

Guidelines for the Sustainable Management of Contaminated Sites in the former Yugoslav Republic of Macedonia

Part 2: Remediation of Contaminated Sites

15 May 2018

Responsibility

Title	Guidelines for the Sustainable Management of Contaminated Sites in the former Yugoslav Republic of Macedonia – Part 2: Remediation of Contaminated Sites
Client	UNIDO, Vienna International Center
Project Leader	Matthijs Bouwknecht
Author(s)	Boudewijn Fokke and Annika Tella
Project number	1251431
Number of pages	112 (excluding appendices)
Date	15 May 2018
Signature	This document was released with the explicit approval of authorized project management.

Colophon

Tauw bv
BU Industry
P.O. Box 133
7400 AC Deventer
The Netherlands
Telephone +31 57 06 99 91 1

This document is the property of the client and can be used by the client for the purpose it was drawn up for, with due regard for the intellectual property rights. Copyrights to this document remain with Tauw. The quality and continual improvement of products and processes have the highest priority at Tauw. We operate under a management system that is certified and/or accredited according to:

- NEN-EN-ISO 9001

Contents

Responsibility and Colophon	3
List of Abbreviations	7
Definitions	9
1 Introduction	12
1.1 General	12
1.2 Objectives of the Guidelines	13
1.3 Organization of the Guidelines	13
2 Phase 3: Remediation Assessment	14
2.1 Objectives and Tasks	14
2.2 Selection of Feasible Remediation Techniques	17
2.2.1 Techniques for short-term remediation measures	19
2.2.2 Techniques for mid-term remediation measures	21
2.2.3 Techniques for long-term remediation measures	22
2.3 Conceptual Design of Feasible Remedial Options	23
2.3.1 Approach	23
2.3.2 Conceptual design	24
2.4 Selection of the Best Remedial Option	41
2.4.1 Multi Criteria Decision Analysis (MCDA)	42
2.4.2 Example of a Multi Criteria Decision Analysis	43
2.5 Preliminary design preferred remedial option	44
2.5.1 Additional technical survey	44
2.5.2 Preliminary design	45
2.5.3 Preliminary design supervision	47
2.5.4 Design of a Health and Safety (H&S) Plan	48
2.6 Project Risk Management	53
2.6.1 Approach	53
2.6.2 Implementation	54
2.7 Design of Stakeholder Involvement Plan	57
2.7.1 Stakeholders analysis	57
2.7.2 Stakeholder involvement	57
2.7.3 Monitoring stakeholder involvement	58
2.8 Reporting of Remediation Assessment	59

3	Phase 4: Remediation Management	63
3.1	Objectives and Tasks	63
3.2	Tendering Process and Methods	64
3.2.1	Introduction	64
3.2.2	Tendering process	66
3.2.3	Tendering methods	69
3.3	Detailed Remediation Design	72
3.3.1	Introduction	72
3.3.2	Site Preparation	73
3.3.3	Storage of hazardous substances	74
3.3.4	Buried hazardous waste	76
3.3.5	Contaminated building(s) and infrastructure(s)	77
3.3.6	Contaminated soil and groundwater	79
3.3.7	Environment management	81
3.4	Remediation Management	83
3.4.1	Introduction	83
3.4.2	Preparation	84
3.4.3	Remediation Site Zoning	86
3.4.4	Start Work Analysis	88
3.4.5	Toolbox meeting	88
3.4.6	Administrative tasks	89
3.4.7	Remediation of the Site Components	89
3.5	Remediation Evaluation and Closure	93
3.5.1	Remediation Evaluation	94
3.5.2	Remediation Closure	94
3.6	Reporting of remediation management	95
4	Phase 5: Monitoring and Aftercare	98
4.1	Objectives and Tasks	98
4.2	Updating Monitoring and Aftercare Plan	101
4.3	The Monitoring and aftercare Plan	102
4.3.1	The Monitoring	102
4.3.2	The Aftercare	106
4.4	Organization of Monitoring and Aftercare	107
4.4.1	General	107
4.4.2	Costs	108
4.5	Reporting of Monitoring and Aftercare	108
5	References	112

List of Abbreviations

Countries and Government institutions / structures

FAO	Food and Agriculture Organization of the United Nations
UNIDO	United Nations Industrial Development Organization
USEPA	United States Environmental Protection Agency
MEPP	Ministry of Environment and Physical Planning of the Republic of Macedonia

Other abbreviations

AST	Aboveground Storage Tank
CoC	Chemicals of Concern
CSM	Conceptual Site Model
CSS	Composite Soil Sample
EMP	Environmental Management Plan
EMTK	Environmental Management Toolkit
EOX	Extractable Organic Halogen
GPS	Global Positioning System
HCH	Hexachlorocyclohexane
H&S	Health and Safety
ID	Identification
ICSM	Initial Conceptual Site Model
LNAPL	Light Non-Aqueous Phase Liquid
m bgl	meters below ground level
mg / kg d.m.	Milligram per kilogram dry matter
n.a.	Non applicable
OHIS	Organic Chemical Industry of Skopje, OHIS AD
PPE	Personal Protective Equipment
POPs	Persistent Organic Pollutants
RA	Risk Assessment
RBCA	Risk-Based Corrective Action Toolkit
RPE	Respiratory Protective Equipment
SOPs	Standard Operating Procedures
UST	Underground Storage Tank
µg / l	Microgram per litre

Reference R005-1251431BFF-lvi-V04-NL

Definitions

Benzene hexachloride	Hexachlorocyclohexane, often incorrectly used for Lindane (γ -HCH)
Conceptual Site Model	A representation of the characteristics in graphical or pictorial forms that is used to present identified potential nature and sources of contamination, their likely spatial distribution in soil (or other environmental media), routes of exposure (pathways), and the potential effects of the contaminants on the site and on adjacent sites and other receptors
Contaminant	Any hazardous substance that does not occur naturally, or occurs at greater levels than natural background and has the potential to cause significant harm to relevant receptors
Contamination / pollution	Direct or indirect introduction of materials, substances, or heat into the air, water or land, which may be harmful to human health or to the quality of aquatic or terrestrial ecosystems, which may result in damage to material property, or which impair the status of natural resources
Decision making process	A sum of activities of the council, including defining and determining issues that should be resolved, proposals and solutions, reviewing and adoption of regulations and measures
Desktop study	Interpretation of historical and current information in order to establish knowledge on presence of potentially polluting activities and to understand the environmental setting of the site in terms of pathways and receptors
DNAPL	Dense Non-Aqueous Phase Liquid - Chemicals that are more dense than water, insoluble or only slightly soluble in water that exists as a separate liquid phase in environmental media
Environmentally harmful substance	A biological or physical agent, or phenomenon/ state, the presence of which in the environment may induce direct or postponed threat to or pollution of one or more environmental media or areas, as well as other irritant, inflammable and explosive matters which exhibit such properties when of certain quantity, concentration or intensity
Environmental media	Water, air and soil
Environmental monitoring	Systematized measuring, monitoring and documenting of the conditions, quality and changes in the environmental media of a site

Hazardous substance / waste	Any substance, or a preparation containing one or more hazardous substances, the properties of which pollute and damage the environment and are hazardous to human life and health, with proven acute, chronic, toxic and other harmful effects
Hexachlorobenzene	Hexachlorocyclohexane, often incorrectly used for Lindane (γ -HCH)
Lindane	Gamma-hexachlorocyclohexane (γ -HCH)
LNAPL	Light Non-Aqueous Phase Liquid - Chemicals that are less dense than water, insoluble or only slightly soluble in water that exists as a separate liquid phase in environmental media
Long-term	Longer than three years after decision is taken to remediate
Mid-term	Within max two/three year after decision is taken to remediate
Monitoring Plan	Plan that describes the monitoring of the implementation of short- and mid-term remediation measures
Monitoring and Aftercare Plan	Plan that describes the monitoring and aftercare of the implementation of the long-term remediation measures
Natural background	The concentration of hazardous substance consistently present in the environment that has not been influenced by localized human activities
Pathway	A route by which a receptor is or might be affected by contaminant
Permit for project implementation	The decision of the competent authority granting a consent to the investor/ applicant for approval of proceeding with the project implementation
Personal Protective Equipment (PPE)	Any equipment that the worker wears, holds and uses at work, in order to be protected simultaneously from one or more dangers that could endanger his or her safety and health at work
Preliminary Site Assessment	A non-intrusive investigative research conducted to obtain as much detailed site history and contamination information as possible without having to collect, sample or analyse environmental media
Preventive measures	All measures that are taken or planned at all levels of work, for preventing or reducing the risks to occupational safety and health
Polluter	Any legal or natural person the activity of which causes, directly or indirectly, pollution of the environment
Pollution / contamination	Direct or indirect introduction of materials, substances, or heat into the air, water or land, which may be harmful to human health or to the quality of aquatic or terrestrial ecosystems, which may result in damage to material property, or which impair the status of natural resources
Receptor	Organisms or resources that could be adversely affected by a contaminant, for example humans, animals, ecosystems, properties, or controlled waters

Register of Polluting Matters	A catalogue classifying waste, hazardous and harmful matters and substances, by their chemical composition and by the extent of their hazard
Remediation	Any action undertaken for eliminating, reducing, controlling or mitigating the risks resulting from contamination
Remediation Assessment	Remediation Assessment comprises the conceptual design of at least three feasible remedial options, the selection of the best remedial option and the preliminary design of the best remedial option.
Remediation Closure	The completion of remediation, after the predetermined remediation objectives have been met
Risk	The probability that a hazardous substance, when released into the environment, will cause an adverse effect in exposed humans or other living organisms. In Macedonian Law on Environment, risk is defined as the likelihood of occurrence of a specific effect on the environment within a specified period or under specified circumstances
Risk Assessment	An analysis of the potential for adverse effects on receptors caused by chemical(s) of concern from a site
Site Assessment	An intrusive investigation and assessment of a site in order to identify and determine the presence, nature and extent of potential subsurface contamination
Site Component	The most common site components of a contaminated site are storage areas for hazardous substances; contaminated building(s) and infrastructure(s); buried hazardous waste; and contaminated soil and groundwater. Components are always site specific and therefore, identifying other site components are possible as well
Short-term Storage	Within a year after decision is taken to remediate Presence of a certain quantity of hazardous substances for the purpose of warehousing, depositing in safe custody or keeping in stock
Substance	A chemical element or its compounds in the natural state or obtained by means of a production process, including the additives necessary to preserve their stability and impurities deriving from the manufacturing process, with the exception of solvents which can be separated without affecting the stability of the substance or the change in its composition

1 Introduction

Disclaimer

These Technical Guidelines are a part of the Guidelines for the Sustainable Management of Contaminated Sites and are made to assist the Ministry of Environment and Physical Planning of the Republic of Macedonia (MoEPP) and UNIDO in implementing the removal of technical and economic barriers for initiating the clean-up activities for Alpha-HCH, Beta-HCH and Lindane contaminated sites at OHIS in Skopje, Macedonia.

These Technical Guidelines are based on the experiences of the authors. In no event shall the authors, the Ministry of Environment and Physical Planning of the Republic of Macedonia (MoEPP) or UNIDO be liable for any direct, indirect, special, incidental or consequential damage arising out of, or related to, the use of these Guidelines.

It is expected that the reader(s), or person(s) using these Guidelines, have professional knowledge of the field of environmental investigation, and master the basics of chemistry and soil science. Hence, the Guidelines will not go into detail on explaining such knowledge.

1.1 General

UNIDO, in association with the Former Yugoslav Republic of Macedonia, is currently (2017) implementing a project in the scope of the National Implementation Plan (NIP) of the Stockholm Convention on Persistent Organic Pollutants (POPs) entitled '*Removal of Technical and Economic Barriers for initiating the Clean-up Activities for Alpha-HCH, Beta-HCH and Lindane Contaminated Sites at OHIS*'. Due to the addition of Lindane (γ -HCH) and its isomers to the Stockholm Convention as POPs in 2009, the OHIS site in Skopje is now recognized as POPs contaminated site. One of the key priority challenges (no. 8) of the National Implementation Plan (NIP) of Macedonia is to clean up and remediate this site.

This set of Guidelines for the Sustainable Management of Contaminated Sites covers all internationally recognized five phases of sustainable management of contaminated sites. The Guidelines have been divided in the following documents:

- Part 1: Assessing Contaminated Sites –
 - Phase 1: Preliminary Site Assessment
 - Phase 2: Site assessment
- Part 2: Remediation of Contaminated Sites
 - Phase 3: Remediation Assessment
 - Phase 4: Remediation Management
 - Phase 5: Monitoring and Aftercare

- Part 3: Standard Operating Procedures (SOPs)

1.2 Objectives of the Guidelines

These Guidelines provide an easy-reference manual for the standardized phases of sustainable management of contaminated sites. These Guidelines are intended to assist *Authorities* and the Private Sector that are responsible for the enforcement, remediation and maintenance of the sustainable management of contaminated sites during the full process from assessing until reporting on contaminated sites. Easy to use templates to report each Phase are provided at the end of the individual sections.

Risk based approach is the leading principle in these Technical Guidelines. This means that all decisions on contaminated land management should be based on protection of human health, the ecosystem and the preventing contaminants to migrate. Moreover, the site assessment should focus on collecting relevant information required to determine the likely health and environmental impacts associated with the site. Since the resources available for contaminated site management are limited, the resources should be allocated based on the risks to human health the ecosystem and migration (also referred to as the environmental risks).

1.3 Organization of the Guidelines

The sustainable management of contaminated sites is a stepwise process with the five phases. The approach and the steps described in these Guidelines are based on international best practice.

Technical and methodological instructions for the following Sections in this Part 2 of the Guidelines are described in detail:

- Phase 3: Remediation Assessment (Section 2) which comprises the conceptual design of a least three feasible remedial options, the selection and preliminary design of the best remedial option
- Phase 4: Remediation Management (Section 3) is the implementation of the remediation by tendering, detailed design of the remediation, remediation of site component(s), remediation closure and evaluation, and reporting the remediation process and results
- Phase 5: Monitoring and Aftercare (Section 4) starts after the short-term risk reduction measures are completed and residual contamination is left. Monitoring and aftercare needs to be implemented to ensure that the remediation end results are sustained

Please refer to the Part 3 - Standard Operating Procedures (SOPs) of these Guidelines for supplementary information on the procedures. It is strongly advised to follow the technical procedures presented in these Guidelines as much as possible, in order to meet the required quality and to obtain reliable results in contaminated site management.

For more information on the Macedonian national legislation and policies, please refer to Annex 1 of 'Report summarizing the results of the reviews and outlining the literature and legal acts and practices for the development of the national regulatory acts' (Stefanoni and Pejcinovska-Andonova, 2015).

2 Phase 3: Remediation Assessment

2.1 Objectives and Tasks

Phase 3 in contaminated site management, the Remediation Assessment, is only implemented when the Phase 2, Site Assessment, has identified risks related to human health, ecosystem and or contaminant migration. Remediation Assessment comprises the conceptual design of at least three feasible remedial options, the selection of the best remedial option and the preliminary design of the best remedial option.

The Remediation Assessment is divided into the *Remediation Assessment* and *the design of the Remediation Plan*. The objectives of the Remediation Assessment are: to select the best remedial technique for the different site components, to conceptually design at least three feasible remediation options and to select the best remedial option based on the risk reduction, the environmental merits and the costs. The objectives of the Remediation Plan are to present the preliminary design of the best remedial option; to obtain approval for the site remediation in Phase 4 (Remediation Management); and to provide technical input for Phase 4 and 5 (Monitoring and Aftercare). The process to be followed for Remediation Assessment of contaminated sites is illustrated in Figure 2.1.

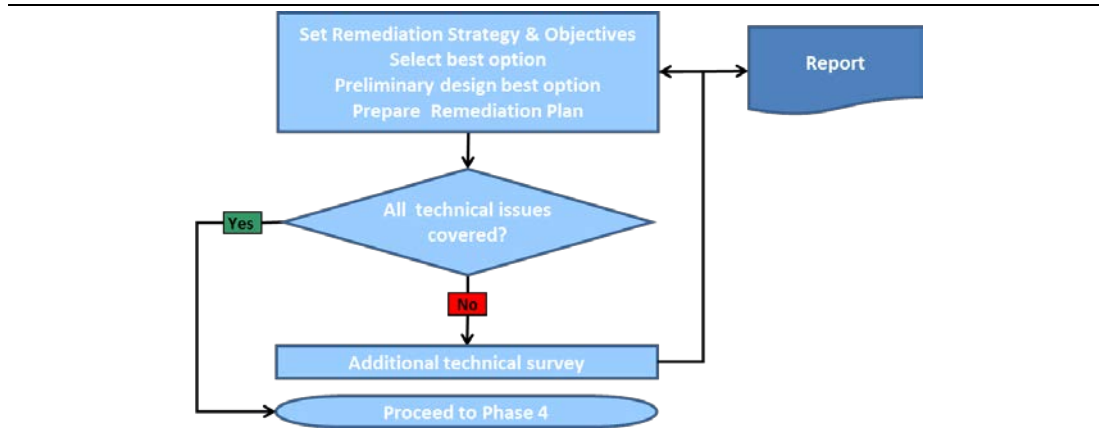


Figure 2.1 Process of Phase 3, Remediation Assessment, of the sustainable management of contaminated sites (source: Tauw, 2015a)

A careful Remediation Assessment makes it possible in the next stage (Remediation Management) to focus on minimizing human health risks, ecosystem risks and contaminant migration risks by removing the direct environmental risks in the short-term (within a year after decision is taken), reducing and removing the potential environmental risks in the mid-term (within max two / three year after decision is taken), and containing and monitoring the latent environmental risks in the long-term (longer than three years).

The Conceptual Site Model (CSM) and results of the Risk Assessment are the input for the Remediation Assessment (see Part 1 of these Guidelines - Assessing Contaminated Sites). The most important components of contaminated sites are in general, as described in Part 1 of these Guidelines:

1. Storage of hazardous substances
2. Contaminated buildings and infrastructures
3. Buried hazardous waste
4. Contaminated soil and groundwater and source area(s) also called hotspots

A Remediation Plan should be prepared before the implementation of any remediation actions. The plan should specify the objectives, targets of remediation activities and describe the selection process of the best remedial option and the preliminary design of the selected option. The Remediation Plan of the best remedial option contains for the four mentioned site components (as far as applicable):

1. A (re)packaging plan for the hazardous substances in a storage
2. A decontamination plan for the contaminated buildings and infrastructures
3. An excavation plan for the buried hazardous waste
4. A remediation plan for the contaminated soil and groundwater and source area(s)

It is advised to use as much as possible the standard methods as described in these Guidelines to draw up these plans. For the first three site components, standard methods of remediation / cleaning presented in these Guidelines are suitable for most sites.

For the selection of a remediation option for contaminated soil and groundwater and the source area(s), a Remediation Assessment is a crucial step. **A standard method for remediating contaminated soil and groundwater is not available**, since soil and groundwater remediation depends on the site characteristics such as for example soil type, depth of groundwater, current and future site use, and type and extent of the contamination. Therefore, the Remediation Assessment described in these Guidelines is focused on remediating contaminated soil and groundwater, including the source area(s). The way a detailed design is made, depends on how the remediation project will be tendered. For this reason, Section 3, describing Remediation Management, discusses the different tendering methods of a site remediation project. Before starting with the Remediation Assessment, it is important to understand the applicable regulatory requirements of the contaminated site and the remediation to be performed. The responsible party or parties must identify all applicable and relevant laws and regulations prior to starting the remediation tasks. The responsible party or parties either are usually the current or past site owner or site operator, someone who organized the disposal of hazardous substances at the site; someone transporting the substances unless the facility legally received the materials., All responsibilities for the remediation should be clearly stated and reflected in the remediation contract(s) in situations with more than one responsible party.

A detailed design of a remediation project is necessary to have a successful project. To come to a detailed design a stepwise process has to be followed. Figure 2.2 illustrates the five different remediation design steps. The first four design steps are described in this Section 2, whereas the last step of the design of a remediation, the detailed design, is carried out in Phase 4, Remediation Management (Section 3).

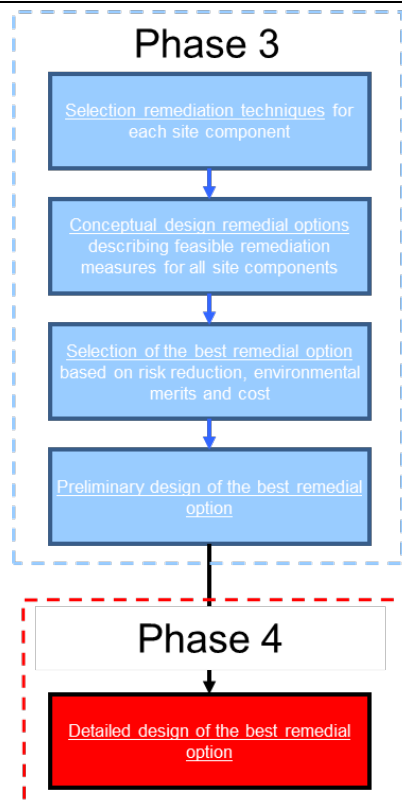


Figure 2.2 Remediation design steps (source: Tauw, 2015a)

2.2 Selection of Feasible Remediation Techniques

When selecting feasible remediation techniques, the options can be narrowed down by considering if they are going to reach the set objectives and required standards; and if they are sustainable, socially acceptable, commercially available at a given location and cost-effective. If the remedial targets have not been established, this must be done before the remedial options are being considered. If a natural, uncontaminated, background quality is not feasible, alternative approaches must be considered in order to keep the risks for human health, ecosystem and contaminant migration minimal. Some risk components and their management options are shown in Figure 2.3.

These Guidelines provide information on assessing the most suitable and sustainable remedial technique for each site component. A sustainable approach has to balance social, environmental and financial aspects, while taking into account scientific evidence and good governance. When comparing remediation options, environmental factors such as resource use, emissions and costs of the options have to be considered.

Techniques for destroying the pure POP pesticides are not described in these Guidelines. For potentially applicable POPs destruction, irreversible transformation and pre-treatment technologies, we refer to Appendix 2 of UNEP, 2011: *Selection of Persistent Organic Pollutant Disposal Technology for the Global Environment Facility*.

