stage to landfarming	Capping & Institutional control	Exposure occurring during implementation: Dermal, Ingestion, Inhalation Mechanical hazards during implementation Geotextile membrane degrades Growing and consumption of food continues	Implementation of HSE plan, health monitoring PPE, Overalls & Gloves Respiratory Protection Equipment Masks, separate rest area and eating area Implementation of HSE plan Periodic inspection, provision for maintenance Chain of custody procedure required Input from recognised expert Liaison with farmer and local community Progress monitoring and project validation testing
	Phytoremediation via coppicing trees Not selected: More effective methods for material with greater contamination Phytoremediation is an unproven technology	Phytoremediation (no capping)	Exposure occurring during implementation: Dermal, Ingestion, Inhalation Mechanical hazards during implementation Geotextile membrane degrades Coppiced trees uptake contaminants and require further management Growing and consumption of food continues	Implementation of HSE plan, health monitoring PPE, Overalls & Gloves Respiratory Protection Equipment Masks, separate rest area and eating area Implementation of HSE plan Periodic inspection, provision for maintenance Chain of custody procedure required Input from recognised expert Liaison with farmer and local community Proper disposal of coppiced material Progress monitoring and project validation testing
	Bioremediation by windrow Not selected as windrow turner machinery would be expensive to hire/buy and there is a marginal difference in performance between windrows and landfarming	Source Management *Ex situ* bioremediation	See above	See above

	Bioremediation by *ex situ* landfarming Not selected as *ex situ* requires removal and replacement over impermeable geotextile	Source Management *Ex situ* bioremediation	See above	See above
	Bioremediation by in situ land farming to degrade biodegradable contaminants. Selected	Source Management *In situ* bioremediation	Spreading of dust during formation & turning Equipment expense Equipment breakdown Contaminated leachate running through clean areas Exposure during implementation Mechanical hazards Treatment does not reach target level	Use geotextile cover, apply water spray to keep damp and suppress dust release Long term maintenance regime of geotextile Ensure capping of drinking water wells from perched aquifer Use of HSE plan, health monitoring Adequate supervision of formation Progress monitoring and validation testing Use of nutrients and fertilizer Contracting of specialist in bioremediation to design system
	Bioremediation by in situ land farming to degrade biodegradable contaminants. Selected Contamination is limited to upper 0.15 m so accessible to ploughing machinery	Source Management *In situ* bioremediation	Spreading of dust during formation and turning Equipment expense Equipment breakdown Contaminated leachate running through clean areas Exposure during implementation Mechanical hazards Treatment does not reach target level	Use geotextile cover, apply water spray to keep damp and suppress dust release Long term maintenance regime of geotextile Ensure capping of drinking water wells from perched aquifer Use of HSE plan, health monitoring Adequate supervision of formation Progress monitoring & validation testing Use of nutrients & fertilizer Contracting of specialist in bioremediation to design system
	Landfill/controlled stockpile & Stabilization Not selected as low down on EU waste hierarchy	Pathway management Off-site landfill	Breakdown of landfill construction Leachate formation and leakage	Minimum construction standards according to EU Landfill regulations Monitoring of landfill stockpile condition