In this section, examples of possible short, mid, and long-term remediation techniques are presented for the site components described in previous sections and Part 1 of these Guidelines. These site components are

1. Storage of hazardous substances
2. Contaminated buildings and infrastructures
3. Buried hazardous waste
4. Contaminated soil and groundwater, including source area(s)
 - 4.1. Pure hazardous waste mixed with soil, the source area or hotspot
 - 4.2. Strongly contaminated soil and contaminated groundwater
 - 4.3. Moderately contaminated soil and contaminated groundwater
 - 4.4. Slightly contaminated soil and contaminated groundwater

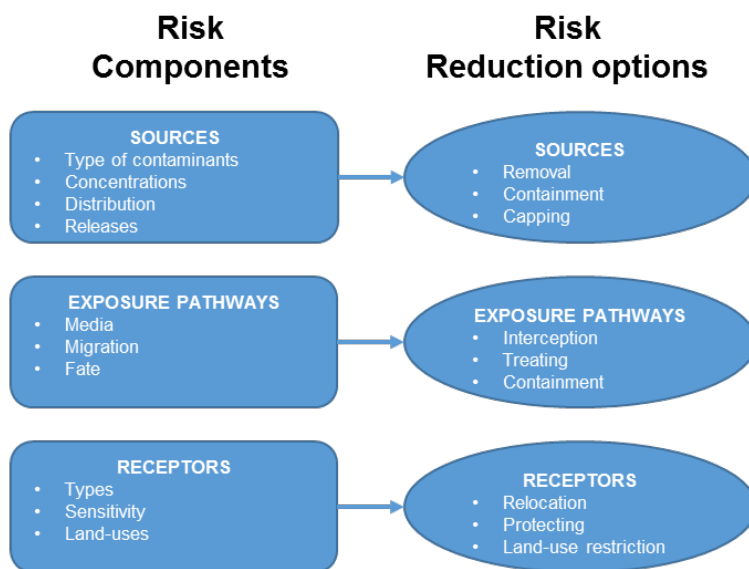


Figure 2.3 Risk components and their corresponding management options (Adapted from source: UNIDO, 2010)

2.2.1 Techniques for short-term remediation measures

If people are directly exposed (as receptors) to contaminants, the first objective of the short-term remediation measures is to minimize the exposure of the receptors to the contamination rather than to focus on the removal of the source. The short-term measures are divided therefore in:

- Emergency measures for minimizing exposure risks
- Other short-term measures for removing or treating the source area

Emergency measures for minimizing the exposure risks are:

- Raising awareness of the potential receptors, i.e. the affected groups
- Preventing physical contact of the receptors with the contaminants by:
 - Closing off storages of hazardous substances
 - Closing off the contaminated buildings and infrastructures
 - Forced ventilation of buildings
 - Fencing off the areas with remains of hazardous substances, for instance, buried or in a bunker
 - Fencing off or restricting the use of the areas with contaminated soil and groundwater

The other short-term measures for removing the known sources and / or preventing further (off-site) migration of contaminants are:

- When dealing with small quantities:
 - Removal, (re)packaging and destruction of hazardous substances in storage facility
 - Removal, (re)packaging and destruction of hazardous substances stored in a bunker
 - Excavation, (re)packaging and destruction of buried hazardous substances
 - Decontaminating and demolishing of contaminated structures like bunker / building and controlled landfilling of the decontaminated rubble
 - Excavation, packaging and destruction of the source area in the soil
- When dealing with large quantities of hazardous waste like mining waste or HCH waste:
 - Capping
 - Containment by pump and treat

The examples of short-term remediation measures for all four site components are given in Table 2.1.

Table 2.1 Selected short-term remediation measures for the four selected site components

Site components	Type of measure	Objective	Strategy	Measures
1. Hazardous substances in storage or bunker				
	Emergency	Minimize exposure risk for receptors	Awareness raising avoiding contact	<ul style="list-style-type: none"> • Inform stakeholders of the danger present • Closing off storage • Place warning signs • Limit accessibility by fencing • Restrict land-use
	Other short-term	Avoiding further exposure risk for receptors and off-site migration	Source removal	<ul style="list-style-type: none"> • Collect & (re)pack • Temporary storage awaiting final destruction • Transport and final destruction
2. Buried hazardous substances				
	Emergency	Minimize exposure risk for receptors	Awareness raising Avoiding contact	<ul style="list-style-type: none"> • Inform stakeholders of the danger present • Place warning signs • Temporary capping • Limit accessibility by fencing • Restrict land-use
	Other short-term	Avoiding further offsite migration	Source removal or containment	<ul style="list-style-type: none"> • Excavation • Packaging and temporary storage awaiting final destruction • Transport and final destruction • Permanent / temporary capping
3. Contaminated building				
	Emergency	Minimize exposure risk for receptors	Awareness raising Avoiding contact	<ul style="list-style-type: none"> • Inform stakeholders of the danger present • Place warning signs • Limit accessibility by closing of the building and / or by fencing
	Other short-term	Avoiding further offsite migration	Source removal	<ul style="list-style-type: none"> • Decontaminated building • Demolish building • Transport and control land filling of rubbles
4. Contaminated soil and groundwater				
4.1 Pure hazardous waste mixed with soil, the source area or hotspot	Emergency	Minimize exposure risk for receptors	Awareness raising Avoiding contact	<ul style="list-style-type: none"> • Inform stakeholders of the danger present • Placing warning signs • Limit accessibility by fencing • Restrict land-use • Restrict groundwater usage
	Other short-term	Avoiding further off-site migration	Source removal	<ul style="list-style-type: none"> • Excavation of source area • Packaging and temporary storage awaiting final destruction

Site components	Type of measure	Objective	Strategy	Measures
				<ul style="list-style-type: none"> • Transport and final destruction • Enforce limited accessibility by maintaining fencing • Restricting land-use • Enforce restricting groundwater usage

2.2.2 Techniques for mid-term remediation measures

The mid-term site remediation measures focus on further reducing the risks related to human and environmental exposure and contaminant migration related to soil and groundwater. The objective can be reached by the remediation and / or containment of the contaminants in soil and groundwater.

Soil and groundwater that contain contaminant concentrations above human health risk levels can be excavated (soil), pumped (groundwater) and transported for treatment. If concentrations are below human health risk levels but above the ecological risk levels, the contamination should be contained, remediated in-situ or treated on-site. For these areas, land-use restrictions will need to be imposed. Generally, phytoremediation, (phyto)-containment and land-use restrictions are the most cost effective risk reduction measures.

Mid-term remediation measures for minimizing exposure are:

- Raising awareness of the affected groups on a regular basis
- Preventing physical contact with the contaminants by:
 - Maintaining the fencing off of the contaminated site components
 - Enforcing restricted land use and restricted use of groundwater
 - Soil vapour extraction to prevent vapour intrusion

Mid-term measures for preventing further (off-site) migration are:

- Removal of the source zones by soil and groundwater remediation

Examples of mid-term remediation measures for the fourth site component, the contaminated soil and groundwater, are given in Table 2.2.

Table 2.2 Selected mid-term remediation measures for the fourth selected site component

Site components	Type of measure	Objective	Strategy	Measures
4. Contaminated soil and groundwater				
4.2 Strongly contaminated	Mid-term	Minimize exposure risks	Remediation	<ul style="list-style-type: none"> • Inform the stakeholders of the dangers present • Excavate transport to treatment facility and treat soil • Pump and treat groundwater
		Reduce migration risks	Avoiding contact	
		Reduce ecological risks	Awareness raising	
			Enforcement land-use restriction	
Monitoring and aftercare				
4.3 Moderately contaminated	Mid-term	Minimize exposure risks	Remediation	<ul style="list-style-type: none"> • Inform the stakeholders of the dangers present • In-situ or on-site soil remediation • Groundwater remediation • Periodic monitoring of soil quality
		Reduce migration risks	Avoiding contact	
		Reduce ecological risks	Awareness raising	
			Enforcement land-use restriction	
Monitoring and aftercare				

2.2.3 Techniques for long-term remediation measures

The long-term site remediation measures focus on the further reduction of the ecological risks. These objectives can be reached by applying long-term remediation techniques such as phytoremediation and / or containment of the contaminants in soil and groundwater.

The long-term remediation measures minimizing exposure risks are:

- Raising awareness of the affected groups on a regular basis
- Preventing physical contact with the contaminants by:
 - Maintaining the fencing off of the contaminated site components
 - Enforcing restricted land-use and restricted use of groundwater
- Removal of the source zones by:
 - Site-specific soil and groundwater remediation
 - Site-specific containment of contaminated soil and groundwater

Examples of long-term remediation measures for the fourth site component, the contaminated soil and groundwater, are given in Table 2.3.

Table 2.3 Selected long-term remediation measures for the four selected site components

Site components	Type of measure	Objective	Strategy	Measures
4. Contaminated soil and groundwater				
4.4 Slightly contaminated	Long-term	Reduce migration and ecological risks	Containment Awareness raising Avoiding contact Enforcement of land use restrictions Monitoring and aftercare	Maintain vegetation of phytoremediation Set up a barrier to prevent further migration of contaminants through groundwater Inform the stakeholders regularly on the danger of using the site Maintain placed warning signs Enforce limited accessibility by maintaining fencing Periodic monitoring of soil quality

2.3 Conceptual Design of Feasible Remedial Options

2.3.1 Approach

A Remedial Option consists of a set of applicable Remediation Techniques for the different site components for the short, mid and long-term. Remedial options are evaluated by conceptually designing a:

- Remedial option that removes all environmental risks by removal of the contaminant mass, the so-called maximum option
- Remedial option that contains all environmental risks, the so called minimum option

For each of the two options, the selected techniques for the different site components should be described including a brief review of the:

1. Risk reduction achieved by the remediation of the site components
2. Environmental merits of the remediation of the site components
3. Costs of the remediation of the site components

After these two extreme Remedial Options have been described, at least one (preferably more) realistic optimised remedial option should be described using elements of the two extremes.

2.3.2 Conceptual design

Tables 2.4, 2.5, and 2.6 give simple examples of the conceptual design of two extremes and one intermediate remedial option for a site with the fourth site components discussed earlier in these Guidelines:

1. Storage of hazardous substances
2. Contaminated buildings and infrastructures
3. Buried hazardous waste
4. Contaminated soil and groundwater, including source areas
 - 4.1. Pure hazardous waste mixed with soil, the source area or hotspot
 - 4.2. Strongly contaminated soil
 - 4.3. Moderately contaminated soil and contaminated groundwater
 - 4.4. Slightly contaminated soil

The conceptual designs presented in these Guidelines are qualitative in nature and only consider the headlines. In reality, the conceptual design of the options should have more details on:

1. The risk reduction achieved by the remediation
2. The environmental merits of the remediation
3. The remediation costs
4. The planning of the remediation
5. The technical feasibility of the remediation technique(s)
6. The risks of the remediation project, hereafter referred to as the remediation risk factor
7. The social impact of the remediation

These seven aspects are key aspects when selecting of the best remedial option.

The conceptual designs of the options should be uniform and provide a transparent overview of the advantages and disadvantages of each option. For this purpose, tables such as Table 2.4, 2.5, and 2.6 can be used. These tables elaborate on all seven aspects mentioned above facilitate the assessment and selection of the best option.

It should be noted that for the first three site components (storage of hazardous substances, contaminated buildings and infrastructures and buried hazardous waste), there are practically only two options available: complete destruction of contaminant mass or containment. Therefore, no intermediate options for these site components are given in Table 2.6. For the fourth site component, the contaminated soil and groundwater, the options to deal with are multiple and it is often necessary to distinguish between the level of contamination in assessing the advantages and disadvantages of each option. Tables 2.4, 2.5 and 2.6 give examples for contamination in the soil and the groundwater for the following levels of contamination:

1. Source area / hotspot
2. Strongly contaminated soil and groundwater
3. Moderately contaminated soil and groundwater
4. Slightly contaminated soil and groundwater

Table 2.4 Conceptual design of the maximum remedial option

Objective maximum	Strategy	1 Risk reduction	2 Environmental merits	3 Cost	4 Planning	5 Technical feasibility	6 Risk factor	7 Social impact
1. Storage of hazardous substances								
Minimize human exposure risks	Short-term emergency measures <ul style="list-style-type: none"> • Implementation restricted access to the site • Awareness raising 	Human exposure risks are contained	Very high <ul style="list-style-type: none"> • No energy consumption 	Low <ul style="list-style-type: none"> • Execution 	<ul style="list-style-type: none"> • Start ASAP • Maintain until other measures are applied 	Feasible <ul style="list-style-type: none"> • Enforcement of restricted excess stock 	Low <ul style="list-style-type: none"> • Easy to organize • Easy to enforce 	Limited <ul style="list-style-type: none"> • Restrictions on use of storage facility
Removal of all environmental risks by removal contaminant mass	Other short-term measures <ul style="list-style-type: none"> • Removal • Pack • Transport • Temporary storage • Destruction 	All environmental risks are removed	Low <ul style="list-style-type: none"> • High energy consumption • CO₂ emission for transport & destruction High <ul style="list-style-type: none"> • Destruction contaminant mass 	Very high <ul style="list-style-type: none"> • Destruction Low <ul style="list-style-type: none"> • No aftercare & monitoring 	<ul style="list-style-type: none"> • Start ASAP • Mostly a few days to a few weeks 	Feasible <ul style="list-style-type: none"> • Repack • Transport to temporary storage • Destruction 	High <ul style="list-style-type: none"> • Coordination different contractors • High H&S risks 	Limited <ul style="list-style-type: none"> • Possible during short period of removal Thorough <ul style="list-style-type: none"> • Risk is eliminated
2. Contaminated building								
Minimize human exposure risks	Short-term emergency measures <ul style="list-style-type: none"> • Restriction on use • Awareness raising 	Human exposure risks are contained	Very high <ul style="list-style-type: none"> • No energy consumption 	Low <ul style="list-style-type: none"> • Execution 	<ul style="list-style-type: none"> • Start ASAP • Maintain until other measures are applied 	Feasible <ul style="list-style-type: none"> • Enforcement of land-use restriction 	Low <ul style="list-style-type: none"> • Easy to organize • Easy to enforce 	Limited <ul style="list-style-type: none"> • Restrictions on use of building/ infrastructure

Objective maximum	Strategy	1 Risk reduction	2 Environmental merits	3 Cost	4 Planning	5 Technical feasibility	6 Risk factor	7 Social impact
Removal all environmental risks by removal of contaminant mass	Other short-term measures <ul style="list-style-type: none"> • Decontamination • Demolishing building • Land filling rubble 	All environmental risks are removed	Low <ul style="list-style-type: none"> • Energy consumption • CO₂ emission for transport to landfill 	Medium <ul style="list-style-type: none"> • Disposal of rubble Low <ul style="list-style-type: none"> • No aftercare & monitoring 	<ul style="list-style-type: none"> • Start direct after removal of stockpile • Few days to a few weeks 	Feasible <ul style="list-style-type: none"> • Decontamination • Demolition • Transport to landfill 	Low to medium <ul style="list-style-type: none"> • Coordination one contractor • Medium H&S risk 	Limited negative <ul style="list-style-type: none"> • Disturbances during decontamination and demolishing Thorough positive <ul style="list-style-type: none"> • Risk is eliminated
3. Buried hazardous substances								
Minimize human exposure risks	Short-term emergency measures <ul style="list-style-type: none"> • Restricted excess to pit • Awareness raising 	Human exposure risks are contained	Very high <ul style="list-style-type: none"> • No energy consumption 	Low <ul style="list-style-type: none"> • Execution 	<ul style="list-style-type: none"> • Start ASAP • Maintain until other measures are applied 	Feasible <ul style="list-style-type: none"> • Enforcement of restricted excess to pit 	Low <ul style="list-style-type: none"> • Easy to organize • Easy to enforce 	Limited negative <ul style="list-style-type: none"> • Disturbances due to restrictions on land-use
Removal all environmental risks by removal of contaminant mass	Other short-term measures <ul style="list-style-type: none"> • Excavate • Pack • Transport • Temporary storage • Destruction 	All environmental risks are removed	Low <ul style="list-style-type: none"> • Energy consumption • CO₂ emission for excavation, transport & destruction High <ul style="list-style-type: none"> • Destruction contaminant mass 	Very high <ul style="list-style-type: none"> • Destruction Low <ul style="list-style-type: none"> • No aftercare & monitoring 	<ul style="list-style-type: none"> • Start ASAP • Mostly a few days to a few weeks 	Complex <ul style="list-style-type: none"> • If groundwater level is high than bottom of pit Less complex <ul style="list-style-type: none"> • If groundwater is lower than the bottom of the pit 	High <ul style="list-style-type: none"> • Coordination different contractors • High H&S risks • Technical and financial risks high related to amount 	Limited negative <ul style="list-style-type: none"> • Disturbances during removal Thorough positive <ul style="list-style-type: none"> • Risk is eliminated

Objective maximum	Strategy	1 Risk reduction	2 Environmental merits	3 Cost	4 Planning	5 Technical feasibility	6 Risk factor	7 Social impact
4. Contaminated soil and groundwater								
4.1 Source area / Hotspot								
Minimize human exposure risks	Short-term emergency measures <ul style="list-style-type: none"> • Restricted excess to source area • Awareness raising 	Human exposure risks are contained	Very high <ul style="list-style-type: none"> • No energy consumption 	Low <ul style="list-style-type: none"> • Execution 	<ul style="list-style-type: none"> • Start ASAP • Maintain until other measures are applied 	Feasible <ul style="list-style-type: none"> • Enforcement of restricted excess source area 	Low <ul style="list-style-type: none"> • Easy to organize • Easy to enforce 	Limited negative <ul style="list-style-type: none"> • Restrictions on land-use
Removal all environmental risks by removal of contaminant mass	Other short-term measures: <ul style="list-style-type: none"> • Excavate • Load • Transport • Temporary storage • Destruction 	All environmental risks are removed	Low <ul style="list-style-type: none"> • Energy consumption • CO₂ emission for excavation, transport & destruction High <ul style="list-style-type: none"> • Destruction contaminant mass 	Very high <ul style="list-style-type: none"> • Destruction Low <ul style="list-style-type: none"> • No aftercare & monitoring 	<ul style="list-style-type: none"> • Start ASAP • Mostly a few days 	Feasible <ul style="list-style-type: none"> • Pack • Transport to temporary storage • Destruction 	High <ul style="list-style-type: none"> • Coordination different contractors • High H&S risks 	Limited negative <ul style="list-style-type: none"> • Disturbances during removal • Thorough positive • Risk is eliminated

Objective maximum	Strategy	1 Risk reduction	2 Environmental merits	3 Cost	4 Planning	5 Technical feasibility	6 Risk factor	7 Social impact
4.2 Strongly contaminated soil and groundwater								
Removal all environmental risks by removal of contaminant mass	Short-term measures soil <ul style="list-style-type: none"> • Excavate • Load • Transport • Off-site treatment 	All environmental risks are removed	Low <ul style="list-style-type: none"> • Energy consumption • CO₂ emission for excavation, transport & soil treatment High <ul style="list-style-type: none"> • Treatment contaminant mass 	Very high <ul style="list-style-type: none"> • Soil treatment Low <ul style="list-style-type: none"> • No aftercare & monitoring 	<ul style="list-style-type: none"> • Start after source area is removed • Few days 	Feasible <ul style="list-style-type: none"> • Excavation transport to temporary storage awaiting treatment 	High <ul style="list-style-type: none"> • Coordination different contractors • High H&S risks 	Limited negative <ul style="list-style-type: none"> • Disturbances during removal
Removal all environmental risks by removal of contaminant mass	Short-term measures groundwater <ul style="list-style-type: none"> • Install pump and treatment plat • Pump & treat 	All environmental risks are removed	Medium <ul style="list-style-type: none"> • Energy consumption • CO₂ emission for pump & treat • Consumption additives High <ul style="list-style-type: none"> • Treatment contaminant mass 	Very high <ul style="list-style-type: none"> • Treatment Medium <ul style="list-style-type: none"> • Monitoring 	<ul style="list-style-type: none"> • Start after source area is removed • Few months to years 	Feasible <ul style="list-style-type: none"> • Pump & treat 	Low <ul style="list-style-type: none"> • Coordination one contractor • H&S risks 	Limited negative <ul style="list-style-type: none"> • Disturbances during installation • Disturbance during operation

Objective maximum	Strategy	1 Risk reduction	2 Environmental merits	3 Cost	4 Planning	5 Technical feasibility	6 Risk factor	7 Social impact
4.3 Moderately contaminated soil and groundwater								
Removal all environmental risks by removal of contaminant mass	Mid-term measures soil <ul style="list-style-type: none"> • Removal • Load • Transport • Off-site soil treatment in bioremediation facility 	All environmental risks are removed	Moderate <ul style="list-style-type: none"> • Energy consumption • CO₂ emission only for excavation, transport • Area is occupied 	Medium <ul style="list-style-type: none"> • because of land occupation for long time Low <ul style="list-style-type: none"> • No aftercare & monitoring 	<ul style="list-style-type: none"> • Start after removal of strongly contaminated soil • Few weeks 	Feasible <ul style="list-style-type: none"> • Excavate • Transport to bioremediation facility • Bioremediation 	High <ul style="list-style-type: none"> • Coordination different contractors • H&S risks 	Limited negative <ul style="list-style-type: none"> • Disturbances during removal • Thorough positive • Risk is eliminated
Removal all environmental risks by removal of contaminant mass	Mid-term measures groundwater <ul style="list-style-type: none"> • Install pump and treatment plat • Pump & treat 	All environmental risks are contained and gradually removed	Medium <ul style="list-style-type: none"> • Energy consumption • CO₂ emission for pump & treat • Consumption additives 	Very high <ul style="list-style-type: none"> • Treatment Medium <ul style="list-style-type: none"> • Monitoring 	<ul style="list-style-type: none"> • Start after source area is removed • Year to few years 	Feasible <ul style="list-style-type: none"> • Pump & treat 	Low <ul style="list-style-type: none"> • Coordination one contractor • H&S risks 	Limited negative <ul style="list-style-type: none"> • Disturbances during installation • Disturbance during operation

Objective maximum	Strategy	1 Risk reduction	2 Environmental merits	3 Cost	4 Planning	5 Technical feasibility	6 Risk factor	7 Social impact
4.4 Slightly contaminated soil and groundwater								
Contain all environmental risks	Long-term measures soil <ul style="list-style-type: none"> • Phytoremediation • Land-use restriction 	All environmental risks are contained	Very high <ul style="list-style-type: none"> • No energy consumption • No CO₂ emission • CO₂ uptake Moderate <ul style="list-style-type: none"> • Area is occupied • Site-use restriction 	Low <ul style="list-style-type: none"> • Execution High • Aftercare & monitoring 	<ul style="list-style-type: none"> • Start after moderate contaminated soil removed • Few weeks • Aftercare & monitoring 	Feasible <ul style="list-style-type: none"> • Vegetation will reduce run-off • Vegetation reduce infiltration rate by evapotranspiration • Vegetation enhance bioavailability and biodegradation of contaminants • Enforcement land-use restriction 	Low to medium <ul style="list-style-type: none"> • Coordination risk only one contractor • H&S risks minimum • Enforcement land use restrictions a challenge 	Severe negative <ul style="list-style-type: none"> • Disturbance on the long-term • People may use the vegetation (crops and timber) grown on contaminated land Moderate positive <ul style="list-style-type: none"> • Risks are contained
Monitor environmental risks	Long-term measures groundwater <ul style="list-style-type: none"> • Natural attenuation 	All environmental risks are monitored	Very high <ul style="list-style-type: none"> • No energy consumption • No CO₂ emission Moderate <ul style="list-style-type: none"> • Groundwater use restriction 	Low <ul style="list-style-type: none"> • Execution High • Aftercare & monitoring 	<ul style="list-style-type: none"> • Start after moderate contaminated soil removed • Years aftercare & monitoring 	Feasible <ul style="list-style-type: none"> • Monitoring • Enforcement groundwater-use restriction 	Low to medium <ul style="list-style-type: none"> • Coordination risk only one contractor • H&S risks minimum • Enforcement groundwater-use restrictions is challenging 	Moderate positive <ul style="list-style-type: none"> • Risks are contained