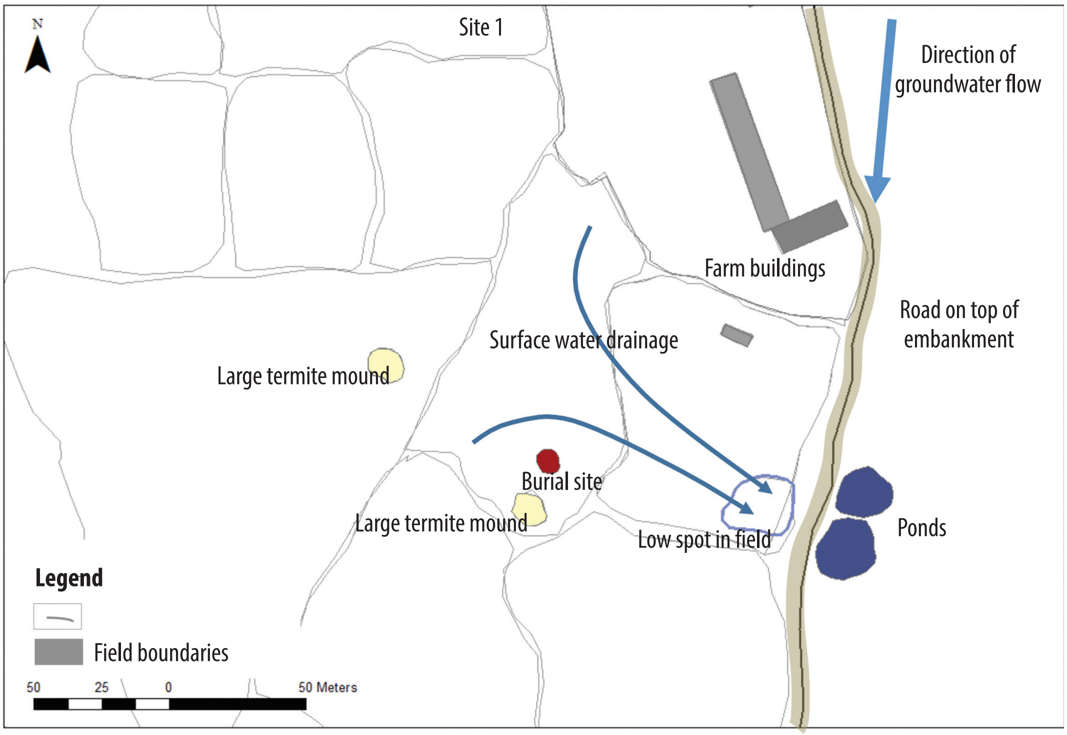
FAO category	Alternatives considered	Remedial strategy	Risk analysis	Risk mitigation
Low risk area: Area C	Pathway interruption by capping using a geotextile membrane, ban consumption of food from fields in the vicinity. Selected	Source management Capping and institutional control	Exposure occurring during implementation: Dermal, Ingestion, Inhalation Mechanical hazards during implementation Geotextile membrane degrades Growing and consumption of food continues	Implementation of HSE plan, health monitoring PPE, Overalls & Gloves Respiratory Protection Equipment Masks, separate rest area and eating area Implementation of HSE plan Periodic inspection, provision for maintenance Chain of custody procedure required Input from recognised expert Liaison with farmer and local community Progress monitoring and project validation testing
	Bioremediation by windrow Not selected as cost benefit not justified and marginal nature of contamination not likely to bring benefits any quicker than alternatives	Source Management *Ex situ* bioremediation	Spreading of dust during formation and turning Equipment expense Equipment breakdown Contaminated leachate running over clean areas Exposure during implementation Mechanical hazards Treatment does not reach target	Use geotextile cover, apply water spray to keep damp Change method to landfarming Maintenance regime Ensure capping of shallow water drinking water wells Use of HSE plan, health monitoring Use of HSE, adequate supervision Progress monitoring & validation testing
	Bioremediation by landfarming Not selected	Source Management *Ex situ* bioremediation	As for bioremediation by windrow	As for bioremediation by windrow
	Bioremediation by landfarming Not selected	Source Management *In situ* Bioremediation	As for bioremediation by windrow	As for bioremediation by windrow
	Banning of growing crops for food and segregating area Possible use with capping	Receptor management	Breakdown of good will from local people Contamination remains Growing and consumption continues	Community meetings & Compensation Use of additional method Erection of fencing and use of warning signs
Area E	Capping of wells	Pathway management		
	Groundwater treatment by in situ chemical oxidation	Source management	Uncontrollable reactions producing dioxin and other organic contaminants as by products Involves use of strong oxidizing chemicals	Verification of system at all stages including, design installation and operation Use of operating procedures and control systems Introduction of HSE plan Use of experienced team and specialized equipment only
	Installation of permeable reactive barrier Not selected too expensive	Pathway management		

Annex 6

Risk reduction selection project case study

This project involved the assessment and potential risk management of 18 sites across a country. The remit of the project was to provide risk management of the top 5 prioritized sites. As per the FAO risk assessment protocol two site visits were made to each site prior to development of the EMP for the purposes of data collection:

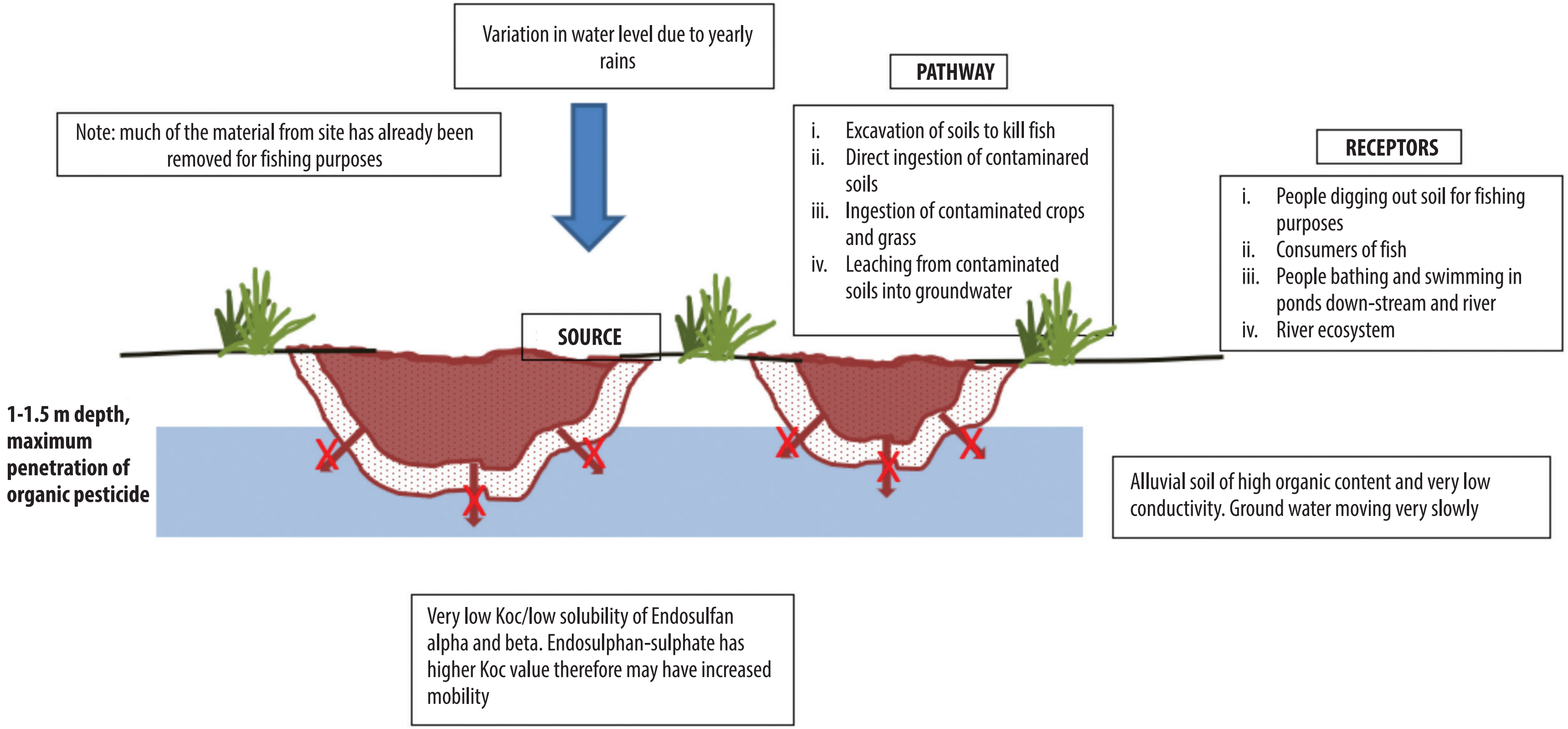
- a visit was made to each site during which time an FAO Rapid Environmental Assessment was conducted and at the same time a preliminary site investigation was completed;
- two years later the intention was that a visit should be made to the top 5 priority sites in order to conduct a detailed site investigation. Operational circumstances allowed for visits to only 4 sites only. Of these, three were determined to be of sufficient risk to require risk management. The rational for risk management intended at each of the three sites is discussed below:



Site 1

Site description and general conditions

This site is located in a relatively remote agricultural area. In the late 1970s farmers hand dug a circular hole approximately 1.75 m deep and 7-8 m diameter. Obsolete pesticides were collected and tipped into the hole. The detailed site investigation showed that the burial area is located in firm alluvial clay and that while there is groundwater at the base of the excavation it is moving so slowly that penetration of contaminants to groundwater resources would take decades, if not longer. Consequently, groundwater is not at risk. Analysis of soil samples taken from around the excavation show that contamination is limited to the excavation itself and that contamination has


Variation in water level due to yearly rains
Note: much of the material from site has already been removed for fishing purposes
PATHWAY
i. Excavation of soils to kill fish
ii. Direct ingestion of contaminared soils
iii. Ingestion of contaminated crops and grass
iv. Leaching from contaminated soils into groundwater
RECEPTORS
i. People digging out soil for fishing purposes
ii. Consumers of fish
iii. People bathing and swimming in ponds down-stream and river
iv. River ecosystem
SOURCE
1-1.5 m depth, maximum penetration of organic pesticide
Alluvial soil of high organic content and very low conductivity. Ground water moving very slowly
Very low Koc/low solubility of Endosulfan alpha and beta. Endosulphan-sulphate has higher Koc value therefore may have increased mobility

not spread via flooding or by wind dispersal to the surrounding area, this includes local surface water ponds 75 m away and a river 2 km away. Following the detailed site investigation, the total quantity of contaminated soils was estimated to be 190 m^3 or 342 tonnes (at a soil density of 1.8 tonnes/m^3). A screen of agricultural pesticides by both gas chromatography and liquid chromatography techniques and subsequent analysis of soil samples shows that endosulfan, a POP pesticide, is the principal contaminant present at a representative concentration of 352 mg/kg.

A complication of events at the site is that local people, including children, have been excavating contaminated soils from the site and using them in the local river to kill fish. Since the time of original contamination, the majority of contaminated soils have been excavated to the top of the groundwater level for this, leaving a hole of approximately 180 m^3.

Conceptual Site Model summary

Sources: 342 tonnes contaminated soils (endosulfan at 352 mg/kg). Endosulfan is a POP.

Pathway: Direct exposure of people during excavation (dermal and ingestion pathways), indirect exposure of eating contaminated fish (unfortunately, not demonstrated by comparison to the endosulfan ADI).

Receptors: Fish in the local river and the riverine ecology, consumers of fish, children and adults collecting soils from the base of the excavation.