Table 2.5 Conceptual design of the minimum remedial option

Objective minimum	Strategy	1 Risk reduction	2 Environmental merits	3 Cost	4 Planning	5 Technical feasibility	6 Risk factor	7 Social impact
1. Storage of hazardous substances								
Minimize all environmental risks by containment	Short, mid & long-term <ul style="list-style-type: none"> • Containment by repair bunker/ storage • Restriction on access & use • Aftercare & monitoring as long as hazardous substances are in stock 	All environmental risks contained	Very high <ul style="list-style-type: none"> • Low energy • No CO₂ emission Low <ul style="list-style-type: none"> • No hazardous substances destruction 	Low <ul style="list-style-type: none"> • Closure • Restriction on access & use High <ul style="list-style-type: none"> • Aftercare & Monitoring 	<ul style="list-style-type: none"> • Start ASAP • Installation few week • Aftercare & Monitoring indefinitely 	Feasible <ul style="list-style-type: none"> • Repairing bunker/ storage • Restriction of access 	Low <ul style="list-style-type: none"> • One contractor involved Medium <ul style="list-style-type: none"> • Enforcement restrictions on use 	Negative <ul style="list-style-type: none"> • Hazardous substances remain Limited negative <ul style="list-style-type: none"> • Restrictions on use storage facility Positive <ul style="list-style-type: none"> • No impact during execution
2. Contaminated building								
Minimize human exposure risks by containment	Short, mid & long-term <ul style="list-style-type: none"> • By closure of building restriction on access & use • Aftercare & monitoring as long as contaminated building is not decontaminated 	All exposure risks are contained	Very high <ul style="list-style-type: none"> • No energy consumption on transport • No CO₂ emission Low <ul style="list-style-type: none"> • No hazardous substances destruction 	Low <ul style="list-style-type: none"> • Closure • Restriction on access & use High <ul style="list-style-type: none"> • Aftercare & Monitoring 	<ul style="list-style-type: none"> • Start ASAP • Installation few week • Aftercare & Monitoring indefinitely 	Feasible <ul style="list-style-type: none"> • Closure of building • Restriction on access & use 	Low <ul style="list-style-type: none"> • One contractor involved Medium <ul style="list-style-type: none"> • Enforcement restrictions on use 	Negative <ul style="list-style-type: none"> • Hazardous substances remain Limited negative <ul style="list-style-type: none"> • Restrictions on use storage facility Positive <ul style="list-style-type: none"> • No impact during execution

Objective minimum	Strategy	1 Risk reduction	2 Environmental merits	3 Cost	4 Planning	5 Technical feasibility	6 Risk factor	7 Social impact
3. Buried hazardous waste								
Minimize all environmental risks by containment	Short, mid & long-term <ul style="list-style-type: none"> • Containment by capping the pit • Restriction on access by fencing • Land-use restriction • Monitoring & aftercare as long as hazardous substances are not removed 	All environmental risks are contained	Very high <ul style="list-style-type: none"> • No energy consumption on transport • No CO₂ emission Low <ul style="list-style-type: none"> • No hazardous substances destruction 	Low <ul style="list-style-type: none"> • Capping Low <ul style="list-style-type: none"> • Restriction on access High <ul style="list-style-type: none"> • Land-use restriction High <ul style="list-style-type: none"> • Aftercare & Monitoring 	<ul style="list-style-type: none"> • Start ASAP • Installation few days to few weeks • Aftercare & monitoring indefinitely 	Feasible <ul style="list-style-type: none"> • Capping • Restriction on access • Land-use restriction 	Low <ul style="list-style-type: none"> • One contractor involved Medium <ul style="list-style-type: none"> • Enforcement restrictions on land-use 	Negative <ul style="list-style-type: none"> • Hazardous substances remain Limited negative <ul style="list-style-type: none"> • Restrictions on land-use Positive <ul style="list-style-type: none"> • No impact during execution
4. Contaminated soil and groundwater								
4.1 Source area/ Hotspot								
Minimize all environmental risks by containment	Short, mid & long-term <ul style="list-style-type: none"> • Containment by capping hot spot • Restriction on access by fencing • Land-use restriction • Monitoring & aftercare as long as hazardous substances are not removed 	All environmental risks are contained	Very high <ul style="list-style-type: none"> • No energy consumption on transport • No CO₂ emission Low <ul style="list-style-type: none"> • No hazardous substances destruction 	Low <ul style="list-style-type: none"> • Capping Low <ul style="list-style-type: none"> • Restriction on access High <ul style="list-style-type: none"> • Land-use restriction High <ul style="list-style-type: none"> • Aftercare & Monitoring 	<ul style="list-style-type: none"> • Start ASAP • Installation few days to few weeks • Aftercare & monitoring indefinitely 	Feasible <ul style="list-style-type: none"> • Capping • Restriction on access • Land-use restriction 	Low <ul style="list-style-type: none"> • One contractor involved Medium <ul style="list-style-type: none"> • Enforcement restrictions on land-use 	Negative <ul style="list-style-type: none"> • Hazardous substances remain Limited negative <ul style="list-style-type: none"> • Restrictions on land-use Positive <ul style="list-style-type: none"> • No impact during execution

Objective minimum	Strategy	1 Risk reduction	2 Environmental merits	3 Cost	4 Planning	5 Technical feasibility	6 Risk factor	7 Social impact
4.2 Strongly contaminated soil and groundwater								
Minimize all environmental risks by containment	Short, mid & long-term soil <ul style="list-style-type: none"> • Containment by fencing • Erosion control • Phytoremediation • Restricted land-use • Monitoring & aftercare as long as contaminated soil is not remediated 	All environmental risks are contained	High <ul style="list-style-type: none"> • No energy consumption • No CO₂ emission • CO₂ uptake 	Low <ul style="list-style-type: none"> • Installation High • Land-use restriction • Aftercare & monitoring 	<ul style="list-style-type: none"> • Start ASAP • Planting will take few weeks • It will take months to years before vegetation cover and organic topsoil is established • Aftercare & monitoring indefinitely 	Feasible <ul style="list-style-type: none"> • Vegetation will reduce run-off • Vegetation reduce infiltration rate by evapotranspiration • Vegetation enhance bioavailability and biodegradation of contaminants • Enforcement land-use restriction 	Low <ul style="list-style-type: none"> • One contractor involved • H&S risks are minimum High <ul style="list-style-type: none"> • Enforcement of land use restrictions will be a challenge 	Severe negative <ul style="list-style-type: none"> • Permanent Restrictions on land-use • People may use the vegetation (crops and timber) grown on contaminated land Moderate positive <ul style="list-style-type: none"> • Risks are contained
Minimize all environmental risks by containment	Short, mid & long-term groundwater <ul style="list-style-type: none"> • Pump & treat preventing migration • Monitoring & aftercare as long as contaminated groundwater is not remediated 	All environmental risks are contained	Medium <ul style="list-style-type: none"> • Energy consumption • CO₂ emission for pump & treat • Consumption additives 	High <ul style="list-style-type: none"> • Treatment Medium • Monitoring 	<ul style="list-style-type: none"> • Start after source area is contained • Years 	Feasible <ul style="list-style-type: none"> • Pump & treat 	Low <ul style="list-style-type: none"> • Coordination one contractor • H&S risks • Enforcement groundwater-use restrictions is challenging 	Limited negative <ul style="list-style-type: none"> • Disturbances during installation

Objective minimum	Strategy	1 Risk reduction	2 Environmental merits	3 Cost	4 Planning	5 Technical feasibility	6 Risk factor	7 Social impact
4.3 Moderately contaminated soil and groundwater								
Minimize all environmental risks by containment	Short, mid & long-term soil <ul style="list-style-type: none"> • Containment by fencing • Restricted land-use • Phytoremediation • Aftercare & monitoring 	All environmental risks are contained	<ul style="list-style-type: none"> • Very high because no energy consumption and no CO₂ emission 	<ul style="list-style-type: none"> • Low execution • High for monitoring and aftercare 	<ul style="list-style-type: none"> • Start ASAP • Planting will take few weeks • It will take months to years before vegetation cover and organic topsoil is established. Monitoring maintenance forever 	Feasible <ul style="list-style-type: none"> • Vegetation will reduce run-off • Vegetation reduce infiltration rate by evapotranspiration • Vegetation enhance bioavailability and biodegradation of contaminants • Enforcement land-use restriction 	Low <ul style="list-style-type: none"> • One contractor involved • H&S risks are minimum High <ul style="list-style-type: none"> • Enforcement of land use restrictions will be a challenge 	Severe negative <ul style="list-style-type: none"> • Permanent Restrictions on land-use • People may use the vegetation (crops and timber) grown on contaminated land Moderate positive <ul style="list-style-type: none"> • Risks are contained
Long-term measures groundwater Natural attenuation	<ul style="list-style-type: none"> • All environmental risks are monitored 	Very high <ul style="list-style-type: none"> • No energy consumption • No CO₂ emission Moderate Groundwater use restriction	Low <ul style="list-style-type: none"> • Execution High • Aftercare & monitoring 	<ul style="list-style-type: none"> • Start after moderate contaminated soil removed • Years • Aftercare & monitoring 	Feasible <ul style="list-style-type: none"> • Monitoring • Enforcement groundwater-use restriction 	Low to medium <ul style="list-style-type: none"> • Coordination risk only one contractor • H&S risks minimum • Enforcement groundwater-use restrictions is challenging 	Moderate positive <ul style="list-style-type: none"> • Risks are contained 	Long-term measures groundwater <ul style="list-style-type: none"> • Natural attenuation

Objective minimum	Strategy	1 Risk reduction	2 Environmental merits	3 Cost	4 Planning	5 Technical feasibility	6 Risk factor	7 Social impact
4.4 Slightly contaminated soil and groundwater								
Minimize all environmental risks by containment	Short, mid & long-term <ul style="list-style-type: none"> • Containment by fencing • Restricted land-us • Phytoremediation • Aftercare & monitoring 	All environmental risks are contained	Very high <ul style="list-style-type: none"> • Low energy consumption • No CO₂ emission 	Low <ul style="list-style-type: none"> • For execution High • Aftercare & monitoring 	<ul style="list-style-type: none"> • Start ASAP • Planting will take few weeks. • It will take months to years before vegetation cover and organic topsoil is established. Monitoring maintenance forever 	Feasible <ul style="list-style-type: none"> • Vegetation will reduce run-off • Vegetation reduce infiltration rate by evapotranspiration • Vegetation enhance bioavailability and biodegradation of contaminants • Enforcement land-use restriction 	Low <ul style="list-style-type: none"> • One contractor involved • H&S risks are minimum High <ul style="list-style-type: none"> • Enforcement of land use restrictions will be a challenge 	Severe negative <ul style="list-style-type: none"> • Permanent Restrictions on land-use • People may use the vegetation (crops and timber) grown on contaminated land Moderate positive <ul style="list-style-type: none"> • Risks are contained
Long-term measures groundwater Natural attenuation	All environmental risks are monitored	Very high <ul style="list-style-type: none"> • No energy consumption • No CO₂ emission Moderate <ul style="list-style-type: none"> • Groundwater use restriction 	Low <ul style="list-style-type: none"> • Execution High Aftercare & monitoring	<ul style="list-style-type: none"> • Start after moderate contaminated soil removed • Years Aftercare & monitoring 	Feasible <ul style="list-style-type: none"> • Monitoring • Enforcement groundwater-use restriction 	Low to medium <ul style="list-style-type: none"> • Coordination risk only one contractor • H&S risks minimum Enforcement groundwater-use restrictions is challenging	Moderate positive <ul style="list-style-type: none"> • Risks are contained 	Long-term measures groundwater Natural attenuation

Table 2.6 Conceptual design of the intermediate remedial option

Objective intermediate	Strategy	1 Risk reduction	2 Environmental merits	3 Cost	4 Planning	5 Technical feasibility	6 Risk factor	7 Social impact
1. Storage of hazardous substances								
Removal of all environmental risks by removal contaminant mass	Other short-term measures <ul style="list-style-type: none"> • Removal • Pack • Transport • Temporary storage • Destruction 	All environmental risks are removed	Low <ul style="list-style-type: none"> • High energy consumption • CO₂ emission for transport & destruction High <ul style="list-style-type: none"> • Destruction contaminant mass 	Very high <ul style="list-style-type: none"> • Destruction Low <ul style="list-style-type: none"> • No aftercare & monitoring 	<ul style="list-style-type: none"> • Start ASAP • Mostly a few days to a few weeks 	Feasible <ul style="list-style-type: none"> • Repack • Transport to temporary storage • Destruction 	High <ul style="list-style-type: none"> • Coordination different contractors • High H&S risks 	Limited <ul style="list-style-type: none"> • Possible during short period of removal • Thorough • Risk is eliminated
2. Contaminated building								
Minimize human exposure risks by containment	Short, mid & long-term <ul style="list-style-type: none"> • By closure of building restriction on access & use • Aftercare & monitoring as long as contaminated building is not decontaminated 	All exposure risks are contained	Very high <ul style="list-style-type: none"> • No energy consumption on transport • No CO₂ emission Low <ul style="list-style-type: none"> • No hazardous substances destruction 	Low <ul style="list-style-type: none"> • Closure • Restriction on access & use High <ul style="list-style-type: none"> • Aftercare & Monitoring 	<ul style="list-style-type: none"> • Start ASAP • Installation few week • Aftercare & Monitoring indefinitely 	Feasible <ul style="list-style-type: none"> • Closure of building • Restriction on access & use 	Low <ul style="list-style-type: none"> • One contractor involved Medium <ul style="list-style-type: none"> • Enforcement restrictions on use 	Negative <ul style="list-style-type: none"> • Hazardous substances remain • Limited negative • Restrictions on use storage facility Positive <ul style="list-style-type: none"> • No impact during execution

Objective intermediate	Strategy	1 Risk reduction	2 Environmental merits	3 Cost	4 Planning	5 Technical feasibility	6 Risk factor	7 Social impact
3. Buried hazardous waste								
Removal all environmental risks by removal of contaminant mass	Other short-term measures <ul style="list-style-type: none"> • Removal • Pack • Transport • Temporary storage • Destruction 	All environmental risks are removed	Low <ul style="list-style-type: none"> • Energy consumption • CO₂ emission for excavation, transport & destruction High <ul style="list-style-type: none"> • Destruction contaminant mass 	Very high <ul style="list-style-type: none"> • Destruction Low <ul style="list-style-type: none"> • No aftercare & monitoring 	<ul style="list-style-type: none"> • Start ASAP • Mostly a few days to a few weeks 	Complex <ul style="list-style-type: none"> • If groundwater level is high than bottom of pit Less complex <ul style="list-style-type: none"> • If groundwater is lower than the bottom of the pit 	High <ul style="list-style-type: none"> • Coordination different contractors 	Limited negative <ul style="list-style-type: none"> • Disturbances during removal Thorough positive <ul style="list-style-type: none"> • Risk is eliminated
4. Contaminated soil and groundwater								
4.1 Source area / Hot spot								
Removal all environmental risks by removal of contaminant mass	Other short-term measures: <ul style="list-style-type: none"> • Removal • Pack • Transport • Temporary storage • Destruction 	All environmental risks are removed	Low <ul style="list-style-type: none"> • Energy consumption • CO₂ emission for excavation, transport & destruction High <ul style="list-style-type: none"> • Destruction contaminant mass 	Very high <ul style="list-style-type: none"> • Destruction Low <ul style="list-style-type: none"> • No aftercare & monitoring 	<ul style="list-style-type: none"> • Start ASAP • Mostly a few days 	Feasible <ul style="list-style-type: none"> • Repack • Transport to temporary storage • Destruction 	High <ul style="list-style-type: none"> • Coordination different contractors • High H&S risks 	Limited negative <ul style="list-style-type: none"> • Disturbances during removal Thorough positive <ul style="list-style-type: none"> • Risk is eliminated

Objective intermediate	Strategy	1 Risk reduction	2 Environmental merits	3 Cost	4 Planning	5 Technical feasibility	6 Risk factor	7 Social impact
4.2 Strongly contaminated soil and groundwater								
Removal all environmental risks by removal of contaminant mass	Mid-term measures soil <ul style="list-style-type: none"> • Removal • Load • Transport • Off-site soil treatment 	All environmental risks are removed	Low <ul style="list-style-type: none"> • Energy consumption • CO₂ emission for excavation, transport & soil treatment 	Very high <ul style="list-style-type: none"> • Soil treatment Low <ul style="list-style-type: none"> • No aftercare & monitoring 	<ul style="list-style-type: none"> • Start after source area is removed • Few days 	Feasible <ul style="list-style-type: none"> • Excavation transport to temporary storage awaiting treatment 	High <ul style="list-style-type: none"> • Coordination different contractors • High H&S risks 	Limited negative <ul style="list-style-type: none"> • Disturbances during removal
Removal all environmental risks by removal of contaminant mass	Short-term measures groundwater <ul style="list-style-type: none"> • Install pump and treatment plat • Pump & treat 	All environmental risks are removed	Medium <ul style="list-style-type: none"> • Energy consumption • CO₂ emission for pump & treat • Consumption additives High <ul style="list-style-type: none"> • Treatment contaminant mass 	Very high <ul style="list-style-type: none"> • Treatment Medium <ul style="list-style-type: none"> • Monitoring 	<ul style="list-style-type: none"> • Start after source area is removed • Few months to year 	Feasible <ul style="list-style-type: none"> • Pump & treat 	Low <ul style="list-style-type: none"> • Coordination one contractor • H&S risks 	Limited negative <ul style="list-style-type: none"> • Disturbances during installation • Disturbance during operation

Objective intermediate	Strategy	1 Risk reduction	2 Environmental merits	3 Cost	4 Planning	5 Technical feasibility	6 Risk factor	7 Social impact
4.3 Moderately contaminated soil and groundwater								
Minimize all environmental risks by containment	Short, mid & long-term soil <ul style="list-style-type: none"> • Containment by fencing • Restricted land-us • Phytoremediation • Aftercare & monitoring 	All environmental risks are contained	<ul style="list-style-type: none"> • Very high because no energy consumption and no CO₂ emission 	<ul style="list-style-type: none"> • Low execution • High for monitoring and aftercare 	<ul style="list-style-type: none"> • Start ASAP • Planting will take few weeks • It will take months to years before vegetation cover and organic topsoil is established. Monitoring maintenance forever 	Feasible <ul style="list-style-type: none"> • Vegetation will reduce run-off • Vegetation reduce infiltration rate by evapo-transpiration • Vegetation enhance bioavailability and biodegradation of contaminants • Enforcement land-use restriction 	Low <ul style="list-style-type: none"> • One contractor involved • H&S risks are minimum High <ul style="list-style-type: none"> • Enforcement of land use restrictions will be a challenge 	Severe negative <ul style="list-style-type: none"> • Permanent Restrictions on land-use • People may use the vegetation (crops and timber) grown on contaminated land Moderate positive <ul style="list-style-type: none"> • Risks are contained
Removal all environmental risks by removal of contaminant mass	Mid-term measures groundwater <ul style="list-style-type: none"> • Install pump and treatment plat • Pump & treat 	All environmental risks are contained and gradually removed	Medium <ul style="list-style-type: none"> • Energy consumption • CO₂ emission for pump & treat • Consumption additives 	Very high <ul style="list-style-type: none"> • Treatment Medium <ul style="list-style-type: none"> • Monitoring 	<ul style="list-style-type: none"> • Start after source area is removed • Year to few years 	Feasible <ul style="list-style-type: none"> • Pump & treat 	Low <ul style="list-style-type: none"> • Coordination one contractor H&S risks	Limited negative <ul style="list-style-type: none"> • Disturbances during installation • Disturbance during operation

Objective intermediate	Strategy	1 Risk reduction	2 Environmental merits	3 Cost	4 Planning	5 Technical feasibility	6 Risk factor	7 Social impact
4.4 Slightly contaminated soil and groundwater								
Contain all environmental risks	Long-term measures for soil <ul style="list-style-type: none"> • Containment • Phytoremediation • Land-use restriction 	All environmental risks are contained	Very high <ul style="list-style-type: none"> • No energy consumption • No CO₂ emission • CO₂ uptake Moderate <ul style="list-style-type: none"> • Area is occupied 	Low <ul style="list-style-type: none"> • Execution High <ul style="list-style-type: none"> • Aftercare & monitoring 	<ul style="list-style-type: none"> • Start after moderate contaminated soil removed • Few weeks • Aftercare & monitoring indefinitely 	Feasible <ul style="list-style-type: none"> • Vegetation will reduce run-off • Vegetation reduce infiltration rate by evapotranspiration • Vegetation enhance bioavailability and biodegradation of contaminants • Enforcement land-use restriction 	Low to medium <ul style="list-style-type: none"> • Coordination risk only one contractor • H&S risks minimum • Enforcement land use restrictions a challenge 	Severe negative <ul style="list-style-type: none"> • Permanent Restrictions on land-use • People may use the vegetation (crops and timber) grown on contaminated land Moderate positive <ul style="list-style-type: none"> • Risks are contained
Long-term measures groundwater Natural attenuation	All environmental risks are monitored	Very high <ul style="list-style-type: none"> • No energy consumption • No CO₂ emission Moderate <ul style="list-style-type: none"> • Groundwater use restriction 	Low <ul style="list-style-type: none"> • Execution High <ul style="list-style-type: none"> • Aftercare & monitoring 	<ul style="list-style-type: none"> • Start after moderate contaminated soil removed • Years • Aftercare & monitoring 	Feasible <ul style="list-style-type: none"> • Monitoring • Enforcement groundwater-use restriction 	Low to medium <ul style="list-style-type: none"> • Coordination risk only one contractor • H&S risks minimum • Enforcement groundwater-use restrictions is challenging 	Moderate positive <ul style="list-style-type: none"> • Risks are contained 	Long-term measures groundwater Natural attenuation

2.4 Selection of the Best Remedial Option

Based on the conceptual design of the feasible remedial options described in the previous section, a stepwise process has to be followed for selecting the best remedial option. Figure 2.4 visualizes this stepwise process. The aim of this process is to select the best remedial option from the conceptual designed options, by implementing the best available techniques, using environmentally sustainable methods, while not entailing excessive costs. The comparison of the options and selection of the best option can be carried out by using a simple evaluation tool called Multi-Criteria Decision Analysis (MCDA).

The criteria considered in the MCDA process are the seven key aspects mentioned in the previous section, which are:

1. The risk reduction achieved by the remediation
2. The environmental merits of the remediation
3. The remediation costs
4. The planning of the remediation
5. The technical feasibility of the remediation technique(s)
6. The remediation risk factor
7. The social impact of the remediation

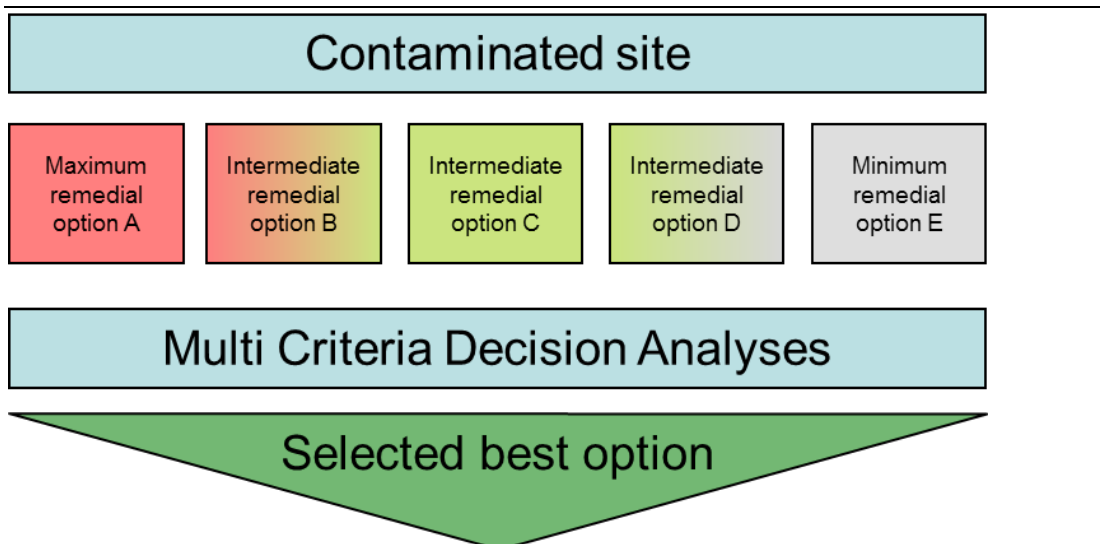


Figure 2.4 The process of selecting the best remedial option (source: Tauw, 2015a)

2.4.1 Multi Criteria Decision Analysis (MCDA)

This section gives a short review on how the above-mentioned seven aspects should be used for selecting the best remedial option from the remedial options conceptually designed in the previous section.