Risk reduction objectives: Eliminate the pathways of direct exposure (inhalation, skin adsorption and ingestion exposure pathways) during excavation and of people taking away contaminated soil for the purposes for poisoning fish.

Risk reduction criterion: Due to presence of children in the situation it was decided that the [8]US EPA generic screening level for residential areas is the most appropriate risk reduction criterion.

Risk reduction strategy:

Comparison with the conservative risk reduction criterion generic US EPA screening level shows that human health is not generally at risk at the site. It is of note that the screening level was recently raised from 37 mg/kg to 370 mg/kg. Consequently, in terms of human health, soils previously requiring risk management now can be left *in situ*. However, due to the toxicity of endosulfan to fish and invertebrates and using contaminated soils to kill fish by local people, there is evidently some danger to the ecology of the local river. In addition, endosulfan is a POP and therefore subject to the Basel and Stockholm Conventions. In this situation it is in breach of the lower POPs limit of 50 mg/kg.

Potential risk reduction approaches and techniques

A long list of appropriate techniques and approaches that were considered is available in Annex 2.

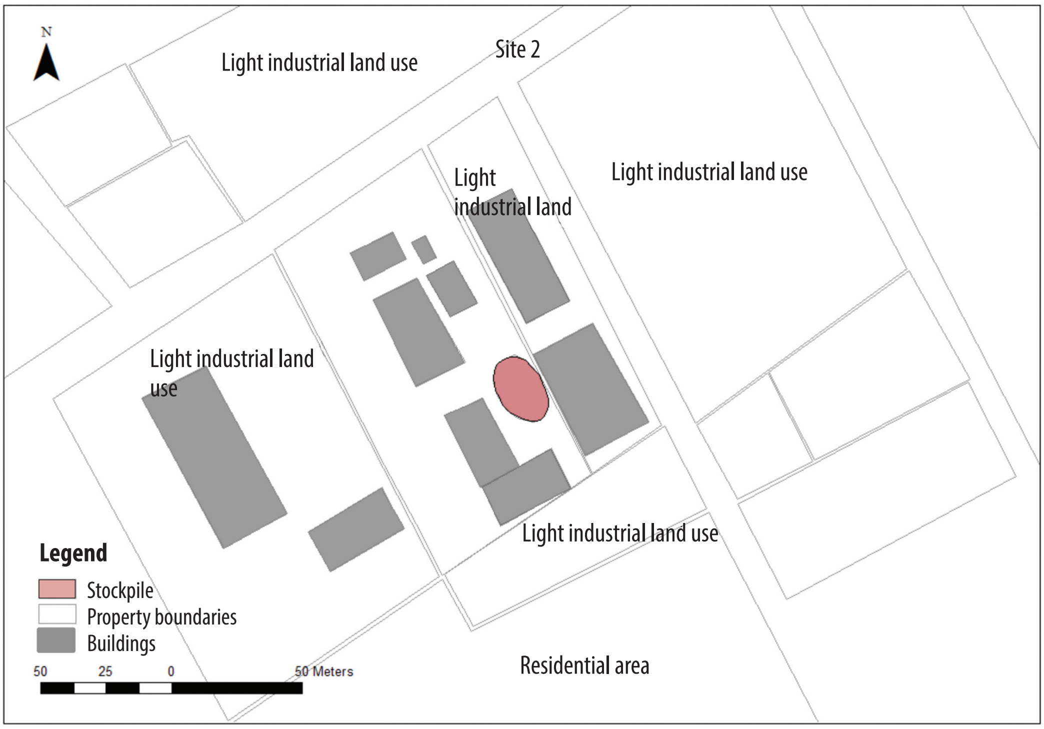
The long list was then analysed broadly to remove any techniques obviously not suitable and the remaining were later subject to matrix and SWOT analysis. The matrix and SWOT analysis can also be seen in Annexes 3 (matrix analysis) and Annexes 4 (SWOT analysis):

Because of the initial concerns that soils were breaching the human health screening level and the danger from excavation of soils for the purposes of fishing, it was originally intended that removal of the risk by excavation followed by appropriate disposal would be the best form of risk reduction. Disposal techniques considered were sequestration by underground landfill and stabilization followed by landfill at a national facility. Capping of the soils was not considered as an option and all capping techniques were removed from the long list selection as not suitable. However due to the revision of the SL and the depth that the contamination is currently

[8] As the US EPA screening levels are frequently revised this level has not been quoted

found (1.75 m below ground level) capping of the site using a concrete slab at this level is now considered viable. The use of concrete would prevent any further excavation of the soils. Filling the void above the concrete with non-contaminated soils would allow farming to continue as before. As the main contaminant is an organochlorine POP pesticide, bioremediation techniques will not be effective and therefore are not considered further. The relatively low concentration and quantity of soil involved means that thermal treatments either at an off-site facility or on-site would not be justified.

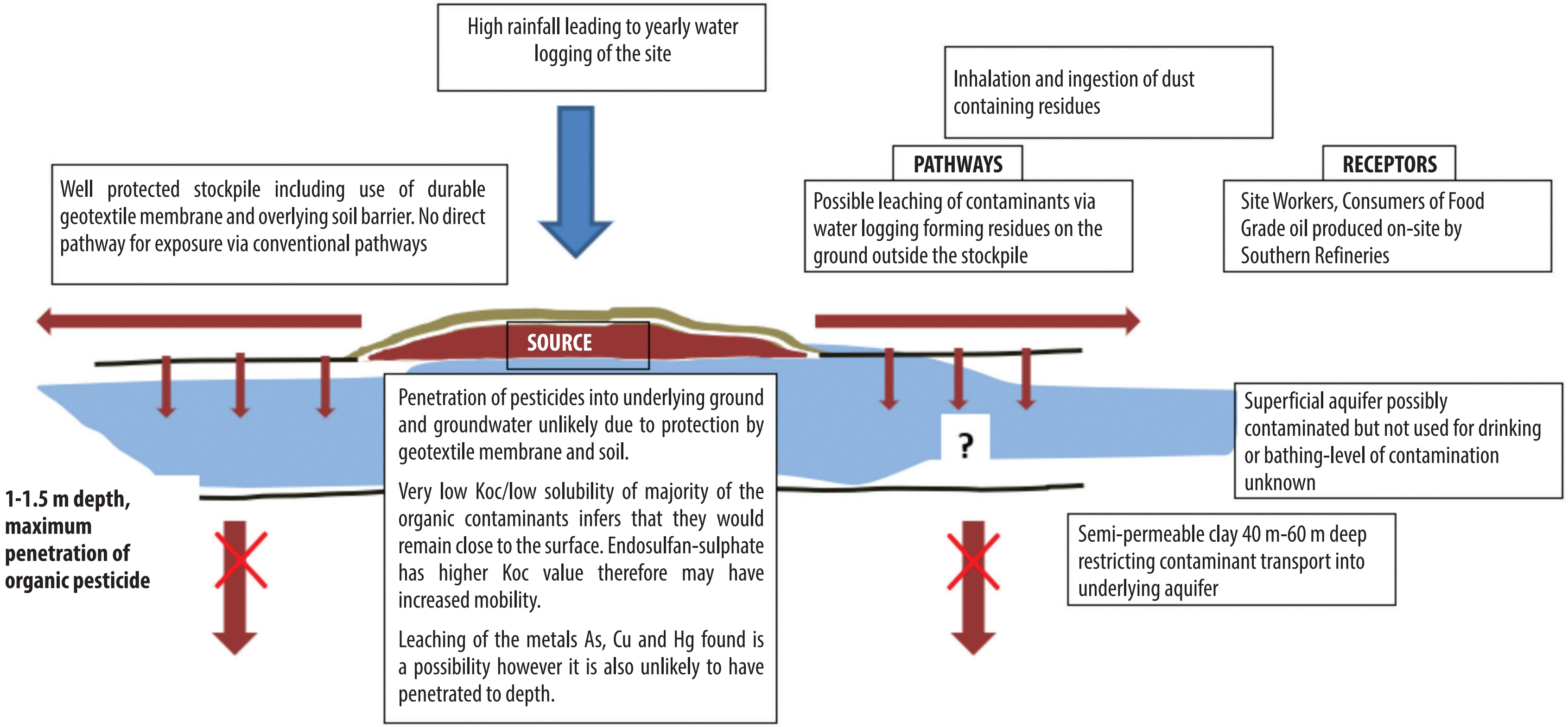
Because of the continuing behaviour of local people to use the soils for fishing and the consequent danger to the river ecology, this site is seen as a high priority.



Site 2

Site description and general conditions

This is the location of a stockpile of soil contaminated with various obsolete pesticides including endosulfan (140 mg/kg), toxaphene (1 400 mg/kg), trifluralin (956 mg/kg) and prometryn (960 mg/kg). The stockpile also has a total arsenic concentration of 626 mg/kg. The stockpile is in good condition and has been covered by a heavy duty geo-textile fabric and 200 mm of clean soil. The site is located in an industrial area and is within a food and soap oil manufacturing compound. The current owners of the site want to build over the area where the soils are currently located with another factory building. The soils need to be moved and disposed of according to national and international regulations and guidelines. Because of the local hydrogeological conditions and the very good conditions of the stockpile any threat to groundwater resources suitable for consumption by people has been discounted by the project hydrogeologist. Whilst there is demonstrated to be a very high level of pesticide within the stockpile, the stockpile is in very good condition. As people working at the facility are not currently suffering from exposure and there is no imminent danger via other exposure pathways, such as the consumption of contaminated groundwater, the general level of risk at the site is therefore low.