1. Risk reduction achieved by the remediation

The ultimate goal of the remediation is to have no restrictions on land-use. However, due to different practical challenges (for example budget, technical limitations, site-specific characteristics), it is may not be pragmatic to achieve this goal. As long as direct risks remain on the site, it is a strong negative deviation from the ultimate goal of the remediation. As such, the best remedial option regarding this aspect is the one that achieves the greatest reduction in environmental risks.

2. Environmental merits of the remediation

Environmental merits are the potential environment effects (both positive and negative) of a remediation option. Generally, a remediation option can:

1. Reduce or eliminate the magnitude of the contamination and / or prevent the spreading of contamination
2. Increase the stock of clean natural resources (for example soil and water)

However, remediation action also uses resources (for example energy, water and space), and may involve actions which may result in the transfer of contamination into other media (for example air and water emissions). Altogether, these aspects (both costs and benefits) determine the final environment merits of a remediation option. The environmental merits should be rated in both local (impacts on soil, groundwater and air quality; construction materials needed) and global scale (quantity of hazardous substances destructed).

3. Remediation cost

The costs of a remedial option consist of the costs of implementation (preparation and operation) and the cost for the monitoring and aftercare (maintenance). Low costs indicate that the operation is very efficient in achieving a given risk reduction. The more intense and complex the monitoring and aftercare requirements are, generally, the less sustainable will be the solution given on going funding demands. Therefore, the costs for monitoring and aftercare should be kept to an absolute minimum.

4. Planning of the remediation

The score for planning is based on the time needed to complete the remediation and the time needed for monitoring and aftercare.

5. Technical feasibility

Regarding the technical feasibility, techniques that can be executed in the Republic of Macedonia are considered more feasible. This implies that technologies needing import of specialized equipment and on-site technical foreign support for prolonged periods are not deemed technically feasible. Besides the availability of the technology and required skills in the Republic of Macedonia, the various techniques are also scored for the robustness.

6. Remediation risk factor

The remediation risk factor is assessed based on the number of contractor parties involved in the implementation, the proposed techniques, the project management risks, failures either in time, and / or money, sustainability or from an H&S perspective, and the dependence on climate conditions.

7. Social impact of the remediation

The social impact of a remediation option is assessed based on; (1) the potential for fostering national capacity / infrastructure related to hazardous waste and soil remediation; (2) the potential for short and long-term job creations from the deployment of the option; (3) the potential for improvement of the livelihood of those using the site; and (4) the risk that the solution proposed is not accepted by local population and / or other stakeholders.

2.4.2 Example of a Multi Criteria Decision Analysis

The proposed scoring to use for the MCDA consist of the following five levels:

1. One point to the criteria that are **not in compliance** with the objectives
2. Two points to the criteria that are **partly in compliance** with the objectives
3. Three points to the criteria that are **almost in compliance** with the objectives
4. Four points to the criteria that are **in compliance** with the objectives
5. Five points to the criteria that are **in compliance with the objectives and have additional benefits**

, The best remediation option is the one that gets the highest score after using this scoring methodology. An example of the options with the best score (5) is given in Table 2.7.

Table 2.7 Remediation options that get the highest points in the MCDA due to being in compliance with the objectives and having additional benefits

MCDA criteria	Remediation option with five points in the MCDA
1. Risk reduction	There are no remaining environmental risks Allows all desirable site and surrounding land-use
2. Environmental merits	Mitigates all risks with the least environmental impact Destroys the most hazardous substances molecules Consumes the least energy Emits the smallest amount of residues in air (CO ₂ , Green House Gasses) in water and soil
3. Cost	Has the lowest cost to implement Has the lowest cost to operate Has the lowest cost for monitoring and aftercare
4. Planning	Remediation completed within the shortest time No monitoring and aftercare needed
5. Technical feasibility	The proposed remediation techniques are feasible The chosen techniques do not need input from foreign specialized companies The chosen techniques are easy to duplicate
6. Risk factor	Has a minimum of project risks
7. Social impact	Improves capacity / infrastructure related to hazardous waste and soil remediation Has the best short, mid and long-term job creation possibilities Have the highest possibilities to be accepted by local community

2.5 Preliminary design preferred remedial option

When the best remedial option has been chosen based on the Multi Criteria Decision Analysis as described in the previous section, the selected option should be preliminary designed. This section elaborates on the additional technical survey, the preliminary design, the supervision and the design of a health and safety (H&S) plan.

2.5.1 Additional technical survey

Before specifying the detailed design of the remediation option, it should be determined whether there are any design parameters that may affect the costs, the planning, or the targeted objectives. At this stage, it is often decided to carry out additional technical surveys including pilot and / or laboratory tests for determining if the proposed remediation technique is effective and applicable under the given site conditions. The survey and evaluation reports of the pilot / laboratory tests should be attached to the Remediation Plan. The results are then used to adapt and fine-tune the preliminary design of the selected option. If necessary, the CSM should be updated and reported in the Remediation Plan.

2.5.2 Preliminary design

Depending on the site components, one or more of the below mentioned plans containing the preliminary remediation design should be part of the overall Remediation Plan. These plans give the technical description of the remedial activities for the different site components. The plans are:

1. Storage of hazardous substances

- **Hazardous substance (small quantities) collection and destruction plan** starting with an introduction, stating the precondition for the collection, packaging, temporary storage and the final destruction of the hazardous waste.

It should be clear if enough funds are available for destruction of the hazardous substances or that a temporary storage awaiting final destruction is needed because of lack of funds. After the introduction, technical details such as a summary of the inventory (results of Phase 2 Site Assessment), the site conditions and the accessibility of the site are elaborated. Based on the inventory data, the type and amounts of the needed packaging materials are listed including equipment needed to carry out the activities. Separate section of the plan is devoted to the H&S aspects. The plan has also a separate section with a conservative cost estimate. Reference is made to the Environmental Management Toolkit (EMTK) of the FAO (2009) to prepare such packaging plan for obsolete pesticides stocks

- **Hazardous substance (large quantities) containment plan** starting with an introduction, stating that the site-specific situation is as such that in-situ or off-site containment is, because of the large quantities, the only feasible option. Precondition for the containment of the hazardous waste are also given in the introduction. After the introduction, technical details such as a summary of the detailed site assessment (results of Phase 2, Site Assessment), the site conditions and the accessibility of the site are elaborated. Based on the inventory data, the extent and type of containment (pre-treatment, top cover and / or bottom liner) is described. A separate section of the plan is devoted to the H&S aspects, monitoring and aftercare. The plan has also a separate section with a conservative cost estimate

2. Contaminated building

- **Decontamination plan** starting with an introduction, stating the precondition for the decontamination of the building (storage building or bunker). It should be clear if the building has to be maintained or has to be demolished, how the building could be cleaned or decontaminated from hazardous substances. After the introduction, details such as technical condition and the contaminated status of the building are summarized (results of Phase 2, Site Assessment). Based on the assessment data the needed type of decontamination equipment is listed. Separate sections of the plan are devoted to the H&S aspects and to a conservative cost estimate

- **Demolition plan** is needed when the building is demolished. This plan starts also with an introduction, stating the expected degree of decontamination. It should be clear if there are still hazardous substance present such as asbestos, (asbestos inventory should be available) and contaminated foundations of the building. The plan also provides information on the necessary pre-treatment of rubble before disposal at a sanitary landfill. Based on the assessment data the needed type of demolition equipment is listed. Separate sections of the plan are devoted to the H&S aspects and to a conservative cost estimate
3. **Buried hazardous waste**
- **Excavation plan** starting with an introduction, stating the precondition for the excavation of buried hazardous substances. It should be clear if enough funds are available to destruct the buried hazardous waste or that a temporary storage, awaiting final destruction, is needed due to a lack of funds. After the introduction, technical details such as the types, amounts and conditions of the buried hazardous substances (results of Phase 2 Site Assessment) are given. The conditions of the pit and the accessibility of the pit are also elaborated. Based on the inventory data, the type and amounts of the needed packaging materials are listed, including equipment needed to excavate and pack the removed hazardous substances. Separate sections of the plan are devoted to the H&S aspects and to a conservative cost estimate
4. **Contaminated soil and groundwater**
- **Soil and groundwater remediation plan** starting with an introduction, stating the precondition for the soil and groundwater remediation such as soil and groundwater target values. After the introduction, the soil and groundwater survey results are summarised (results of Phase 2 Site Assessment). The preliminary design including objectives with respect to risk reduction and the legal issues are described in a separate section. Other sections of the plan are devoted to the H&S aspects, the monitoring and supervision of the remediation. This plan includes also a section on the monitoring and aftercare after the short-term remediation measures are executed and the mid and long-term remediation measures are installed. This remediation plan also includes a conservative cost estimate for the selected option with the cost for the short-term remediation measures, the mid and long-term remediation measures and the aftercare and monitoring

The preliminary design of the selected, preferred remedial option should have a cost estimate. This cost estimate is used for the financial planning. SOP 8.1.2 gives a high-level checklist for a preliminary design and a cost estimate for the preferred remedial option.

2.5.3 Preliminary design supervision

Environmental supervision should examine the services provided by the contractor in order to ensure that the remedial measures are implemented according to the Remediation Plan, in the best possible manner. The Remediation Plan should present the preliminary design for the supervision, with at least the preconditions of the supervision including the environmental monitoring of the remediation, the responsible parties and the supervision and monitoring tasks. The preliminary design of supervision will be used for the detailed design later on.

The supervision tasks for the earlier mentioned site components are:

1. Packaging of hazardous substances

- Maintaining a daily log
- Recording the amount, type and condition of the hazardous substances
- Recording deviation from the hazardous substance collection plan / containment plan
- Checking the correct labelling of the packed hazardous substances / recording the top cover and bottom liner materials and construction (construction containment measures)
- Recording the amounts and types of waste conveyed off-site
- Monitoring safe and environmentally sound behaviour

2. Decontamination of contaminated building

- Maintaining a daily log
- Recording the amount, type and condition of the hazardous substances and demolition waste
- Recording deviation from the decontamination and demolition plan
- Recording the amounts and types of waste conveyed off-site
- Monitoring safe and environmentally sound behaviour

3. Excavation of buried hazardous substances

- Maintaining a daily log
- Recording the amount, type and condition of the excavated hazardous substances
- Checking the correct labelling of the packed excavated hazardous substances
- Recording the amounts and types of waste conveyed off-site
- Sampling the soil of the sides and bottom of the cleared pit
- Monitoring safe and environmentally sound behaviour

4. Soil and groundwater remediation

- Maintaining a daily log
- Recording the amount, type and condition of the remediated soil
- Recording the amount and quality of the pumped and treated groundwater
- Sampling the soil of the sides and bottom in case of the excavation
- Monitoring safe and environmentally sound behaviour
- Monitoring the remediation progress

2.5.4 Design of a Health and Safety (H&S) Plan

Already in this phase but at least prior to the start of a remediation work, a Health and Safety (H&S) plan should be prepared in order to guarantee implementing personal H&S rules in an early stage of the project and to ensure a safe, healthy and environmentally sound remediation. Based on the type of contamination and the type work to be carried out, H&S procedures can be more lenient or strict. The H&S plan should be developed by a trained H&S professional with experience in managing the health risks associated with the specific hazardous substances at the site. The H&S plan should appoint adequate supervision to ensure that all safety measures are applied correctly and adequately. The H&S plan should address at least:

1. The project H&S regulations
2. The H&S site specific regulations
3. The required H&S equipment
4. The Personal Protective Equipment (PPE)
5. The communication tools to advocate safe and healthy performance
6. The project site zoning

Each of these six aspects is further elaborated below.

1. The project H&S regulations

The principle of the implementation of H&S procedures is that everybody involved should be aware of the health risks when being exposed to hazardous substances. The best method to implement safe behaviour is to raise the awareness. For guaranteeing safe behaviour, all site workers should be aware that they share the responsibility of the safe behaviour of themselves and everybody involved. If someone sees an unsafe act or an unsafe situation, he / she has the obligation to warn the others. There should always be one person in the field responsible for the safety. This safety person is familiar with the safety procedures and always instructs visitors upfront entering the contaminated site.

Figure 2.5 presents a conclusive image of an H&S information package. It is advised to use clear infographic in the H&S training of the project staff. These trainings should be held at regular intervals, starting upfront of the start of the work and repeated during for instance the toolbox meetings (see below) and or other project meetings. SOP 2.4.1 presents an example of such an H&S training package.

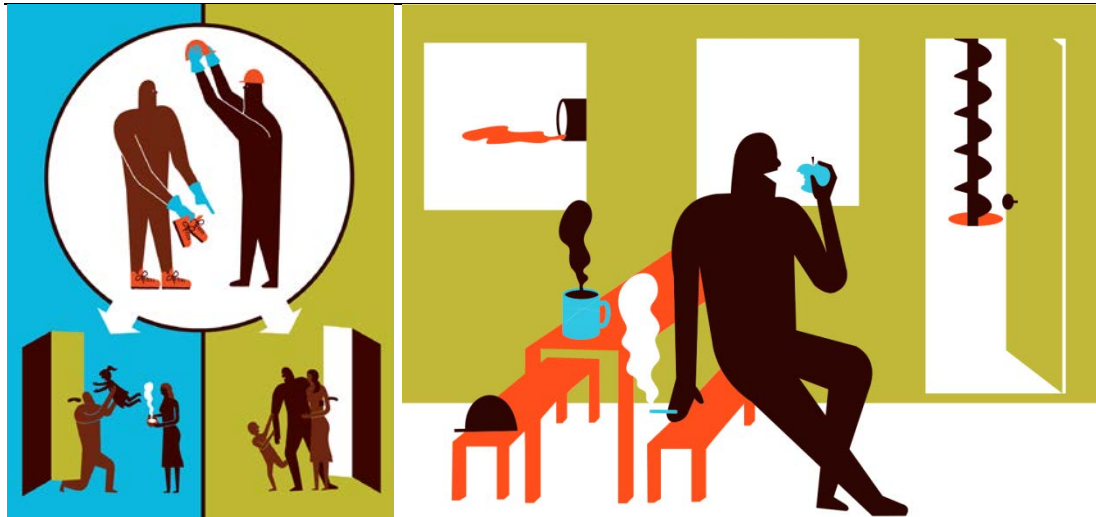


Figure 2.5 All site workers should share the responsibility of safe behavior of everyone (source: Tauw safety infographics)

2. The H&S site specific regulations

If the remediation site is on a site of for instance a commercial or industrial property, the site-specific rules such as site entry procedure and H&S rules should be respected. These site specific rules have to be known in this phase of the project to be able to anticipate in the project planning, the involved extra cost and the site entrance rules and restriction.

3. The required H&S equipment

The required H&S equipment is strongly dependent on the working environment and the tasks. The Remediation Plan should give a list of the H&S equipment to be used during the remediation. SOP 8.1.3 presents an example of such list to be added to the Remediation Plan. The final list will be based on the detailed design in the next Phase, the Site Remediation Management.

4. The required PPE

The required Personal Protective Equipment (PPE) is strongly dependent on the working environment, the tasks and climate conditions. The Remediation Plan should give a list of the PPE to be used during the different stages of remediation and at the different places (see the **6. project site zoning**). SOP 8.1.3 presents an example of such a PPE list to be added to the Remediation Plan. The final PPE list will be based on the detailed design in the next Phase, the Site Remediation Management.

5. The communication tools to advocate safe and healthy performance

The tools to advocate safe and healthy performance during the entire project execution are:

- The daily Start Work Analysis
- The toolbox meetings at regular intervals
- Other periodic project meetings

Start Work Analysis is a short meeting for the team working in the field, organized on a daily bases before the work starts. The objectives of a Start Work Analysis are to inform:

- The team of all the activities planned for this working day
- The individual team members of what is expected from him / her today
- The individual team members about the safety issues, such as the PPE to be used and the on-site main traffic movements

Start Work Analysis are held with the team working that day at the site and are only used to inform the field staff in how things have to be done in a safe and environmentally sound manner. The daily Start Work Analysis is also used to verify if the individual team members understand what they have to do; what the colleagues are doing; and how to work safe.

Start Work Analysis are held in small working groups and are chaired by the supervisor of the group. The meetings are short, about 15-30 minutes, and informal. The Start Work Analysis provides a direct method of communication and exchange of information between field staff and supervision with the purpose of improving safety and health by directly involving workers in issues that are important to them.

Toolbox meetings are short meetings for the team working in the field, organized periodically (weekly). The objectives of a toolbox meeting are to enhance:

- Team building and enhance commitment
- Safety involvement and awareness at grass-roots level
- Rising people's awareness of their responsibility for working safely, e.g. housekeeping, wearing PPE, following the rules and procedures et cetera
- Finding solutions to problems
- Commitment on productivity
- Discuss important issues on health, safety and occupational health

Toolbox meetings should be held at regular intervals, with some meetings being held as the need arises. The meetings may be run by managers, supervisors, leading hands, team leaders, and H&S committee members or by an employee who has an important issue for discussion. Meetings can be held anywhere provided there is enough space, it is quiet enough and it will not interfere with other people working nearby.

Toolbox meetings are not meant to be a lengthy training session, but rather a quick exchange of ideas on how some aspects of safety can be improved or fixed. However, toolbox meeting should not be held under time pressure, there should be enough time to allow all participants to contribute. A brief written record of the toolbox meeting should be kept, together with the names of attendees, points raised and conclusions reached. The contents and the frequencies of the toolbox meetings will depend on the specific project situation and should be made specific in the detailed remediation design.

Suggested topics for discussion at a toolbox meeting are:

- Use of PPE
- Working methods
- Emergency procedures
- Other HSE procedures
- Planned inspections and results of inspections carried out
- Causes of recent incidents, accidents, injuries and near misses that have happened and the lessons learnt
- Possible preventive actions to be taken
- Feedback on safety performance

The toolbox meetings should not be a one way but interactive meeting, therefore the chair should:

- Invite people to raise safety issues about which they are concerned
- Invite ideas on workplace modification, new plant or equipment
- Ask for employee input on reducing manual handling problems or how to modify tasks to reduce risks

6. The project site zoning

Contaminated media should be prevented from contaminating uncontaminated areas. Therefore, contaminated soil should be stored in a properly designated location before off-site disposal, in order to prevent it from escaping into the environment. Site visitors should not be exposed to contaminated soil and groundwater. To achieve this, the remediated site should be divided in clearly indicated zones regarding H&S risks. The configuration of the zoning and the organization of safe working areas depend on conditions at the site (site components, toxicity and quantity of hazardous substances et cetera) and on the activities planned during the remediation (repackaging, decontamination of building material, soil and groundwater remediation et cetera). In all cases, a contaminated site should be at least divided into the following zones:

- **The contaminated zone** - the zone with contaminated materials
 - Close proximity to hazardous materials
 - High risk of exposure when working
 - Repackaging of waste into new containers
 - Control measures in place for the decontamination of workers
 - High levels of supervision and control during operations
 - Close monitoring of workers and work methods based on operating procedures
 - High levels of PPE and environmental protection

- **The decontamination zone** - the zone to be used by workers to travel from the clean zone to the contaminated zone and back; and for the mobilization and demobilization of materials and equipment that are needed in the contaminated zone
 - Lower levels of PPE and environmental protection

- **The clean zone** - the zone without contaminated materials
 - Minimal risk of exposure
 - Storage of materials pending removal from site

The decontamination zone, also facilitates the decontamination of personnel, materials and equipment before leaving the contaminated zone. The decontamination zone can be a cabin with shower and lockers, or a tent for workers and an outdoor area for materials and equipment, as long as Zone 2 is split into a clean and a contaminated compartment. A schematic figure of a project site layout with H&S zoning is given in Figure 2.6.

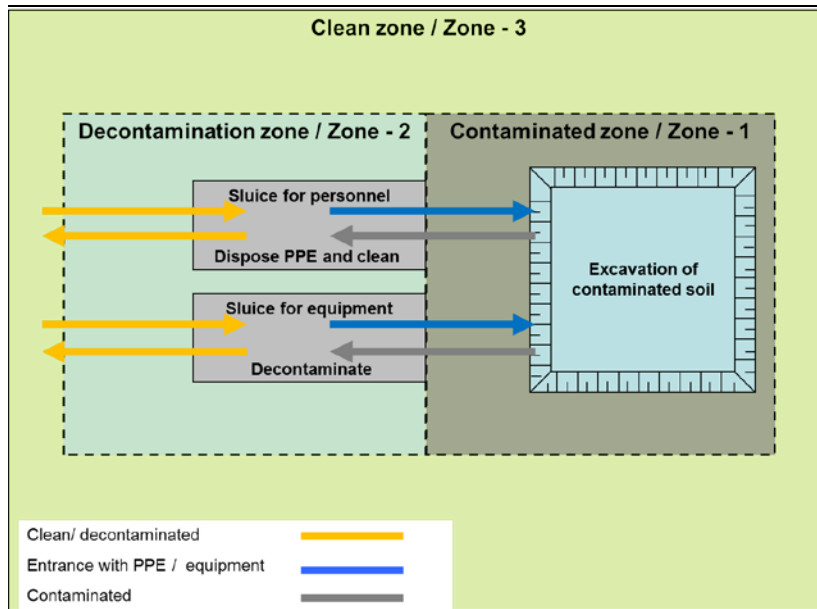


Figure 2.6 Remediation site layout with the contaminated zone, the decontamination zone and the clean zone (source: Tauw, 2015a)

2.6 Project Risk Management

No project is successful without proper project risk management. Therefore, it is advised to implement project risk management in this phase of the sustainable management of contaminated sites.

2.6.1 Approach

A risk is an event that, when triggered, causes problems for the project. The risks can stem from e.g. technical, organizational, legal, environmental, financial, social, or political issues. Project risks are for instance:

- No guaranteed safety during and after remediation
- Negatively influenced quality of remediation results
- Higher remediation cost than the calculated budget
- Longer execution of the remediation than planned

A project manager needs to already know all project risks during the project design and project preparation, in order to ensure that the project is safe, successfully implemented, carried out within the budgeted costs and planned time, and that the site-use is safe after completion of the remediation.

In order to manage project risks, they should be first identified and assessed. For each identified risk, proper control measures should be selected and implemented. Once the control measures have been implemented, the risks should be evaluated again and the original list of risks should be updated. For these new and remaining risks, control measures should be selected again. This process has to be repeated at regular intervals during the whole project period. Figure 2.7 illustrates this continuous risk management cycle throughout the remediation project. The system to preliminarily assess the environmental risks (see Part 1 of these Guidelines); can also be used to assess the other project risks.