High rainfall leading to yearly water logging of the site
Inhalation and ingestion of dust containing residues
PATHWAYS
RECEPTORS
Well protected stockpile including use of durable geotextile membrane and overlying soil barrier. No direct pathway for exposure via conventional pathways
Possible leaching of contaminants via water logging forming residues on the ground outside the stockpile
Site Workers, Consumers of Food Grade oil produced on-site by Southern Refineries
SOURCE
Penetration of pesticides into underlying ground and groundwater unlikely due to protection by geotextile membrane and soil.
Very low Koc/low solubility of majority of the organic contaminants infers that they would remain close to the surface. Endosulfan-sulphate has higher Koc value therefore may have increased mobility.
Leaching of the metals As, Cu and Hg found is a possibility however it is also unlikely to have penetrated to depth.
?
Superficial aquifer possibly contaminated but not used for drinking or bathing-level of contamination unknown
1-1.5 m depth, maximum penetration of organic pesticide
Semi-permeable clay 40 m-60 m deep restricting contaminant transport into underlying aquifer

Conceptual Site Model summary

Sources: 245 m^3 tonnes or 441 tonnes of contaminated soils

Pathway: Because of the good condition of the stockpile, it is well contained, there are no pathways.

Receptors: Currently none

Risk reduction objectives: Ensure future duty of care of the soils so that they are disposed of properly

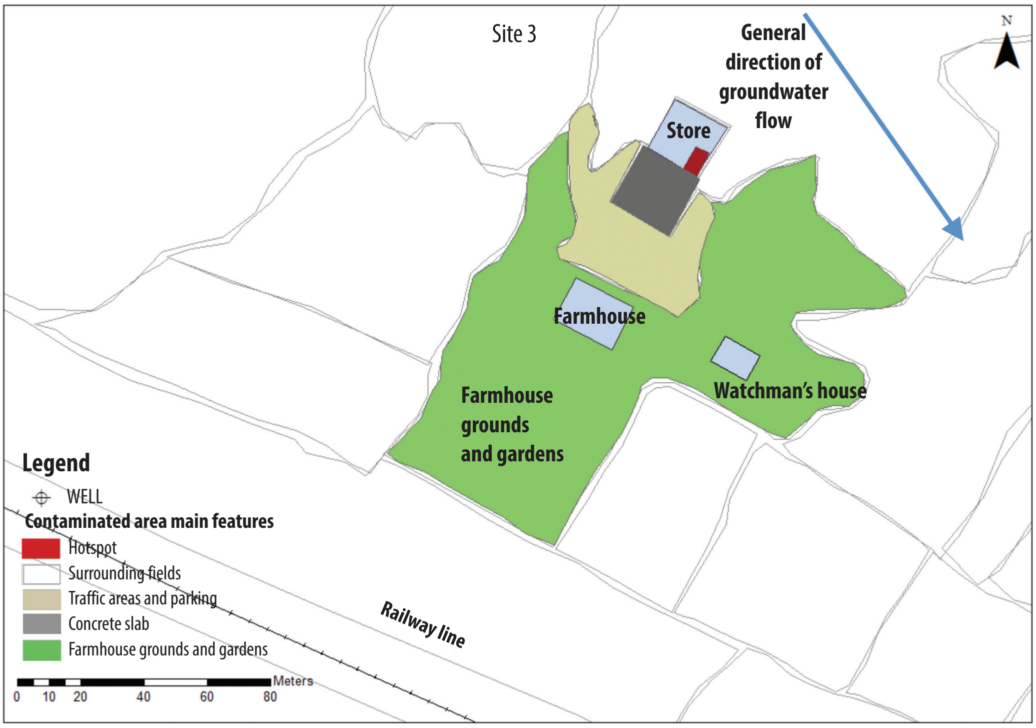
Risk reduction criterion: US EPA generic screening level for industrial areas

Risk reduction strategy:

Risk reduction in this scenario largely relates to removing the stockpile from its present location and ensuring that the soils are disposed of appropriately so that they do not pose a problem in the future.

Amongst the long list of techniques, the following were subject to SWOT and matrix analysis.

With this in mind the decision rests on finding the most appropriate form of disposal. It is of note that three of the contaminants breach the Stockholm Convention Low POPs limit of 50 ppm. Due to the high concentration of arsenic, both thermal desorption and HTI plants would have difficulty in accepting this particular waste. Due to the presence of arsenic and organochlorine chemicals it is unlikely that bioremediation techniques would be effective. Arsenic residues would be particularly amenable to stabilization using an alkaline material such as cement or mixing with lime, organochlorines could be further stabilized by the use of granular activated carbon or finely crushed charcoal.



Site 3

Site description and general conditions

The contaminated site is a hotspot found around a store located on a farm close to other farm buildings including the farmhouse and employee quarters, which is now used for housing a watchman and his family. The farm land around the store is currently cultivated for a number of different crops primarily by small holders. The farmhouse is not in use presently but may be in the future. The presence of the watchman restricts access to the farm buildings and visits to the site are minimal. The store is the location where drums of endosulfan are kept. Over time a considerable quantity of endosulfan has leaked into the ground beneath the store. The project geologist/hydrogeologist present during the investigation determined that ground conditions in the local area consisted of alluvial materials, specifically clay and gravel lenses interbedded with loam soils. Groundwater in a well up stream of the site was determined to be at 7-8 m below ground level. A river is located to the south of the site approximately 2 km away. Groundwater flows in a general south easterly direction towards the river however there are no drinking water or irrigation water abstraction points down gradient of the site. The conceptual site model indicates that ground and surface waters are not at risk.

The investigation and risk assessment determined that the single biggest issue affecting the site is the grossly contaminated soil in and around the pesticide store. In this area, in the top 1m of the ground surface, soils have 7 400-16 000 mg/kg of endosulfan that clearly breach the current US EPA residential levels for endosulfan of 370 mg/kg (current at the time of issuing the EMP). Soils deeper in the soil profile at 1-2 m are not grossly contaminated but do breach the Stockholm Convention Lower POPs limit of 50 mg/kg.

Whilst it has been demonstrated that there are grossly contaminated soils at this site, because of the storehouse and concrete slab providing protection of the hotspot, the general level of risk is relatively low. The most immediate problem is to emphasise the urgency of repackaging the remaining containers of endosulfan inside the store to prevent further leakage.

The total quantity of contaminated material including soils and building materials is estimated to be:

Category	Tonnes	Volume (m^3)
Soils and building materials more than 50 mg/kg and more than 370 mg/kg	144	80
Soils more than 50 mg/kg but less than 370 mg/kg	202	112.2
Total	346	192

Conceptual Site Model summary

Sources: Endosulfan contaminated hotspot

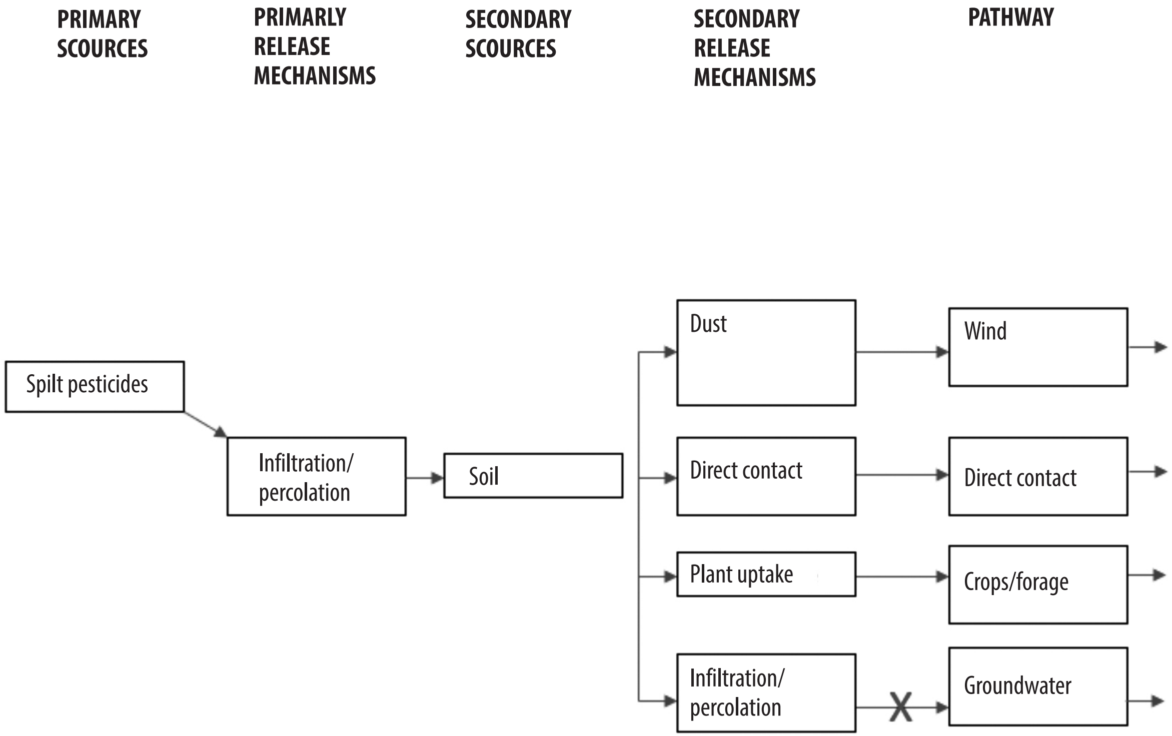
Pathway: Possible direct exposure pathways (inhalation, skin and ingestion pathways)

Receptors: Currently watchman, family and site visitors, future farm workers and farmhouse occupants (including women and children)

Risk reduction objectives:

To reduce or eliminate inhaled and ingested, wind dispersed residues of Endosulfan from the hotspot and contaminated building materials at and around the pesticide store to the watchman and family, visitors to the farm and future residents of the farmhouse;

Risk reduction criterion: Due to the presence of children now and potentially in the future the US EPA generic screening level for residential areas of 370 mg/kg has been selected.