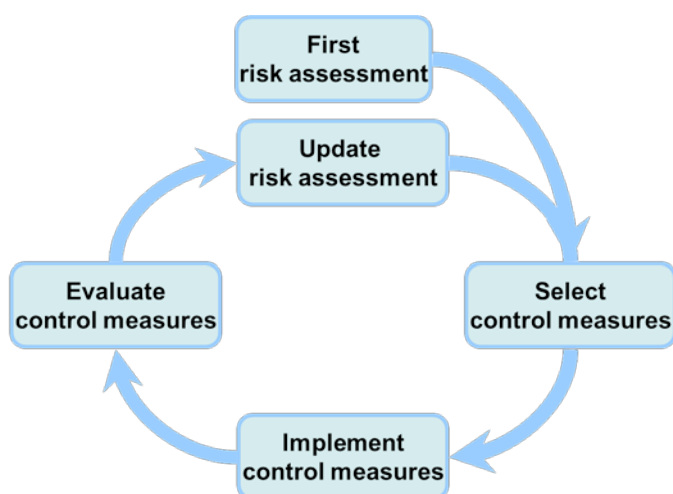


Figure 2.7 Continuous project risk management (source: Tauw, 2015a)

2.6.2 Implementation

The main goals of the continuous risk management are to control, reduce and / or eliminate the project risks. Therefore, it is advised to start with project risk management already in Phase 3, Remediation Assessment. As a consequence, the first cycle of risk management will be general during the conceptual design of the remedial options; detailed in the preliminary design of the selected option; and concrete in Phase 4 and 5 (Remediation Management and Monitoring and Aftercare).

The risk management measures depend on the likelihood and the impact of the risk. Likelihood may be the statistical probability for an event to occur over certain period of time, whereas the magnitude of an impact may be expressed as number of people at risk or as a value of possible environmental damage.

As shown in Figure 2.8, the measures can be divided in:

- Insuring a risk when the likelihood is low and the impact large
- Preventing a risk when the likelihood is high and the impact is large
- Accepting a risk when the likelihood is low and the impact is small
- Reducing a risk when the likelihood is high and the impact is small

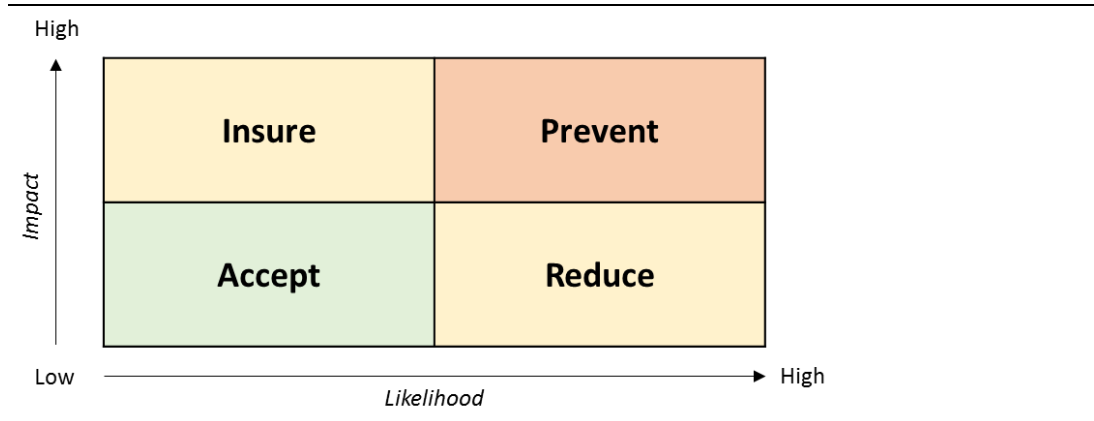


Figure 2.8 Risk management measures depend on the likelihood and the impact of the risk

For each identified project risk, a control measure has to be designed and implemented. All risks and control measures should be filled in a project management Risk log and this Risk Log should be updated at regular intervals (at least after each project risk management phase). An example of a project management Risk Log is presented in Table 2.8.

Table 2.8 Example of a project management Risk Log. It is recommended to use a fixed number of terms so that the information provided is consistent. In this example the terminology for likelihood*, impact and Strategy*** are elaborated.**

Likelihood*	Impact**	Strategy***	Risk control measures	Responsibility	Action by
Technical/ Environmental Performance risks					
Risk: Big Bags break during handling and transport causing spill of contaminated soil / materials Consequence: Exposure to and migration of contaminants					
Likely	Moderate	Prevent	<ul style="list-style-type: none"> • Repack damaged big bags in UN approved over-seized big bags • Close monitoring & supervision 	<ul style="list-style-type: none"> • Contractor • Commissioner 	<ul style="list-style-type: none"> • Contractor • Monitoring consultant
Risk: Workers are not familiar with the use of the PPE and therefore do not use their PPE in the correct way Consequences: Exposure to contaminants					

Likelihood*	Impact**	Strategy***	Risk control measures	Responsibility	Action by
Likely	Moderate	Prevent	<ul style="list-style-type: none"> Request in contract phase, safety observation & regular safety meetings Close monitoring and supervision Reward safe behaviour Enforce strict site zoning 	<ul style="list-style-type: none"> Commissioner Contractor Contractor Contractor 	<ul style="list-style-type: none"> Commissioner Monitoring consultant Contractor Contractor
Project planning risks					
Risk: Procurement process delayed Consequence: Less time available for implementation					
Likely	Moderate	Prevent	<ul style="list-style-type: none"> Monitor procurement process very closely Plan with clear deadlines 	<ul style="list-style-type: none"> Project management 	<ul style="list-style-type: none"> Project management
Risk: Soil bioremediation process is not effective Consequence: Process has to be repeated and project cannot be finished within the estimated budget and time					
Possible	Moderate	Accept	<ul style="list-style-type: none"> Monitor process closely Take more time for remediation Allow land filling as fall back scenario when, also after extra time, remediation target levels are not reached 	<ul style="list-style-type: none"> Contractor Commissioner Commissioner 	<ul style="list-style-type: none"> Monitoring consultant Contractor Contractor
Financial risks					
Risk: More contaminated soil and buried hazardous substances are to be excavated and treated than estimated Consequence: Budget exceeds					
Not likely	Large	Prevent	<ul style="list-style-type: none"> Remove, repack and temporary store all at a dedicated storage Only allow the contractor to destruct amount mentioned in contract As fall back scenario, the remaining will be safeguarded until additional budget is available 	<ul style="list-style-type: none"> Contractor Commissioner Commissioner 	<ul style="list-style-type: none"> Contractor Contractor Commissioner
Social risks					
Risk: People / stakeholders are not informed well Consequence: People / stakeholders do not except and they cause project delay					
Possible	Moderate	Prevent	<ul style="list-style-type: none"> Request for assistance from local authorities in stakeholder involvement 	<ul style="list-style-type: none"> Commissioner 	<ul style="list-style-type: none"> Commissioner & local authorities

***Likelihood**

Not likely
Possible
Likely
Probable
Very likely

****Impact**

Very small
Small
Moderate
Large
Very large

*****Strategy**

Insure
Prevent
Accept
Reduce

2.7 Design of Stakeholder Involvement Plan

In the context of contaminated site remediation, stakeholder involvement means generally public participation (involving inhabitants of the municipality in decision making at local level) and awareness raising. A stakeholder can be a person, group of people or organization (non-governmental or governmental organization) with an interest in the project. People living close to contaminated sites should be well informed before a remediation project starts in order to minimize health risks. Stakeholder involvement also avoids accidents, civil unrest and protests around the project. Stakeholder analysis and involvement are described in the following sections.

2.7.1 Stakeholders analysis

Identifying all stakeholders involved is essential for successful planning and implementation of the project. A *Quick Scan Stakeholder Analysis* is a tool that can be used to analyse the stakeholders and their roles in dealing with the contaminated site problems at different levels in the society. Instructions on how to carry out a *Quick Scan Stakeholder Analysis* is presented in SOP 8.1.4 (Model for making a Quick Scan Stakeholder Analysis).

It is advised to start the stakeholder analysis already in Phase 3 (Remediation Assessment), in order to identify all stakeholders to be involved and all activities needed for effectively involving them, before the remedial activities (Phase 4) are started. The main stakeholders that should be involved, and / or targeted for awareness raising activities are for instance:

- Organization:
 - The provincial and local authorities
 - Mass organizations and other relevant local civil society organizations
 - Related provincial and local departments, sectors and units (H&S, emergency, natural resources and environment and agriculture, et cetera)
- Community and other group at risks:
 - People who live at or near the contaminated sites and are using natural resources (for example soil, water) from the contaminated sites

The golden rule for stakeholder involvement is that questions of any stakeholder about project activities should be responded systematically and on short notice.

2.7.2 Stakeholder involvement

The objectives of stakeholder involvement are to make sure that all stakeholders are well informed before a remediation project starts; the groups at risk know how to minimize health risks and avoid accidents; and the community is informed and has no protests around this project. A stakeholder involvement plan should be made in order to determine the activities needed for each stakeholder group in order to create involvement, common project ownership and shared inspiration to reach project objectives.

A team of trained consultants should do the planning and implementation for stakeholder involvement. Generally, the ideal team to carry out this task should include:

- A social expert with reasonable understanding of remediation projects activities
- A technical expert with an interest in social issues, involved in the technical preparation and execution of the clean-up and remediation campaigns

The stakeholder involvement tasks depend on the type and nature of the remediation project. Therefore, a trained consultant has to analyse the site-specific situation in close cooperation with the local stakeholders. The main tasks and purposes of the stakeholder involvement tasks are:

- Authorities:
 - The provincial and local authorities and mass organizations need to be informed about the threats that pose to public health and the environment in order to support the project
 - Related provincial and local departments, sectors and units (H&S, emergency, natural resources and environment and agriculture, et cetera) have to be informed about all aspects of the project in order to be involved and be supportive when project activities concern public health issues, transport of hazardous substances and / or contaminated soil, and storage of hazardous substances
- The community and other groups at risks:
 - People who live at and near the site, and are using natural resources (for example soil, water) from the contaminated sites form a separate stakeholder group that needs special attention. Site users are not always aware of the fact that the activities are in their own interest. Therefore, they need to be informed about the importance of cooperation in order to have a safe and successful project
 - The local population living close to the contaminated sites has to be informed about the risks that these contaminants pose for their health and the health of their family members. They should be consulted in public hearings as part of the decision making process involving all project activities

2.7.3 Monitoring stakeholder involvement

Monitoring the results of the stakeholder involvement plan can help to assess if project stakeholder planning was successful. Monitoring can be used as an instrument to correct project stakeholder implementation or to clarify that stakeholder involvement activities are changing and that the initial planning is not correct anymore. The plan for the monitoring of stakeholder involvement should be described in a separate section of the Remediation Plan.

2.8 Reporting of Remediation Assessment

The objectives of a Phase 3 Remediation Assessment report are:

- To inform the relevant stakeholders about the environmental baseline conditions and the possible remedial solutions of the contaminated site
- To obtain approval from the authorities to proceed to (Phase 4) the Remediation Management
- To provide technical input for the next Phase, Phase 4
- To provide information on cost for the next Phase, Phase 4

1. Introduction

In order to be able to transfer all data to the next phase, this chapter describes the contents of the Phase 3 report, which comprises four parts. The content of these four parts is described in detail in the following sections. The four parts are:

- General information
- Summary of the Site Assessment results
- Remediation Assessment
- Remediation Plan

2. General information

The structure of this section should include:

- A page with basic information (Name of the project, location, total proposed budget and sources of funding)
- A list of all stakeholders involved with detail contacts
- The objectives and goals of the remediation project
- The legal basis of the project
- The necessary for the implementation of the project which summary
 1. The site assessment results and the effects of the contamination situation at the site to the surrounding population and environment
 2. The relevant conclusions and recommendations to prove that project implementation is necessary

3. Summary of site assessment results

This part of the Phase 3 report is used to present the main results of the Site Assessments obtained in Phase 1 and 2 (see Part 1 of these Guidelines). Site Assessment reports should be attached with the Phase 3 report as Appendices. The main information presented includes:

- Information of the site:
 - Natural conditions, including description of:
 - Geographical location
 - The topography, geology and local climatic / weather conditions

- The hydrology of the site, especially information related to groundwater levels and main surface streams
- Information on the soil characteristics (physiochemical properties and soil profiles)
- Socio-economic conditions, including a description of:
 - Population, especially the population living in and adjacent to the site
 - Land-use status and land-use planning of the site and the surrounding area
 - Information of living conditions, hygiene (for example usage of household and drinking water) and health status of the population; and information on any suspected health impacts to the population resulting from the contaminated sites
- Other general information, included:
 - Coordinates and elevation of the site
 - Site location maps with site boundaries
 - Information about site owners, site users or current main contacts of the site (name, address, phone and their relationship with the site)
- Site assessment results:
 - Information about past surveys in chronological order
 - Information of historical, current and future site-use
 - The main results of the site assessment, with update CSM and description of all relevant source zones, receptor pathways and receptors
 - Results of the environmental Risks Assessment with description of all identified environmental risks

4. Remediation Assessment

This part of the Phase 3 report presents the results of the assessment of remediation options and the reasoning for the selection of the best options:

- Listing of the remedial options:
 - Description of conceptual designs of at least three viable remediation options.
The description should be to such an extent that it is possible to:
 - Inform all stakeholders about the essence of the project
 - Prepare a preliminary design of each option
 - Estimate the cost for each option with an accuracy of plus / minus 30 %
 - Selection remedial option:
 - Description of the used criteria for the comparison of different conceptual designs
 - Description of the MCDA results for the selection of best remediation option, and the reasoning for selection of the preferred remedial option

- Topics of concern of the selected option, including:
 - Description of gaps to the detailed design of the preferred option
 - Proposals on how to bridge these gaps
 - Description of uncertainties of the preferred remediation option
 - Proposals on how to reduce the uncertainties
- Conclusions and recommendations:
 - Listing of the conclusions of the MCDA
 - Summary of the selected remedial option
 - Listing of the conclusions of the gaps and uncertainties
 - Listing of the needed additional surveys, lab tests and/ or pilots tests

5. Remediation Plan

This part of the Phase 3 report describes the technical design of the preferred remediation option, which included detail description of technical measures applied for each site components.

- For each of the technical measures the following information should be included:
 - Objectives of the technical measure
 - Expected outcomes (for example risk level reduction, remediation target values)
 - Expected workloads (for example volume of soil needed to be remediated)
 - Applied technology (if appropriate) and the implementation processes
 - Requirements for ensure H&S
 - Requirements for supervision and monitoring during remediation
 - Requirements for monitoring and aftercare
 - Stakeholder involvement tasks
- Remediation Planning:
 - The main activities with time frame and milestones per site component
 - The responsibility for implementation in the following plans:
 - Plan for implementation of the chosen technical measures
 - Plan for ensure H&S during implementation
 - Plan for supervision and monitoring during remediation
 - Plan for monitoring and aftercare
- Estimated costs for the implementation of the preferred option. A cost estimate is essential for the project management to allocate budget. The cost estimate as part of the Remediation Plan has to be drafted so that it gives an overview of all associated costs. Cost specification requires expert knowledge of civil engineering and remediation processes

The cost estimation may be changed, or revised, to a certain degree because the detail execution design for remediation (established in Phase 4) may varied, to a certain degree, from the preliminary design (established in Phase 3) dependent on the size and type of remediation techniques. The cost estimate should be conservative in nature because it is used for budgetary purposes. The Cost estimation should contains at least, but not limited to the following items:

- Preparation an execution costs
- Supervision and laboratory costs
- Monitoring and aftercare costs
- Contingencies

3 Phase 4: Remediation Management

3.1 Objectives and Tasks

Phase 4 of the sustainable management of contaminated site, the Remediation Management, is only implemented when Phase 2, Site Assessment, has identified environmental risk(s), the preferred remedial option has been selected and preliminary designed (as described in Section 2). Remediation Management comprises: tendering; detailed design; remediation of the site components; remediation closure; project evaluation and reporting.

The objectives of Remediation Management are to remove the direct environmental risks in the short-term; to reduce and remove the potential environmental risks in the mid-term; and to contain and monitor the latent environmental risks in the long-term. The process to be followed for Remediation Management of contaminated sites is illustrated in Figure 3.1.

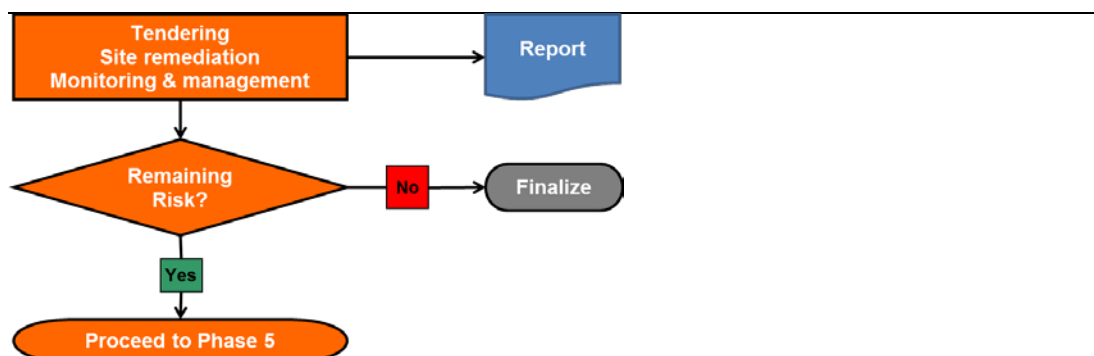


Figure 3.1 Process of Phase 4, Remediation Management, of the sustainable management of contaminated sites (source: Tauw 2015b)

The Remediation Management focuses on the next fourth site components (described in the previous sections):

1. Storage of hazardous substances
2. Contaminated building
3. Buried hazardous substances
4. Contaminated soil and groundwater, including the source area(s)

Before starting with the Remediation Management, it is important to understand the applicable regulatory requirements of the contaminated site and the remediation to be performed.

The responsible party has to ensure that the remediation activities carried out at the contaminated site are in compliance with all applicable regulatory requirements. The responsible party is usually either the current or past owner or operator; someone who organized the disposal of hazardous substances at the site; someone transporting the substances unless the facility legally received the materials. In situations with more than one responsible person, each person is jointly and severally liable for the remediation of the site and can be held liable for the entire cost of the remediation.

3.2 Tendering Process and Methods

3.2.1 Introduction

The most beneficial and secure way to execute the site remediation strongly depends on how the remediation project is brought to the market. There are different clean up and remediation methods suitable for the different site components:

- Hazardous substances are packed, temporarily stored and then finally destroyed
- Contaminated buildings are decontaminated, demolished or renovated and the decontaminated rubble is sent to a controlled landfill
- Buried hazardous substances are excavated, packed and temporarily stored prior to final destruction
- Contaminated soil and groundwater are remediated and, if applicable, the source zone is excavated, packed, and temporarily stored prior to final destruction

Regarding the remediation, there are short, mid and long-term risk reduction measures as shown in Table 3.1 for soil and Table 3.2 for groundwater. The tables also provide information if a measures can be carried out:

- On-site measures
- Off-site measures
- In-situ measures
- By local contractors
- By experienced (inter)national contractors

On-site measures involve the collection and packaging of the hazardous substances, the excavation and removal of the heavily contaminated soils, the installation of on-site and / or in-situ remediation systems, and the on-site treatment and / or in-situ remediation of contaminated soil and / or groundwater. Local contractors mostly carry out these activities

Off-site measures involve off-site transport, temporary storage, (inter)national transport to a destruction and / or treatment facility to destruct the hazardous substances and to treat heavily contaminated soils, and is mostly carried out by more experienced (inter)national contractors.

By tendering these different types of measures (on-site / off-site) separately, the prices are most likely more competitive than tendering these different activities as one bid-package. Splitting the activities in different tenders gives local contractors the opportunity to bid as well, which stimulates the local economy. More specialized (inter)national contractors are more inclined to tender for the activities related to their core businesses.

Table 3.1 Differentiation of short, mid and long-term risk-reduction measures for soil

Short, mid and long-term risk-reduction measures	Site components										
	Hazardous substances storage		Contaminated buildings		Buried hazardous substances		Source area		Contaminated soil		Slightly
								Strongly	Moderate		
Excavate					S		S		S		
Remove & pack	S				S						
Load in means of transport	S				S		S		S		
Decontaminate			S								
Demolish/ renovate			S								
Transport to temporary storage	S				S		S				
Transport to temporary landfill			S								
Temporary storage	S				S		S				
Transport to destruction facility	S				S		S				
Destruct	S				S		S				
Transport soil to treatment facility								S		S	
Treat								S		S	
Install in-situ treatment installation										S	
In-situ remediate										M	
Monitor	S		S		S		S		S		
Monitor and aftercare										M	
S: Short-term remediation measures discussed in Phase 4								Carried-out on-site			
M: Mid-term remediation measures discussed in Phase 4								Carried-out off-site			
L: Long-term remediation measure discussed in Phase 5								Carried-out in-situ			
											Mostly by local contractors
											Mostly by (Inter)national contractor

Table 3.2 Differentiation of short, mid and long-term risk-reduction measures for groundwater

Short, mid and long-term risk-reduction measures	Groundwater			
	Strongly	Moderate	Slightly	
Install in-situ treatment installation	Short			
Treat	Short			
Install pump & treat installation		Short		Short
Pump & Treat		Mid		Long
Monitoring	Short			
Monitoring and aftercare		Mid		Long
S: Short-term remediation measures discussed in Phase 4	Carried-out on-site			
M: Mid-term remediation measures discussed in Phase 4	Carried-out in-situ			
L: Long-term remediation measure discussed in Phase 5	Mostly by local contractor			
	Mostly by (Inter)national contractor			

3.2.2 Tendering process

Tendering is the process from the very first announcement to put specific remediation activities out for tendering, to the signing of a contract between the commissioner and the winning contractor to execute the site remediation activities. This section gives a general description of the three main tendering steps. No detailed description of the tendering process is given, since often the authorities tendering remediation projects have their own tendering procedures and rules to be followed.

A detailed description of the tendering procedures and rules is given in the Law on Public Procurement of the Republic of Macedonia (Official Gazettes Num. 136/07; 130/08; 97/10; 54/11; 185/11; 24/12; 15/13; 149/13; 28/14; 43/14; 130/14; 180/14; 27/15; 78/15; 192/15; 27/16; 120/16)

The tendering process can be divided in the following three steps:

1. The Expression Of Interest (EOI)
2. The request For Proposal (RFP)
3. The contracting

The expression of Interest (EOI)

The commissioner publishes an EOI on a website, (inter)national and / or local newspaper. The contracting authority may conduct open, restricted, or simplified competitive procedure with the publication of a notice by using electronic means through the ESPP (Electronic Public Procurement System; Article 54, paragraphs 1 of the Law on Public Procurement).

The contracting authority may also publish the advertisement of this paragraph and in an appropriate business publication or a technical or professional journal that is available to the wider international expert and other public. In this publication, potential bidders are invited to express their interest in the remediation activities or the project. The EOI is a short article containing the project context, a general project description, the main preconditions, applicable selection criteria and a brief general project planning. In addition, this publication elaborates on the tendering procedures and tender planning. Besides, the publication provides necessary information on the data that should be entered in the EOI and when the EOI has to be submitted.

The contracting authority is obliged to state in the tender documentation the requirements, conditions, criteria and other necessary information in order to provide the economic operator with complete, accurate and precise information regarding the manner of conducting the procedure for awarding a public procurement contract (Article 32, paragraph 1 of the Law on Public Procurement).

The contracting authority defines the technical specifications (Article 33, paragraph 2 of the Law on Public Procurement):

- By reference, as a rule, in the following order: application of Macedonian standards in accordance with European standards, European technical approvals (European technical attests), common technical specifications used in the European Union, international standards or other technical references introduced by side of European standardization bodies. If they are not prescribed, the technical specifications are defined by reference to the Macedonian standards, national technical approvals or national technical specifications related to the use of the goods, the design solution or the performance of the works. Each reference should be followed by the words 'or equivalent'
- In terms of performance requirements or functional characteristics of the subject of the contract, which should be described sufficiently precisely to enable bidders to accurately understand the subject of the contract and the contracting authority to make the selection of the most favorable tender

The contracting authority shall state the criteria for determining the capability and the rules to be applied, the minimum number of candidates it intends to choose and, if necessary, the maximum number of candidates.

After the deadline has passed for submitting the EOI, the commissioner lists all the potential bidders. This is the so-called *longlist*. The EOIs from the longlisted potential bidders are assessed based on the selection criteria. The bidders not meeting the selection criteria are informed in writing that they have not been selected to tender. The bidders that meet the selection criteria are put on a *shortlist*. The shortlisted potential bidders are informed in writing that they are invited to tender. The contracting authority is obliged to send the invitation to participate in the dialogue phase to all selected candidates simultaneously.

Request for proposal (RFP)

The RFP is made available to the *shortlisted* potential bidders and contains at least the following documents:

- A Letter of Invitation with:
 - The content of the RFP
 - A request to confirm whether or not the potential bidder will submit a proposal
 - Whether or not there is a pre-bid meeting and if so, where and when
 - How, until when and where clarifications can be obtained
- Instructions to potential bidders with:
 - The explanations of definitions used in the RFP
 - General information
 - The content of the contractor's proposal
 - How to prepare the proposal and how to submit the proposal
 - How the proposal is evaluated and how the contract is awarded
- Terms of Reference (ToR) with:
 - General background and the Conceptual Site Model (CSM)
 - Objectives of the assignment
 - Scope of work / design and duration of the work
 - Final products and expected results
 - Monitoring and reporting
 - Qualifications, required experience and competencies
 - Administrative support and reference documents
 - Terms and conditions of payment including payment schedule
- Proposal Submission Form
- Documents establishing the eligibility and qualifications of the bidder
- Technical Proposal standard form explaining what information has to be submitted, such as:
 - Bidder's organization capacity and expertise
 - Approach, methodology, work plan and Health Safety and Environment Plan (HSE-Plan)
 - Proposed project staffing

- Financial Proposal Form explaining what information has to be submitted, such as;
 - Summary of the financial offer
 - Cost breakdown in bill of quantities
- Form for security performance
- Standard form of contract for the Services, including:
 - The content of the contract but with the blanks to be filled in when the contractor is selected to enter the contracting phase
 - General terms and conditions

The best proposal is the proposal with highest total score and should be from the bidders offering the best quality for the lowest cost.

The contract

When the bidder with the highest total score and the commissioner agree on the remediation activities described in the technical proposal and on the costs given in the financial proposal, the commissioner and the contractor will seal this agreement in a contract. The contract contains the general conditions applicable for the remediation activities that have to be delivered and all the documents of the proposal submitted by the contractor.

The announcement for awarding a public procurement contract for an open procedure, a restricted procedure, a competitive dialogue, a negotiated procedure with prior publication of a contract notice and a design contest shall be submitted for publication in the ESPP (Electronic Public Procurement System and in the "Official Gazette of the Republic of Macedonia". If the estimated value of the public procurement contract excluding VAT is more than EUR 50,000 for goods and services, or over EUR 200,000 for works, the contract notice for public procurement shall be published in the Official Journal of the European Union. The contracting authority may publish the advertisement of this paragraph and in an appropriate business publication or a technical or professional journal that is available to the wider international expert and other public (Article 54, paragraph 1 and 2 of the Law on Public Procurement).

3.2.3 Tendering methods

Before tendering, the tendering organization needs to decide on the best way to put the remediation activities on the market. This section describes the three different methods to tender remediation activities. The three methods are:

1. Item Rate Based Tendering
2. Tendering using detailed Terms of Reference
3. The Result Based Tendering

1. Item Rate Based Tendering

The Item Rate Based Tender is the most elaborated of the three methods of tendering. In this method of tendering, the overall rule is that the greater the details in the design, the more effective is the tender. In an item rate based tender, the contractors are required to quote the rates for each item mentioned in the bill of quantities. The total cost for each item is the product of the rate given by the contractor and the quantity mentioned in the bill of quantities. This type of tendering gives the less specialized contractors the opportunity to participate in the tendering because all activities to be carried out are itemized in detail and a contractor just carries out what is asked for in the different items. This means also that the tendering organization is required to develop the design of the remediation activities in detail (see Section 3.3 for Detailed Remediation Design).

The main advantages of the Item Rate Based Tender are:

- It benefits local contractors who have limited experience with site remediation
- It leaves little room for difference between the offers, as they will all price the same items

The main disadvantages of the Item Rate Based Tender are:

- The tendering organization is fully responsible for the quality of the activities, including any errors in the design and therefore in the bill of quantities
- The price offer is not fixed, but based on the actual amounts of the carried out items
- It requires intensive supervision to ensure that all items are carried out correctly

Item Rate Based Tenders are most suitable for straightforward non-complex remediation activities. Examples are the installation of a fence, or the collection, packaging and transport of hazardous substances to a secure storage location.

2. Tendering using Detailed Terms of Reference

The second method of tendering is the tendering by supplying a detailed Terms of Reference (ToR). In this second type of tender, the tendering organization provides contractors with the preliminary design of Phase 3, guidelines on the needed techniques and the specifications of the related materials. The tendering organization does not specify the remediation activities in detail, but only describes clear remediation preconditions, goals and objectives. The tendering contractor prepares the detailed design and he produces the financial offer based on the detailed design.

The main advantages of tendering using a detailed ToR are:

- It leaves the detailed design to the contractor and requires therefore less technical design capacity from the tendering organization
- It offers the possibility to enter into a lump sum contract

The main disadvantages of tendering using a detailed ToR are:

- The ToR should be very clear on information that determine the price, such as the preconditions, goals and objectives
- It can lead to disputes when remediation activities deviate from the original plan

Tendering using a detailed ToR with technical drawings is most suitable for straightforward, non-complex activities, especially in situations where the contractors already have experience with these types of remediation projects. An example is the excavation of contaminated soil.

3. Result Based Tendering

The third tender method, the 'Result Based Tender', does not specify the technique for remediating the site component(s). It rather gives a set of preconditions, goals and objectives in the bid documents. An example of such prescription is:

'Removal and disposal of around 150 cubic meters (225 tonnes) of soil contaminated with POP pesticides concentration levels of above 50 mg/ kg dry matter from the project area as indicated on the map in the attachment. The soil removed off-site should have a moisture content of ≤ 10 %. The moisture content should be demonstrated by analysis of one representative composite soil sample, which should be made from five individual samples taken after the soil is excavated, but before off-site removal. The groundwater depth varies between 1 - 2 m bgl. The soil shall be excavated without drainage due to the danger of enhanced soil consolidation. The soil may be dewatered (if needed) in an on-site temporary dewatering depot, but cannot be cleaned on-site. The excavation should be backfilled with soil suitable for agricultural purposes. The verification of the removal of the contaminated soil with concentration above 50 mg/ kg dry matter has to be carried out by the contractor. For the verification, the contractor will take one composite soil sample from every 20 square meter of the pit. One composite soil sample should be made from five individual soil samples, with a sampling depth of max 0.1m. The estimated quantity for removal and disposal is 225 tonnes of contaminated soil, which is 150 cubic meter times the specific weight of 1.7 tonnes. The contractor is asked to give one price including excavation, dewatering, off-site removal and disposal at a sanitary landfill or soil treatment, and any other work involved. This also includes obtaining all necessary permits and licenses to execute the remediation activities described in this item. The contractor is asked to give a price per ton to cover the cost when the total amount of excavated soil (with moisture content of 10 % or less) exceeds 250 tonnes.'

The main advantages of a Result Based Tender are:

- It gives the contractor freedom to decide on how to reach the set goals
- Supervision is limited to the verification of the different items in the tender
- The contract is always a lump sum contract

The main disadvantages of a Result Based Tender are:

- The tendering organization needs expert knowledge to assess proposals
- The tendering organization requires expert knowledge during execution to monitor

This type of tendering is best for larger scale remediation projects where experienced contractors are invited. The tendering organization should have expert assistance in assessing which bids are the most advantageous.

3.3 Detailed Remediation Design

3.3.1 Introduction

The different tendering methods demand different descriptions of the required remediation activities in the RFP. As explained above, the *detailed design* is part of the RFP in an Item Rate Based tender. The RFP of a tender using detailed ToR provides a *less detailed design* of the remediation activities, whereas the RFP for a Result Based Tender only contains a *description of the desired end-results*. No matter which method of tendering is chosen, a detailed design has to be made to establish the costs for the activities. **The method of tendering determines which contracting partner is responsible for the detailed design.** This section therefore presents a description of a detailed design.

A detailed design tender describes the needed remediation activities with great accuracy. In essence, it is the elaboration of the Remediation Plan as prepared during Phase 3 (see Section 2). The detailed design of the remediation gives the exact site location and the locations of the different clean and contaminated site components. It also describes the site situation and provides quantities such as volumes, distances and tonnage for each site component to be cleaned, rehabilitated, contained, removed and / or remediated (the complete CSM). This is prior to defining any specifications of the remediation techniques.

The detailed design provides such detail that it is possible for a contractor / bidder to calculate the remediation costs. The remediation costs are used for the financial proposal. Technical, scaled drawings and maps illustrating the overall site situation support the detailed design and provide all necessary technical details. All maps should have a North arrow, a scale bar and information on the persons who drew and approved the map with a date.

A design professional (i.e. an engineer) should have sufficient and relevant education, training, and experience to prepare a safe and effective (technical) detailed design of the required site remediation activities as preliminary designed in Phase 3. To be competent, a design professional should be familiar with the characterization of the site, the Site Assessment results (Phase 1 and 2) and the results of the Remediation Assessment and the Remediation Plan (Phase 3). Phase 3 (Section 2) includes the preliminary design as part of the Remediation Plan and this is used as starting point for the detailed design in this Phase 4, Remediation Management.

The next subsections present the preconditions and main features for a (technical) detailed design of the different remediation activities of the earlier mentioned four site components. For each detailed design item, examples on what has to be presented are given in Tables 3.3, 3.4, 3.5, 3.6 and 3.7. The given examples are not described in detail. It is important to note that a detailed design is always site specific.

As described earlier, successful remediation also requires stakeholder involvement, which is elaborated in the stakeholder involvement plan as discussed in Section 2.7. The activities described in the stakeholder involvement plan will be carried during Phase 4, but are mostly not within the scope of the contractor implementing the technical remediation measures.

3.3.2 Site Preparation

The detailed design of the remediation activities should always start with designing the Site Preparations. Table 3.3 gives examples of information that has to be part of a detailed design of the Site Preparation. This part of the detailed design addresses the site organization with a focus on Health, Safety and Environmental (HSE) aspects of the site remediation campaign. The basic site information has already been presented in Phase 1, 2 and 3 reports and has to be used as a reference. HSE aspects should be added. An example is an unpaved site road: improvement of accessibility during the rainy season and combating dust forming during the dry season should be addressed in this section of the detailed design. The detailed design of the site preparation elaborates on all activities to carry out to guarantee a safe, healthy, sustainable, and environmentally friendly remediation.

Table 3.3 Topics to be addressed in the detailed design of the Site Preparation

Topic of Site Preparation	Consult Report	Remark
General information		
Site address	Phase 2	Include a site location description such as: 'The site is situated in the middle of the village behind the house of Mr Xxx
Site contacts	Phase 2	Could be the site owner, the caretaker, the responsible person in the local administration, etc.
Site location	Phase 3	Regional map with site location indicated

Topic of Site Preparation	Consult Report	Remark
Site accessibility	Phase 3	Site layout map indicating all site components and a description of the condition of the site path(s)/ road(s)
Permission / permits	Phase 3	Include where to obtain and explain procedure and the time needed to obtain permission / permits to carry out the remediation activities
Site layout and zoning		
Zoning	Phase 3	Site layout map with the contaminated zone, the decontamination and Zone 3 the clean zone. The specification of the temporary site fencing and zone demarcation are also part of the description
Site layout	Phase 3	Site layout map with all site components and facilities to be installed such as parking place, shelter, canteen etc.
Tools, equipment, material and Personal Protective Equipment (PPE)		
PPE	Phase 3	The type and numbers of for instance coveralls and half-face mask including cartridges for a staff working in the contaminated zone, the clean zone etc.
Safety equipment and materials	Phase 3	This includes for instance the number of fire extinguishers, the set-up of the decontamination zone, the sluice, the first aid kits, spill control kit and the emergency shower
Tools and materials	Phase 3	This includes for instance the big bag filling station, the crane / forklift, wheel loader, truck and hand tools

3.3.3 Storage of hazardous substances

Table 3.4 lists the minimum required information to be included in the detailed design of the collection and packaging campaign of hazardous substances. The Phase 2 report can be used for getting information on the location, the amount, types and conditions of the hazardous substances and should be used as a reference. The collection and packaging plan of Phase 3 describes the general approach of the collection and packaging. The detailed design elaborates on all activities to carry out to remove, pack, transport and temporarily store all hazardous substances in a safe and environment friendly manner, while awaiting final destruction. The last part of the design contains the information needed by the destruction company to destruct safely the hazardous substances and waste. It is proposed to split the detailed design in collection, packaging, transportation, temporary storage and destruction.

Table 3.4 Topics to be addressed in the detailed design of the packaging of hazardous substances

Topic packaging of hazardous substances	Consult Report	Remark
Repackaging		
Hazardous substances	Phase 2	Conveniently listed types, quantities and conditions of solids, liquids and other hazardous substances including photos of the stock(s) and if possible photos of the labels
Packaging material	Phase 3	The types, quantities and specifications of for instance the needed big bags, overhead drums, boxes and PE drums

Topic packaging of hazardous substances	Consult Report	Remark
Staff		The needed staff to pack in a safe and healthy manner. Packing cannot be done without constant supervision. An aspect that should be considered is that working in coverall and respiratory mask during warm weather should be limited in time, dehydration being a constant threat
Transportation		
Legal	Phase 3	Applicable laws and regulations on transportation of hazardous waste. Reference to legal documents and the procedure to obtain a hazardous waste transportation permit should be included
Road condition	Phase 3	Maximum permitted load of road to the destination including dimensions, conditions and photos of the road to destination (temporary storage, destruction facility or for instance a seaport if hazardous substances and its waste are exported for destruction)
Destination	Phase 3	Regional map with site location and destination indicated
Address of destination	Phase 3	Site layout map and description of the temporary storage
Contact	Phase 3	Name and contact details of the destination. Could be site owner, caretaker, the responsible person in the local administration, etc.
Temporary storage		
Storage access condition	Phase 3	A site layout map indicating the temporary storage (if applicable)
Site storage condition	Phase 3	If there is no temporary storage site available, the precondition for such storage should be given
Site storage facilities	Phase 3	The facilities at the temporary storage site needed are for instance loading platform, forklift safety equipment, spill kit, etc., and should be described when the temporary storage is part of the contract
Destruction		
Hazardous substances to be destructed	Phase 2	Analytical results, the number of different packages, and the total tonnage of each distinguished batch are the information needed by a destruction company
Destruction technology		There are several companies using different kinds of techniques to destruct the hazardous substances. A detailed design only presents the detailed information and the preconditions as described in this section. The companies assess themselves if they can destruct the hazardous substances and meet the preconditions
Packaging type accepted by destruction company		This information can only be given if the destruction company is already known
Maximum volume of single parcel accepted by destruction company		This information can only be given if the destruction company is already known
Max weight of single parcel accepted by destruction company		This information can only be given if the destruction company is already known

3.3.4 Buried hazardous waste

Table 3.5 lists the minimum required information to be included in the detailed design of the remediation of a pit with buried hazardous waste. The Phase 2 report gives information concerning the location of the pit, the amount buried, types, and condition(s) of the buried hazardous substances. Phase 2 also gives information on the pit itself, i.e. the dimensions of the pit, the depth to the groundwater, the soil type and the conditions of the sides and cover of the pit. The excavation plan of Phase 3 describes the general approach for the removal of the buried hazardous substances and the packaging. The detailed design elaborates on all activities to carry out to remove, pack, transport and temporarily store all hazardous substances in a safe and environment friendly manner. The design is split-up in the pit excavation, the pit backfilling, the packaging of the contaminated material, i.e. the hazardous substances but also the remediation of the contaminated soil of sides and bottom of the excavation pit, the transportation, the temporary storage and the destruction / en-situ remediation.

Table 3.5 Topics to be addressed in the detailed design of the remediation of buried hazardous substances

Topics buried hazardous substances	Consult Report	Remark
Excavation		
Condition of the pit	Phase 3	Detailed site layout map with the buried hazardous waste including photos of the pit, dimensions and cover
Excavation	Phase 3	Detailed cross section of the pit including the groundwater level, the boundaries of the pit to be excavated with safe slopes
Material and quantities to be excavated	Phase 2	The different batches present in pit should be described (volumes, type, specific weight and form) such as: <ul style="list-style-type: none"> • Clean soil (texture) from the cover and slopes xx m³ • Contaminated soil (texture) from cover, slopes and bottom xx m³ • The different types of packaging of the hazardous substances (bags with xx, drum with xx) • Unknown hazardous substances (bags with xx, drum with xx) • The different types of unpacked hazardous substances xx m³ • Unknown unpacked hazardous substances xx m³
Pit backfilling		
The backfilling	Phase 3	The specification of the backfill such as the type / texture, demanded environmental quality, the backfill height and the compacting demands of the backfill
Repackaging, Temporary storage, Transportation and Destruction see Table 3.4		

3.3.5 Contaminated building(s) and infrastructure(s)

Table 3.6 lists the minimum required information to be included in the detailed design of the decontamination of a contaminated building. A contaminated building can be a specifically dedicated storage building, a bunker or a simple shed. The Phase 2 report provides the location and the details of the building, such as its dimensions, building materials and the parts where and the degree to which the building is contaminated (floor, walls, et cetera). The decontamination / demolishing / renovation plan of Phase 3 describes the general approach of the decontamination, the renovation / demolishing, and the removal of the clean and the decontaminated rubble and / or building materials to a controlled landfill. The detailed design describes the same, but gives far more details on type and quantities so that all costs can be calculated and all activities can be carried out in a safe and environmentally sound manner. The detailed design clearly explains the demolition of the subsoil part of the building to avoid cross contamination of the surrounding soil and / or the subsurface structures. If the building is connected to facilities like water and electricity, a special section in the detail design is devoted to disconnection and removal of such facilities. This section list the different cables and lines with the name and contact details of the owners / providers. The locations of these facilities are provided on separate site location maps with a legend clearly giving the different types.

The detailed design is divided in the decontamination of the building, the renovation and / or demolishing of the building, the off-site removal and transportation, and the landfilling of the decontaminated rubble and / or building materials at a controlled landfill.

Table 3.6 Topics to be addressed in the detailed design of the decontamination of a contaminated building

Topic	Consult Report	Remark
decontamination of building		
Decontamination of the building		
Condition of contaminated building	Phase 2	Detailed site layout map with the contaminated building with photos and specifications of the contaminated part of the building such as: <ul style="list-style-type: none"> • 'The concrete floor of storage is 20 cm thick and the first 10 cm is impregnated by spilled liquid hazardous substances' • 'The plastered walls of the storage show up to 1.5 meter high staining by spilled liquid hazardous substances' • 'Also the iron entrance door is stained by spillage'
Decontamination	Phase 3	Details on the techniques to be used to decontaminate the building such as: <ul style="list-style-type: none"> • The concrete floor has to be removed and kept separate for packaging • The wall of the storage should be cleaned by removing the plaster up to 1.5 meter height, the plaster is kept separate for subsequent packaging • The iron entrance door can be cleaned using cotton waste. The cotton waste is kept separate for subsequent packaging

Topic	Consult	Remark
decontamination of building	Report	
Renovation / demolition		
Renovation	Phase 3	If only part of the building needs decontamination and the building is to be used again, the decontaminated part should be renovated. If this renovation is part of the remediation campaign the specifications of the renovation activities should be given
Demolition	Phase 3	If parts or the whole building are not to be used anymore and demolition is part of the campaign the demolition activities should be divided into: <ul style="list-style-type: none"> • Parts higher than man's height • Parts lower than man's height, but above ground level • Parts lower than ground level
Removal of facilities	Phase 3	If the building is connected to facilities and they have to be removed the following has to be provided: <ul style="list-style-type: none"> • Different types, installation depth and location • A description of a connection to the public water supply is given below: <ul style="list-style-type: none"> – PE water main has a diameter of 25 mm – The piping is installed in a trench of 0.5 meter deep – The trench is filled with coarse sand – The sand in the trench is contaminated (see Phase 2 report) – The removal of the water main will be carried under strict enforcement of the HSE zone 3 rules – The water main entrance the building under the main entrance – The main tape is installed in a cupboard direct left of the main entrance – The water company is xxx and the contact person is Mr yy – The company has to be asked two week in advance to disconnect the building from the water – The location of the water piping is given on the site location map of Appendix c
Transportation see Table 3.4		
Controlled landfilling		
Decontaminated building material	Phase 3	Conditions (moisture content, leaching characteristics) to accept the waste characteristics set by the landfill site management

3.3.6 Contaminated soil and groundwater

Table 3.7 lists the minimum required information to be included in the detailed design of a soil and groundwater remediation. The Phase 2 report gives the location and the details of the soil and groundwater contamination, such as the location, the soil profiles, the volumes, the dimensions and the degree of contamination in the soil and groundwater. The Remediation Plan of Phase 3 describes the general approach of the soil and groundwater remediation. The detailed design describes the same, but gives far more details, so that all remediation measures can be cost calculated and carried out in a safe and environmentally sound manner. The detailed design is divided in site-specific information and the short-, mid- and long-term remediation measures.

Table 3.7 Topics to be addressed in a detailed design of a soil and groundwater remediation

Topic soil & groundwater remediation	Consult Report	Remark
Site-specific information		
CSM	Phase 2	The updated CSM should be part of the detailed design. The site layout maps with the soil and groundwater contamination including cross sections should have such a scale that the layout of the remediation measures can be added. Definitions, dimensions and quantities of the distinguished batches of soil (source area, strongly, moderately and slightly contaminated) should be listed and illustrated with detailed maps and photos
Installation and implementation of short-term remediation measures		
Source area	Phase 3	The source area has to be treated in the same way as buried hazardous waste and the design of the remediation of the source area has the same set-up as the remediation of buried hazardous substances. Therefore reference is made to Table 3.4
Strongly contaminated soil	Phase 3	Strongly contaminated soil is hard to remediate with the currently available bio- and phytoremediation technologies. The short-term remediation measures therefore are often restricted to excavation and transportation to a soil treatment facility. In a detailed design, preconditions such as remediation target values are given and bidders assess whether or not they are able to meet these preconditions
Moderately contaminated soil	Phase 2	Moderately contaminated soil can be remediated with the currently available bioremediation technologies. If the volumes are not too large, the short-term remediation measures are often excavation and transportation to a soil treatment facility. If the volumes are large and bio-, on-site and/ or in-situ remediation is possible, the short-term remediation measures are the installation of the bio-, on-site and / or in-situ remediation equipment. Phytoremediation could be possible, but will take a very long time and when the site is located in an intensively used urban area, this is not a preferable option. In a detailed design, preconditions such as remediation target values are given and bidders assess whether or not they are able to meet these preconditions
Slightly contaminated soil	Phase 2	Slightly contaminated soil can be remediated with the currently available bio- and phytoremediation technologies. If the volumes are small, the short-term remediation measures are often excavation and transportation to soil treatment

Topic soil & groundwater remediation	Consult Report	Remark
		facility or remediated in the same way as the moderate contaminated soil. However, if the volumes are large, remediation is only economically feasible when phytoremediation, containment measures and land use restrictions are implemented. The short-term remediation measures are the installation of containment (erosion control) measures and planting of vegetation for the phytoremediation. In a detailed design, preconditions such as remediation target values are given and bidders assess whether or not they are able to meet these preconditions
Contaminated groundwater	Phase 2	Hazardous substances contaminated groundwater is remediated by pump and treat methods. The short-term remediation measures are the installation of the system to remediate. In a detailed design preconditions such as remediation target values are given and bidders assess whether or not they are able to meet these preconditions
Installation of the mid-term remediation measures		
Moderately contaminated soil		The equipment to remediate the contaminated soil are installed as short-term measures. The mid-term measures are aftercare of the remediation installation and monitoring of the remediation progress (designed in a Monitoring and Aftercare Plan)
Slightly contaminated soil		The equipment to remediate the slightly contaminated soil are installed as a short-term measure. The mid-term measures are aftercare of the remediation installation and monitoring of the remediation progress (designed in a Monitoring and Aftercare Plan)
Contaminated groundwater		The equipment to remediate the contaminated groundwater are installed as a short-term measure. The mid-term measures are aftercare of the remediation installation and monitoring of the remediation progress (designed in a Monitoring and Aftercare Plan)
Installation of the long-term remediation measures		
Slightly contaminated soil		The long-term measures are aftercare of the remediation installation and monitoring of the remediation progress (designed in a Monitoring and Aftercare Plan)
Contaminated groundwater		The long-term measures are aftercare of the remediation installation and monitoring of the remediation progress. If the groundwater contamination allows a long-term remediation, technique is natural attenuation. The US Environmental Protection Agency (EPA) defines natural attenuation as 'a variety of physical, chemical, or biological processes that, under favourable conditions, act without human intervention to reduce the mass, toxicity, mobility, volume, or concentration of contaminants in soil or groundwater'. The long-term measure is monitoring of the natural attenuation progress (designed in a Monitoring and Aftercare Plan)

3.3.7 Environment management

In addition to the on-site Health and Safety risks, remediation actions will result in effects on the environment surrounding the remediation site. Depending on the type of remedial actions, the environment may be exposed to contaminants that are released by the remedial actions, and to additional effects such as noise, traffic, dust, odour, vibrations et cetera.