	Human		Biota	
Exposure route	**Home**	**Work**	**Land based**	**Aquatic**
Ingestion	•	•	•	
Inhalation	•	•	•	
Dermal	•	•		
Inhalation	•	•	•	
Ingestion	•	•	•	
Dermal	•	•	•	
Ingestion	•	•	•	•
Ingestion		•		•
Inhalation				
Dermal		•		•

Potential risk reduction approaches and techniques

Amongst the long list of techniques, the following were later subject to SWOT and matrix analysis:

The rationale behind selection is:

As groundwater is not an issue at this site, the focus of risk reduction is towards the contaminated soils. It is evident that direct exposure to the contaminant is required to be dealt with due to potential exposure by farm worker, visitors and future residents. According to the Stockholm and Basel Conventions, concentrations of the POPs chemical endosulfan means that the hotspot beneath the store require destruction or neutralization. On-site treatment techniques would be technically difficult due to the farm operations and the closely situated farm buildings. The low quantities of soils mean that mobile and in-situ thermal treatments would not be economic. As with the other sites due to the existence of organochlorine chemicals within the contaminant profile bioremediation techniques would not be possible. Excavation and disposal of the soils is therefore the only real possibility. High concentrations of POP pesticide therefore would require thermal treatment. As thermal desorption is only able to deal with relatively low concentrations of chemical, HTI is therefore the outstanding option. For the lesser contaminated soils, the breach of the Lower POPs limit also necessitates risk reduction, however as the concentration of pesticide does not justify the expense of thermal treatment some other form of disposal should be considered. This is discussed further in the Strategic Assessment below.

Risk reduction strategy:

In view of the above rational the following is the risk reduction strategy:

- safeguarding of leaking Endosulfan stocks inside the store ASAP;
- demolition of the store;
- excavation, segregation and removal of grossly contaminated soils and concrete slab from 0 m to 1 m below ground level within the hotspot;
- excavation, segregation and removal of soils from -1 m to -2 m below ground level;
- placement of clean fill in the resulting void.

Strategic Assessment in Country X

A strategic assessment of the disposal capacity of the country concerned indicates that there is only one facility available dedicated to the disposal of hazardous wastes. This particular facility is a hazardous waste landfill that practises co disposal and stabilization of wastes with alkaline ash from various non-hazardous incinerators. It is monitored and regulated by the country's environment agency. Importantly legislation governing management of disposal sites defers to that of a neighbouring country.

Operation of the site allows the use of the alkaline ash as pre-treatment to improve the leaching quality of the mainly acid wastes that come into the site from industrial sources. National Legislation currently relies on a neighbouring country accepting POPs contaminated material. This stipulates that until 2018 leachate testing will govern the upper concentration of POPs material that is allowed to enter the facility. Beyond this point in time the limit will rest at 50 ppm per POPs species.

The facility has confirmed that it would be able to accept organochlorine contaminated soils and also soils contaminated with arsenic from the stockpile at Site 2. The facility would be prepared to use granular activated carbon or crushed charcoal in order to pre-treat the organochlorine contaminated wastes to maximise the concentration of organochlorine permitted. The current status is that tests are being carried out to determine the upper level that could be accepted at the facility, bearing in mind the pre-treatment process. Soils determined to be above the permitted level would be sent for thermal desorption.

Site	Cat. 1 (tonnes)	Cat. 2 (tonnes)	Contaminants of concern
1		342	Endosulfan (352 mg/kg)
2		441	Arsenic (626 mg/kg), Trifluralin (956 mg/kg) and Toxaphene (1 400 mg/kg) Endosulfan (140 mg/kg)
3	144	202	Endosulfan (16 000 mg/kg maximum value)

Rationalisation of Risk Reduction Strategy and Disposal

On examination of the soils at the three sites, soils at Site 3 require excavation followed by off-site thermal treatment. High concentrations of POPs in excess of the operating optimum of 10 000 ppm for thermal desorption would indicate that High Temperature Incineration is the favoured option. Despite the existence of high POPs concentrations in the soils at Site 2, due to the presence of Arsenic these soils would not be suitable for thermal treatment. The only real alternative is stabilization followed by sequestration, as there is a local facility available, the use of this facility would be recommended. Soils at Site 1 can be dealt with using in situ methods by capping the contaminated area with concrete and covering with clean soils.

Priority for risk management

Despite being below human health screening levels soils at Site 1 are used for fishing in the local river which poses considerable danger to the ecology of the river system. It is recommended that this site should be dealt with as a priority. The other two sites, although they contain very high concentrations of pesticides, including POPs at levels at least ten times higher than the Stockholm Convention Low POPs Limit, do not present an immediate threat to human health. However, all sites need to be dealt with as soon as possible.

Plant Production and Protection Division (AGP)
Food and Ariculture Organization of the United Nations (FAO)

Pesticide-Management@fao.org
www.fao.org/agriculture/plant-production-and-protection/en/

ISBN 978-92-5-132112-6 ISSN 1020-4695

9 789251 321126

CA7499EN/1/01.20