Volatile compounds and odour

If volatile or odorous components are remediated, volatilisation may occur and result in exposure and nuisance. Software is available to estimate the extent of volatilised contamination. An example of such software that is used in The Netherlands is DIVOCOS (Dispersion of Volatile Compounds). Generally, threshold levels for ambient air quality are available; otherwise, levels can be based on risk assessment software. Odour nuisance is more complex and difficult to predict. Trial pitting or excavation can be a useful tool to assess actual exposure and odour risks. A combination of passive and active air monitoring measures can be constructed to monitor and evaluate exposure risks.

Noise

Several remediation activities such as demolition, installation of soil supporting construction (sheet piling) excavation, transport of soil, and soil drilling and remediation equipment (on-site soil/ groundwater treatment plants) will result in noise.

Noise should be limited to the minimum required and can be minimised by keeping distance to sensitive objects, applying activity time zoning or equipping material with noise insulation.

Dust

Excavation, storage and transport of soil may result in generation of (contaminated) dust. Dust can be migrated by wind on and off-site. Several measures can be taken to reduce dust formation to a minimum:

- Keeping the site and soil moist
- Covering excavated (dry) soils
- Taking measures at loading and unloading activities (spraying, screens)
- Minimising transport movement
- Cover the trailers of the trucks during transport

Again, a combination of passive and active air monitoring measures can be constructed to monitor and evaluate dust particles.

Traffic

To prevent traffic intensity near sensitive objects a traffic plan can be constructed, to divert traffic. If the routing of the project traffic is on public roads, the plan will need to be aligned with local authorities.

Vibrations

Traffic, demolition, installation and removal of sheet piles may result in subsurface vibrations that may damage infrastructure and buildings. Analyses of allowable vibration levels needs to be conducted to identify effects of vibrations. If it is expected that vibration are higher than the allowable vibration, the vibrations should be minimised by changing the way if installation and / or have alternative techniques.

Settlement/soil stability

Excavation (supported by geotechnical measures), groundwater extraction and resulting groundwater table depression may result in settlement of subsurface, which can damage infrastructure and buildings. Pressurized in-situ injection technologies may also result in local soil destabilisation. Technical analyses of settlement risks will indicate necessity of preventive actions. Examples of preventive actions are:

- Extended geotechnical support measures
- Groundwater re-infiltration to reduce groundwater table depression
- Reduced injection pressures

Legislation

A remediation project has to comply with all regulations and laws regarding environmental aspects such: as regarding ambient air; odour; dust; noise, vibrations; subsidence; et cetera. The remediation with or without appropriate mitigation measures should comply in particular with:

- Ambient Air levels from the FYR Macedonian legislation
- Minimized odour emissions
- Noise levels not exceeding the minimum levels in the Macedonian legislation
- Emission of contaminated dust / air / water to the environment should be minimized and if necessary control measures must be implemented to avoid emission
- Set limits related for subsidence in Phase 3. Control at constructions, infrastructure and utilities including the public facilities during execution. The subsidence needs to be within the set limits values for subsidence

Potential exposure of the environment to hazardous components, including ambient air, noise, odour, dust and subsidence must be monitored. Sampling and analytical frequency will be defined in an environmental management plan.

Environmental management plan

An environmental management plan is constructed with the following content:

- Description of remediation activities and the environment surrounding of the remedial activities
- Current baseline situation
- Analyses of the environmental impact and risks of remedial actions
- Reference system (screening and action values)
- Monitoring program for the short-term measures
 - Sampling and analytical program
 - Registration of data
- Monitoring and aftercare program for the mid and long-term measures
 - Sampling and analytical program
 - Registration of data
- Action program
 - Preventive actions
 - Mitigation measures
 - Communication strategy
 - Pro-active towards on-site personnel and residents
 - Assignment of communication focal point
 - Information meeting, website, newsletters et cetera

3.4 Remediation Management

3.4.1 Introduction

The Remediation Management can be divided in short, mid and long-term measures. This section describes the management of the short and mid-term measures, whereas the management of the long-term remediation measures is discussed in section 4. This section elaborates on the following on-site remediation tasks:

- Activities as described in the signed contract(s) and will be carried out by the contractor(s)
- Supervision to make sure the activities are carried out in conformity with the contract
- Monitoring to make sure the remediation results are as described in the Remediation Plan and the contract

The objective of the site remediation management is to ensure a correct and safe remediation of the site. The supervisor has the responsibility to check that the contractor respects the applicable regulations and executes the activities as agreed upon in the contract. The supervisor of the activities is NOT responsible for H&S of the workers and other persons on the site.

The contractor is responsible for the day-to-day operations and the H&S of all on-site staff, including third parties, subcontractors, trespassers and the supervisor. The supervisor has the obligation to alert the contractor when unsafe, environmentally unfriendly acts occur, and to stop the work if the acts are persistent and not corrected.

3.4.2 Preparation

The required supervision and monitoring strongly depends on the type of tendering and contract used for the remediation. Table 3.8 indicates how the remediation supervision and monitoring activities relate to the tendering and contract type. An 'Item Rate Based' contract requires nearly constant supervision and monitoring, whereas the requirements for a 'Detailed ToR' contract are somewhat less but still require significant presence on-site. The supervision and monitoring for a 'Result based' contract are limited to the H&S aspects and verification of the remedial results.

Table 3.8 Supervision and monitoring activities relate to the tendering type

Different remediation activities for the different site components	Item rate based contract	Contracted based on detailed ToR	Result based contract
Quantity of used materials and installations	X		
Quality of used materials and installations	X		
Quantity of removed or remediated hazardous substances contaminated materials	X	X	
Quality of removed or remediated hazardous substances contaminated materials	X	X	
Health and safety	X	X	X
End result verification	X	X	X

Preparation for remediation management follows some general lines but also strongly depends on the type of tender chosen. In all cases, the preparation starts with the selection of and preparations by the remediation supervisor. The characteristics of the remediation supervisor are:

- Acknowledges the environmental necessity of the project
- Has the ability to communicate with all stakeholders involved
- Is independent
- Is stress insensible and is not easily pressurized
- Has strong communication skills
- Is observant and consistent
- Has experienced in the construction and civil engineering sector

After the supervisor has been selected, the supervisor has to prepare the remediation supervision. Preparation consists of the following tasks:

- Review of available background documentation (Phase 1, 2 and 3 reports, tendering documentation, contracts, et cetera)
- Preparation of monitoring tools and equipment
- Administrative preparation

Based on the initial review of the background documentation, the remediation supervisor will assess where and how the supervision of the remediation activities will be organized. Supervision and monitoring needs to focus on the following four aspects:

1. Schedule and planning
2. Execution of the activities
3. Field staff behaviour
4. Contractor administration

For these aspects, the supervisor drafts a schedule that includes various witness and hold points:

- **Witness points** are those activities of the remediation that require round the clock presence of the supervisor
- **Hold points** are those activities that require the controlling presence of the supervisor verifying the activity results before continuation

Besides the witness and hold points, supervision and monitoring can be done at various moments during the execution of the activities. The sections below present a suggestion of the organization of the remediation supervision and the associated witness and hold points. Since the remediation, supervision and monitoring are closely related, these management activities are described per site component in the next sections with the exception of the overall / site wide remediation activities such as stakeholder involvement, HSE measures and restricted site-use.

Table 3.9 presents an overview of the site Remediation Management tasks. The Tables 3.10, 3.11, 3.12, and 3.13 in Section 3.4.7 present the remediation tasks and the responsible parties for the different site components on the short- and mid-term.

Table 3.9 Overview of remediation management tasks, responsibilities and reference

Remediation Management Tasks	Responsible party	Witness point	Hold point	Reference document
Stakeholder involvement	Supervisor			Stakeholder involvement plan
Organize stakeholders meeting	Community	X		Stakeholder involvement plan
Monitor progress	Supervisor			Monitoring Plan
Permitting				
Relevant permits for remediation activities, transportation and destruction of contamination	Contractor		X	
Installing site fencing	Contractor			Contract and detailed design
Monitoring quality	Supervisor		X	Monitoring Plan
Monitor HSE	Supervisor			Monitoring Plan
Zoning remediation site				
Install zone 1 contaminated, zone 2 decontamination and zone 3 clean zone	Contractor			Work plan contractor
Supervise zoning	Supervisor		X	Remediation Plan
Enforce zoning	Contractor			Remediation Plan
Implement restricted site use	Public			Risk assessment Phase 2
Monitor enforcement				Monitoring Plan

3.4.3 Remediation Site Zoning

The contractor is responsible for the set-up of the zoning of the site and the general layout of the site. The detailed layout should be presented in the detailed design as part of Phase 4. For the set-up of the zoning see section 2.5.4. Task Based Risk Assessment (TBRA).

Prior to the start of the operations, the contractor should prepare a Task Based Risk Assessment (TBRA), also called Job Safety Analysis (JSA). In essence, this is a review of the upcoming activities and potential risks. The input for the TBRA is the project management Risk Log discussed in Section 2.6 Risk Management.

The difference between the TBRA and the Risk Log is that the TBRA is from the contractor's perspective and the Risk Log is from the project management / commissioner's perspective. Both will overlap. As the contractor is responsible for a safe and sound execution of the remediation measures as defined in his project scope he should manage all related risks.

The assessment by the contractor should identify all risks associated with each remediation task and define appropriate precaution, reduction or prevention measures for each risk. The contractor and his staff working on-site and involved in any other way should be involved in preparing the TBRA. When doing so, everybody understands and provides input with regard to the risks. As part of the project, risk management the TBRA should be regularly updated and communicated to all staff involved in the work. Table 3.10 presents an example of a TBRA.

Table 3.10 An example of a Task Based Risk Assessment (TBRA)

Task	Risks	Prevention	Exposure risk reduction
Loading plastic bags with Hazardous substances in big bags	Ripping of packaging (plastic bags), exposure to Hazardous substances	Only load undamaged plastic bags in big bags. Repack damaged bags in new plastic bags Load big bags inside warehouse	Zone 3 - PPE
	Big bags falling, injury when stuck	Do not use big bags with damaged handles. Check crane safety (hook needed)	
Transfer of big bags to the truck	Getting stuck underneath crane truck	Do not walk next to truck when moving. Prepare track / soil surface for good driving	Use high visibility vest

3.4.4 Start Work Analysis

In the scope of project risk management, the Start Work Analysis was already discussed in the Guidelines for Phase 2, Section 2.5.4.

This section highlights the main aspects of Start Work Analysis from the perspective of the contractor. A Start Work Analysis (SWA) is a short daily meeting organized by the contractor for the team working on-site that day, before the activities are resumed. The objectives of a SWA are to inform:

- The team of all the tasks planned for this working day
- The individual team members of what is expected from him / her today
- The individual team members about the safety issues such as:
 - The PPE to be used
 - The on-site main traffic movements

A SWA is only used to inform the field staff about what and how things have to be done in a safe, healthy and environmentally sound manner. The daily SWA is also held to verify if the individual team members understand what they have to do; what the colleagues are doing; and how to work safely.

New HSE issues raised should be added to the TBRA and if applicable to the project management Risk Log.

3.4.5 Toolbox meeting

In the scope of project risk management the toolbox meeting was already discussed in the Guidelines for Phase 2, Section 2.5.4 Phase 2.

This section highlights the aspects of toolbox meeting from the perspective of the contractor.

The contractor should organize all toolbox meetings. The purpose of a toolbox meeting is to inform all on-site staff about the remediation activities and the needed H&S requirements.

The first toolbox meeting is just prior to the start of the activities in the field. The following toolbox meetings are also organized by the contractor at regular intervals, for instance once every four weeks. Extra toolbox meetings should be held if there are urgent reasons to inform the on-site staff or if there are major changes having an effect on the HSE aspects of the site. The topics of the toolbox meeting should be registered and all who attended should sign the minutes of the meeting. Topics for a toolbox meeting are already mentioned in Section 2.5.4:

New HSE issues raised should be added to the TBRA and if applicable to the project management Risk Log.

3.4.6 Administrative tasks

Prior to the start of the remediation campaign, a review of all project documentations of the contractor is required. The supervisor should check the following documents and material if they are present and correct:

- Work plan / work instructions
- Staff list including staff details and assigned tasks
- PPE and emergency response equipment (for example first-aid kit, appropriate PPE in case of spillage)
- Permits and operating license for heavy machinery
- Log book
- Emergency response plan

3.4.7 Remediation of the Site Components

In this section, the actual remediation of the earlier for different site components is described. The site components:

1. Storage of hazardous substances
2. Contaminated buildings and infrastructures
3. Buried hazardous waste
4. Contaminated soil and groundwater, including source areas
 - 4.1. Pure hazardous waste mixed with soil, the source area or hot spot
 - 4.2. Strongly contaminated soil
 - 4.3. Moderately contaminated soil and contaminated groundwater
 - 4.4. Slightly contaminated soil

1. Cleaning storages of hazardous substances

Table 3.11 gives examples of the management tasks; responsible parties, time scale, and witness and hold points of the cleaning / remediation of storages with hazardous substances.

Table 3.11 Responsibilities during cleaning of with hazardous substances storage

Remediation tasks	Responsible party	Term	Witness point	Hold point	Reference document
Removal & repackaging	Contractor	Short			Contract & detailed design
Supervise labelling	Supervisor		X		Monitoring & Remediation Plan
Monitor HSE performance	Supervisor		X		Monitoring Plan
Supervise completion	Supervisor			X	Monitoring & Remediation Plan
Loading & off-loading	Contractor	Short			Work plan contractor
Monitor HSE	Supervisor		X		Monitoring Plan
Monitor quantities	Supervisor			X	Monitoring Plan

Remediation tasks	Responsible party	Term	Witness point	Hold point	Reference document
Transportation	Contractor	Short			Contract & detailed design
Monitor safe driving	Supervisor		X		Monitoring Plan
Temporary storage packed hazardous substances	Supervisor	Short			Work plan Supervisor
Monitoring HSE	Supervisor		X		Monitoring Plan
Destruction	Contractor	Short			Contract & detailed design
Monitor HSE	Supervisor		X		Monitoring Plan
Monitoring quantities	Supervisor			X	Contract & detailed design
Reporting destruction	Contractor				Contract & detailed design
Assess destruction report	Supervisor				Remediation Plan
Completion	Contractor	Short			Contract & detailed design
Announcement	Contractor				Official announcement
As completed documentation	Contractor				Photo report & log book
Approval completion	Supervisor			X	Contract, detailed design & Monitoring Plan

2. Decontaminating contaminated buildings, infrastructures, and bunkers

Table 3.12 gives as example the management tasks, responsible parties, time scale, and witness and hold points of the remediation/ decontamination of contaminated building(s) and bunker(s).

Table 3.12 Responsibilities during the decontamination of contaminated building

Remediation management tasks	Responsible party	Term	Witness point	Hold point	Reference document
Decontamination	Contractor	Short			Contract & detailed design
Monitor HSE	Supervisor		X		Monitoring Plan
Supervise completion	Supervisor			X	Remediation Plan
Renovation / demolishing	Contractor	Short			Contract & detailed design
Monitoring HSE	Supervisor		X		Monitoring Plan
Supervision completion	Supervisor			X	Remediation Plan
Loading & off loading	Contractor	Short			Work plan contractor
Monitor HSE	Supervisor		X		Monitoring Plan
Monitor quantities	Supervisor			X	Monitoring Plan
Transport to landfill	Contractor	Short			Work plan contractor
Monitor safe driving	Supervisor		X		Monitoring Plan
Land filling	Land fill owner	Short			Land fill regulations
Monitoring HSE	Supervisor		X		Land fill Monitoring Plan
Monitor quantities	Supervisor			X	Contract & detailed design
Completion	Contractor	Short			Contract & detailed design
Announcement	Contractor				Official announcement
As completed documentation	Contractor			X	Photo report & log book

Remediation management tasks	Responsible party	Term	Witness point	Hold point	Reference document
Approval completion	Supervisor			X	Contract, detailed design & Monitoring Plan

3. Excavating buried hazardous waste

Table 3.13 gives as example the management tasks, responsible parties, time scale, and witness and hold points of the remediation of buried hazardous waste.

Table 3.13 Responsibilities during the remediation of buried hazardous waste

Remediation management tasks	Responsible party	Term	Witness point	Hold point	Reference document
Excavation	Contractor	Short			Contract & detailed design
Monitoring HSE	Supervisor		X		Monitoring Plan
Supervision completion	Supervisor			X	Remediation Plan
Packaging	Contractor	Short			Contract & detailed design
Supervise labelling	Supervisor		X		Monitoring Plan
Monitor HSE	Supervisor				Monitoring Plan
Supervise completion	Supervisor		X		Remediation Plan
Loading & offloading	Contractor	Short			Work plan contractor
Monitor HSE	Supervisor		X		Monitoring Plan
Monitor quantities	Supervisor			X	Monitoring Plan
Transportation	Contractor	Short			Contract and detailed design
Monitor safe driving	Supervisor		X		Monitoring Plan
Temporary storage	Supervisor	Short			Work plan Supervisor
Monitoring HSE	Supervisor		X		Monitoring Plan
Monitoring containment	Supervisor		X		Monitoring Plan
Destruction	Contractor	Short			Contract & detailed design
Monitor HSE	Supervisor		X		Monitoring Plan
Monitoring quantities	Supervisor			X	Contract & detailed design
Reporting destruction	Contractor				Contract & detailed design
Assess destruction report	Supervisor			X	Remediation Plan
Completion	Contractor	Short			Contract & detailed design
Announcement	Contractor				Official announcement
As completed documentation	Contractor			X	Photo report & log book
Approval completion	Supervisor			X	Contract, detailed design & Monitoring Plan

4. Remediation of contaminated soil and groundwater

Table 3.14 gives an example of the management tasks; responsible parties, time scale, and witness and hold points of a soil and groundwater remediation.

Table 3.14 Responsibilities in remediating contaminated soil and groundwater

Remediation management tasks	Responsible party	Term	Witness point	Hold point	Reference document
Excavation source and highly contaminated soil	Contractor	Short			Contract and detailed design
Monitor HSE	Supervisor		X		Monitoring Plan
Supervise completion	Supervisor			X	Remediation Plan
Packaging source	Contractor	Short			Contract and detailed design
Supervise labelling	Supervisor		X		Monitoring Plan
Monitor HSE	Supervisor		X		Monitoring Plan
Supervise completion	Supervisor			X	Remediation Plan
Loading	Contractor	Short			Work plan contractor
Monitor HSE	Supervisor		X		Monitoring Plan
Monitor quantities	Supervisor			X	Monitoring Plan
Transportation	Contractor	Short			Contract and detailed design
Monitor safe driving	Supervisor		X		Monitoring Plan
Temporary storage	Supervisor	Short			Work plan Supervisor
Monitoring HSE	Supervisor		X		Monitoring Plan
Monitoring containment	Supervisor			X	Monitoring Plan
Treatment / destruction	Contractor	Short			Contract and detailed design
Monitor HSE	Supervisor			X	Monitoring Plan
Monitoring quantities	Supervisor			X	Contract and detailed design
Reporting destruction	Contractor				
Assess destruction report	Supervisor			X	Contract and detailed design Remediation Plan
Pump & treat highly contaminated groundwater	Contractor	Short			Contract and detailed design
Monitor HSE	Supervisor		X		Monitoring Plan
Supervise completion	Supervisor			X	Remediation Plan
Remediation of moderately contaminated soil					
Excavate and transport to temporary depot / de-watering basin	Contractor	Short	X		Contract and detailed design
Supervision excavation dewatering	Supervisor	Short		X	Monitoring Plan
Installation bio-remediation system	Contractor	Short & mid	X		Contract and detailed design

Remediation management tasks	Responsible party	Term	Witness point	Hold point	Reference document
Bioremediation	Contractor	Short & mid			Contract and detailed design
Monitoring HSE	Supervisor	Short & mid	X		Monitoring Plan
Monitoring completion	Supervisor	Short & mid		X	Monitoring Plan
Aftercare	Supervisor	Short, mid & long	X		Aftercare Plan
Pump & treat moderately contaminated groundwater	Contractor	Mid			Contract and detailed design
Monitor HSE	Supervisor		X		Monitoring Plan
Supervise completion	Supervisor			X	Remediation Plan
Remediation of slightly contaminated soil					
Planting eucalyptus trees	Contractor	Short		X	Contract and detailed design
Monitoring HSE	Supervisor	Short & mid		X	Monitoring Plan
Phytoremediation	Supervisor	Mid & long		X	Monitoring & Aftercare Plan
Monitoring and aftercare	Supervisor	Mid & long		X	Monitoring & aftercare Plan
Natural attenuate slightly contaminated groundwater	Contractor	Long			Contract and detailed design
Monitor HSE	Contractor			X	Monitoring & Aftercare Plan
Supervise completion	Supervisor			X	Monitoring & Aftercare Plan
Completion					
Announcement	Contractor				Official announcement
As completed documentation	Contractor			X	Contract & detailed design Photo report & log book
Approval completion	Supervisor			X	Contract, detailed design, and Monitoring & Aftercare Plan

3.5 Remediation Evaluation and Closure

After completing the remedial actions, the performance of the remedial option is evaluated based on the criteria defined in the Remediation Contract and the objectives set in the Remediation Plan. The Site Remediation Management ends with the completion of the short-term remediation measures and the installation of the mid and long-term remediation measures.

3.5.1 Remediation Evaluation

When the contractor has officially announced that he has carried all the remediation activities as described in the remediation contract, the short-term remedial results need to be reviewed and reported (see Section 3.6). The evaluation is the basis for the settlement of costs between contractor and the commissioning organization. The logbook provided by the supervisor and the documentation provided by the contractor are used for evaluating the monitoring data. The evaluation report is used to transfer the collected information to the party responsible for the Monitoring and Aftercare of the site in the next phase, Phase 5. The evaluation report also gives an updated CSM with the implemented remediation measures and the residual contamination(s) if present.

Organizing the evaluation is the responsibility of the remediation supervisor. The supervisor is also responsible for preparing the evaluation report. The evaluation procedure depends on the remedial measures: with excavation, the evaluation phase is short and takes place almost simultaneously with the remediation phase, whereas with in-situ remediation of soil and groundwater, the evaluation phase can be longer.

The report should contain the evaluation of the conducted remedial activities, compared with the signed remediation contract and the objectives from the Remediation Plan. Any variances from the original plan should be explained. If the planned remedial targets have not been reached, the reasons for this must be clearly stated. Additional remedial activities proposed for achieving the remedial plan objectives should be listed. If possible, the report should also include information confirming that all the local regulatory requirements have been met.

3.5.2 Remediation Closure

The remediation closure is an important milestone in the sustainable management of contaminated sites. At the remediation closure, the direct environmental risks are removed and the remaining risks will be contained and / or remediated in the next phase, the Monitoring and Aftercare. The remediation campaign can only be closed when the contractor has carried out all tasks described in the contract, both the commissioner and the contractor fulfil the financial obligations, and the required documentation is submitted by the contractor. In general, a successful remediation closure means that:

- Standard procedures and authorized contractors have been used for decontaminating and remediating the site
- All waste has been handled, packaged, temporarily stored and disposed or recovered in a manner which complies regulatory requirements
- Soil and groundwater contamination has been remediated and the residual contamination will be isolated and / or monitored in the next phase, Monitoring and Aftercare

3.6 Reporting of remediation management

The reporting of a remediation project depends on the type of contract used. In case of Item Rate Based Contract and a contract using a detailed ToR, the remediation management report consists of a description of the methods and technology that were used, and the final remediation results described in an updated CSM. In case of a Result Based Contract, the remediation management report consists only of a short description of the methods used and the final remediation results described in an updated CSM. This chapter provides an overview of the contents of the remediation management report of an **Item Rate Based** remediation project.

The remediation management report starts with introduction containing:

- Name and address of the commissioner
- Motivation and the objectives of the remediation
- Site location map and site description
- Type of contamination present

Besides the introduction, the remediation management report of an **Item Rate Based** remediation project should have at least the following chapters:

- Site information, including:
 - General information regarding the site:
 - Address, Size, coordinates,
 - Owner, Land register map
 - Current and future use
 - Historical information and site description including:
 - Historic site use
 - Present day site-use
 - Overview of site investigations
 - Detailed CSM of Phase 2 with contamination overview including:
 - Location and type of the contaminants
 - Maximum concentrations measured / reported
 - Reference to the Remediation Plan
 - Reference to any authority approval for the remediation
 - Overview of all stakeholders including their contact details
 - General organizational aspects
- Implementation of the short-term remediation/ risk reduction measures, including:
 - The definition of the area remediated in the short-term
 - The short-term remediation targets and goals
 - The short-term remediation methods and assumptions prior to start of remediation
 - The status of legal and regulatory requirements

- The preparatory work prior to the start of the short-term remediation
- Chronological overview of the short-term remediation activities including:
 - Starting and end date
 - Preparatory works
 - Temporary storage methodology and locations
 - Excavation limits (on a map) including the excavation depths
 - Witness and hold points
 - Problems and solutions
 - Remarks
- Transport on-site and off-site of materials including:
 - Date, quantity, quality, source and destination
- Chronological overview of groundwater extraction:
 - Start and end date
 - Quantity of extracted and treated water
 - Quality of extracted water
 - Method of treatment prior to discharge
 - Quantity treatment materials used
- Other measures that have been implemented to achieve the remediation goals:
 - Location
 - Description of measures
- Installation of the mid- and long-term remediation measures, including:
 - The definition of the area to be mid and / or long-term remediated
 - Mid and / or long-term remediation targets and goals
 - Mid and /or long-term remediation method and assumptions
 - Status of legal and regulatory requirements
 - Chronological overview of the short-term installation works for the mid and long-term remediation measures including the following aspect:
 - Starting and end date
 - Preparatory works
 - Installation
 - Witness and hold points
 - Problems and solutions
 - Remarks
- Monitoring and aftercare, including:
 - The updated CSM
 - Definition of the area to be monitored and cared for
 - Method monitoring and aftercare of the mid and long-term remediation measures
 - Status of legal and regulatory requirements

- Chronological overview of the monitoring and aftercare activities including following aspects:
 - Starting and end date
 - Preparatory works
 - Witness and hold points
 - Problems and solutions
 - Remarks

The following Appendices are included in the report, as far as applicable, to illustrate and support the information presented in the remediation management report:

- Site layout maps and cross sections with:
 - Contaminated site components
 - Soil and groundwater contamination situation at the start of the project
 - Planned activities from the Remediation Plan
 - Excavation with excavation depths and location of intermediate and end results control samples
 - The presence of residual soil and groundwater contamination
- Site layout maps and cross sections with the as build situation
- Soil profile descriptions, sensory observations and field measurement results
- Analytical results in original format (laboratory reports)
- Quantity and statement on the quality of the soil used to backfill the excavations
- Discharged quantities of contaminated materials (including weighing notes)
- Analytical results and sampling data of site drainage effluent and monitoring wells (including original laboratory reports)
- Statement as to the disposal of contaminated materials off-site such as letters of acceptance written by the owner of a landfill
- Site remediation photo report

4 Phase 5: Monitoring and Aftercare

4.1 Objectives and Tasks

Phase 5 in contaminated site management, the Monitoring and Aftercare, is only implemented when the remediation campaign of Phase 4 is completed and a residual contamination remains at the site. Phase 4, Remediation Management, is completed when the short-term remediation measures are completed and the mid and long-term remediation measures are installed and in operation to remediate the residual contamination.

The objectives of Monitoring and Aftercare are to sustain the obtained remediation results.

This can be reached by making sure that:

- No unwanted contaminant spreading develops from the residual contamination
- Human health, ecological and migration risks remain under control and gradually reduce
- The residual contamination is also remediated

Monitoring and Aftercare should continue until it can be demonstrated that the source of contamination is removed and / or the exposure pathways have been permanently broken and /or the remediation migration has come to a standstill. The time needed for Monitoring and Aftercare depends on several site characteristics such as:

- Contaminant properties
- Hydrogeological conditions
- Type of remediation performed

The process to be followed for Monitoring and Aftercare of contaminated sites is illustrated in Figure 4.1.

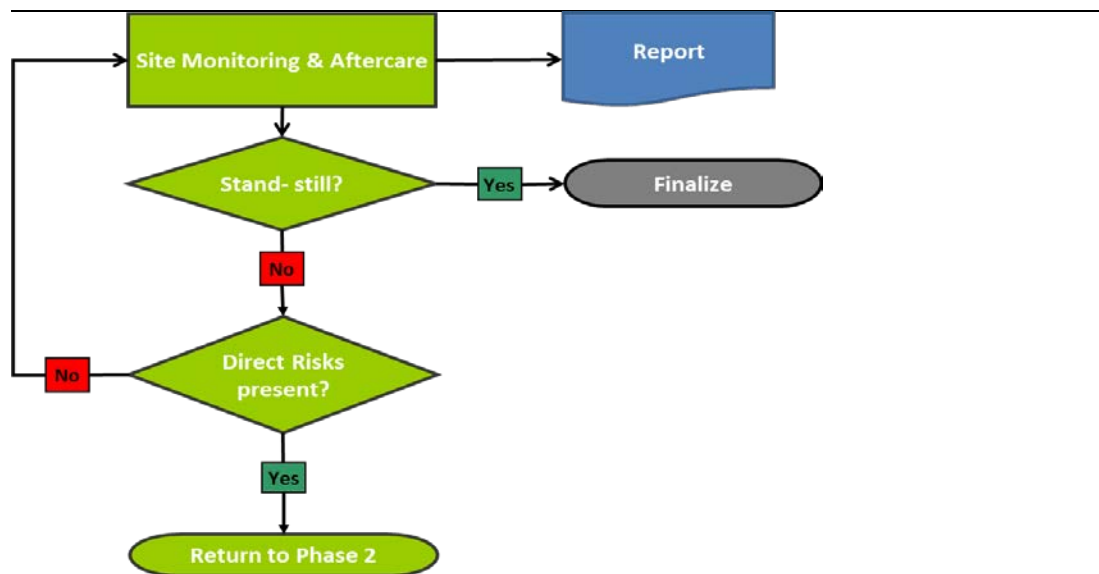


Figure 4.1 Process of Phase 5 of the sustainable management of contaminated sites (source: Tauw, 2015c)

For a better understanding, the term Monitoring and Aftercare and the corresponding objectives in the context of the sustainable management of contaminated sites are explained in more detail below.

Environmental monitoring means to measure and / or observe and document any changes, which may occur over time in the site environmental risk profile. The main objective of site monitoring is to ensure that the mid and long-term remediation measures, installed during Phase 4, Remediation Management, are effective, by:

- Recognizing changes in the environmental impact
- Forecasting possible developments
- Ensuring adequate reactions in case of unexpected events
- Establishing a standstill situation of the contamination in soil and groundwater

Aftercare means the technical support of the implemented risk reduction or remediation measures. Aftercare is essential for sustaining the remedial results. The main objective of the aftercare is to ensure that the mid and long-term operation of the remediation measures are sustained, by:

- Periodic technical inspections
- Periodic technical services
- Technical repairs in case unexpected breakdowns

More than any of the previous phases of the sustainable management of contaminated sites, Monitoring and Aftercare requires clear division and registration of tasks and responsibilities because:

- The yearly financial requirements are often limited in comparison with the short-term remediation campaign
- The technical input is limited but some tasks demand specialized input
- The time span is far longer than any other phases of the sustainable management
- Stakeholder involvement and awareness are crucial success factors

The difference with the other phases is that the Phase 5 tasks are mostly applicable for the site component 'contaminated soil and groundwater'. This is because the environmental risks of the other site components (storage of hazardous substances, contaminated buildings and buried hazardous waste) have been mitigated in Phase 4, the Site Remediation Management.

The following three aspects have to be considered in Monitoring and Aftercare (see Figure 4.2):

1. Organisational
2. Technical
3. Financial

The content of these aspects for the monitoring of the effects of the mid and long-term remediation measures for the residual soil, and groundwater contamination are:

- Organisational aspects:
 - Reliable monitoring sampling and sample analyses are ensured
 - Monitoring is organized for the long-term (years)
 - Enforcement of restricted site-use is institutionalized
 - All relevant stakeholders are informed
 - A local focal point for site monitoring activities is appointed
- Technical aspect:
 - Conducting environmental sampling and analyses
 - Recognizing changes in the environmental impact
 - Forecasting possible developments
 - Ensuring adequate reactions in case of unexpected events
 - Establishing a standstill situation of the contamination in soil and groundwater
 - Reporting and evaluating monitoring data
- Financial aspect:
 - Ensuring yearly budget for:
 - Adequate environmental sampling and analyses
 - Unexpected events
 - Evaluating and reporting the monitoring results

Aftercare of the installations for the mid and long-term risk reduction measures is needed to sustain and improve the remediation results in the soil and groundwater.

The content of these aspects for the aftercare for the installation to contain and / or remediate the residual soil, and groundwater are:

- Organisational aspect:
 - Ensuring that aftercare is carried out by a reliable partners
 - Aftercare is for the long-term (years)
 - A local focal point for site aftercare activities is appointed
- Technical aspect:
 - Inspecting all technical installations periodically
 - Servicing of all technical installations periodically
 - Repairing any technical installation when broken
- Financial aspect:
 - Ensuring yearly budget for
 - Adequate aftercare
 - Unexpected breakdowns
 - Evaluating and reporting the aftercare

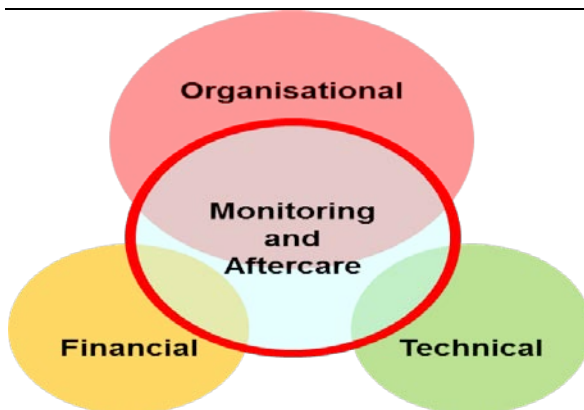


Figure 4.2 Monitoring and Aftercare consists of organisational, financial, and technical aspects (source: Tauw, 2015c)

4.2 Updating Monitoring and Aftercare Plan

Discrepancies between the CSM made in Phase 2 and the real situation revealed during soil and groundwater remediation often occur. The CSM has to be updated based on the situation after the short-term remediation measures are implemented in Remediation Management, Phase 4. In addition, the strategy for the necessary Monitoring and Aftercare has been developed in Phase 4.

The original Monitoring Plan, developed in Phase 4, has to be updated at the end of Phase 4, based on the updated CSM. If this has not been done, the Phase 5 starts with updating of the Monitoring and Aftercare Plan for Phase 5.

4.3 The Monitoring and aftercare Plan

4.3.1 The Monitoring

Monitoring of the site includes monitoring of residual contamination and the parameters directly connected to the environmental status of soil and / or groundwater. Relevant site data should be collected by sampling and analysis (following the analysis program in the updated Monitoring and Aftercare Plan); and by recording technical data of remediation and containment installations (e.g. discharges, pressures and levels). Table 4.1 presents a (simplified) Monitoring Plan for a remediated site with residual contamination in soil and groundwater. This residual contamination is contained and will be remediated by phytoremediation in the long-term. As shown in the table, witness and hold-points are used for the monitoring.

Table 4.1 Example of a Monitoring for the mid and long-term risk reduction / remediation measures

Long-term risk reduction measures	Monitor	Points	
		Witness	Hold
Installed containment measures	Quality, location and function of installation	X	
	Safe behaviour and proper use of PPE site staff	X	
Phytoremediation	Recording effect of phytoremediation	X	
	Periodic soil sampling and analyses		X
	Periodic groundwater sampling and analyses		X
Stakeholders Awareness	Enforcement of restricted site and groundwater use	X	
	Progress of stakeholders involvement	X	

Soil monitoring

If residues of hazardous substances exist in the soil, soil monitoring should be part of the Monitoring Plan of the site. Since residues of hazardous substances in the soil remain stable over prolonged periods, very frequent monitoring of the contamination in the soil will not provide any additional information if there is already a mid / long-term remediation system in place.

Therefore, sampling and sample analysis with a low frequency, for instance yearly, will be sufficient for monitoring the process of soil remediation. As explained in Part 1 of these Guidelines (Site Assessment), analysis of Composite Soil Samples (CSS) for the Chemicals of Concern (CoC) can be used for establishing/ monitor the soil quality.

Groundwater monitoring

Groundwater monitoring is used to gain insight into:

- The development of the groundwater quality
- The off-site migration and / or migration of the residual groundwater contamination to any sensitive objects

Contaminant spreading with the groundwater depends on a number of factors, which should be included in Monitoring Plan and quantified to the maximum extent possible to allow for an objective review of the effectiveness of the mid and long-term remediation measures. These factors are:

- Characteristics of the contaminant (solubility in water)
- Hydrogeological characteristics (groundwater flow direction, rate, level and fluctuation)
- Chemical characteristics of the groundwater (pH, redox potential and regional baseline quality)
- Geology of the area (subsurface medium, horizontal and vertical permeability of the aquifer and porosity of the aquifer)
- Site location characteristics (topography, potential for surface run-off, site use, groundwater use, groundwater abstractions and sensitive objects)
- Site surrounding characteristics (topography, surface run-off, land use of site surroundings, groundwater use, groundwater abstractions and sensitive objects)

Sensitive objects are for instance shallow and deep-wells used for public water supply, surface water bodies used for domestic purposes, for watering livestock and or watering kitchen gardens and agricultural fields.

As a basic rule, these objects are sensitive if they are located within a distance of:

- 10 times the length of the groundwater contamination plume down-gradient
- 2 times the length of the groundwater contamination plume up-gradient
- 3 times the width in a lateral direction of the groundwater plume

Figure 4.3 illustrates this basic rule concerning distances of the groundwater plume to sensitive objects. The Risk Assessment conducted in Phase 2 of the contaminated site management should have identified and recorded these sensitive objects already. If the situation at the site or its surroundings has been changed, the risks should be re-assessed using the CSM updated.

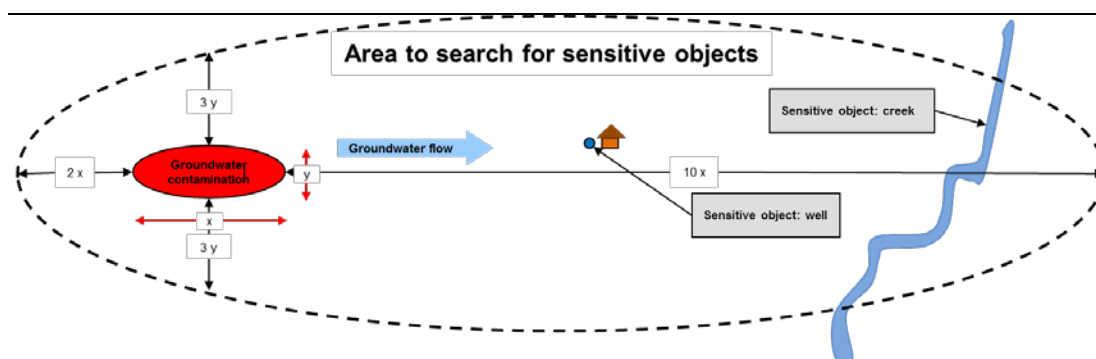


Figure 4.3 Sensitive objects to be considered in the Monitoring Plan (source: Tauw, 2015c)

A monitoring network can only be designed if the sensitive objects and the main components influencing the potential spreading of the residual contamination have been identified. The monitoring network should be designed in such a way that it provides information on contamination spreading in a timely manner; establishes the rate and direction of spreading; and in case the contaminated groundwater flows towards sensitive objects, ensures that sufficient time remains for implementing proper measures.

In addition, the groundwater Monitoring Plan should have a monitoring well or piezometer upstream of the contaminated site that allows for establishing the conditions of the groundwater that flows towards the residual contamination. Where possible, existing piezometers should be used, but only when they are correctly placed, (drinking water wells or wells with unknown configuration should not be used). In order to save costs, a minimum amount of piezometers should be used, as long as proper monitoring of contaminant migration can be ensured.

Figure 4.4 presents an example of a monitoring system to verify horizontal spreading of the residual contaminant. A typical monitoring network consists of the following piezometers (numbers used in the bullet list refer to the numbers given to the monitoring wells in figure 4.4):

1. Up-gradient piezometer, for determining the quality of groundwater flowing towards the contaminated plume (the baseline groundwater quality)
2. Central piezometer, for monitoring the area with the highest contaminant concentrations
3. Down-gradient piezometer at the edge of the groundwater contamination, for monitoring the contaminant migration
4. Back-up piezometer at a distance of approximately double the length of the groundwater contamination plume, for monitoring standstill and unexpected migration
5. Additional piezometers between the piezometer at the end of the residual contamination and the sensitive objects, when the sensitive objects are:
 - a. Within 2-3 times the length of the groundwater contamination

- b. At a distance of around 1 time yearly groundwater flow rate when measured from the sensitive object
6. Piezometers for verifying the direction of spreading perpendicular on the groundwater flow direction (the so-called lateral piezometers). These piezometers should be placed at approximately 2 times the width of the contaminated plume

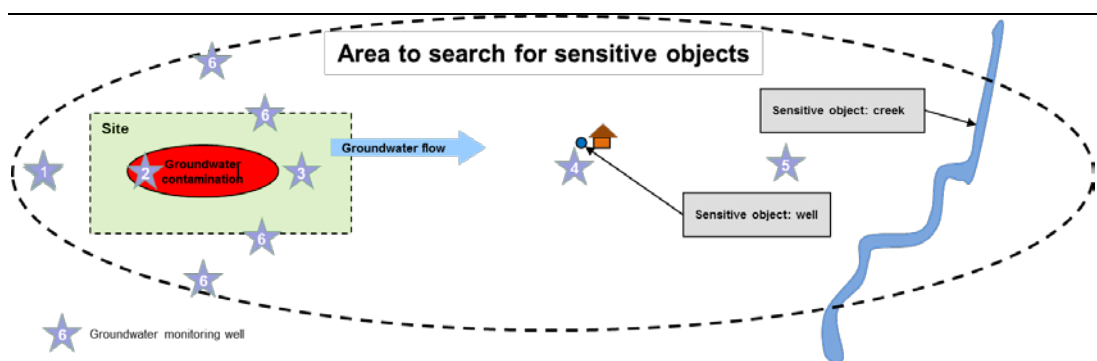


Figure 4.4 Example of a groundwater monitoring layout (source: Tauw, 2015c)

Downward spreading of contamination in the groundwater only applies to those contaminants that readily dissolve in groundwater or that are heavier than water. In the case of the OHIS site, these are mostly the degradation products of HCH (Chlorobenzenes). For monitoring the downward spreading of groundwater contaminants, additional deeper piezometers should be installed down gradient of piezometer number 2 and at the same position as piezometer number 3. The deep piezometers should be placed in such a way that the filter screen is positioned in the deeper groundwater and is not in contact with the shallow groundwater layers. If the piezometer is not installed correctly, it may cause preferential vertical groundwater flow, which may allow the contaminants to migrate in the deeper groundwater. For the description of the installation of deep piezometers, see Part 3 of these Guidelines (SOP 5.3).

Monitoring parameters and frequency are important aspects of a groundwater monitoring. The frequency of monitoring should be different for the different piezometers. Generally, the piezometers in the most contaminated zone of the groundwater plume and at the edge of the plume should be monitored most often, whereas the other piezometers can be monitored with a lower frequency. Monitoring intensity should decrease over time, if there is no significant variation in sequential monitoring rounds. However, if contaminant spreading is suspected, the intensity should increase.

Regarding monitoring parameters, it is often easy to analyse for a whole range of CoC and their associated degradation products. However, contaminant spreading is strongly dependent on the chemical characteristics of the parameters. Therefore, Table 4.2 in Section 4.5 gives, as a rule, the compounds and the frequency that should be monitored at the different locations.

Trigger and Action values for groundwater monitoring

An important part of the monitoring is to determine when a change in the contamination situation is taking place. An objective way to do this is by establishing trigger and action values.

A **Trigger value** is a value at which there is an indication of possible change in the behaviour of the contaminated soil or groundwater. If the contamination in a soil / piezometer sample exceeds the trigger value, this will not necessarily mean that immediate action is required. A trigger value should lead to a review of the contamination situation and possibly adjustment of the monitoring system and frequency. Trigger values can be exceeded for many years continuously without significant actions are required. A common action for an exceeded trigger value is to increase the monitoring frequency, to conduct additional soil sampling or to install additional piezometers in order to understand better, the behaviour of the contamination in the soil or groundwater.

An **Action value** is a value that cannot be exceeded. If the action value in a soil sample or piezometer is exceeded, immediate action is required. Exceeding the action values for longer periods indicates that the remediation and / or containment of the site contamination have not been successful and direct risks are present or imminent. In this case, please refer to Phase 2 (Site Assessment).

Other types of monitoring

In addition to soil and groundwater, it is possible to conduct monitoring for a variety of other components such as ambient air quality, POP residues in crops and livestock products etc. Monitoring for these components is as such only beneficial in case a residual contamination remains that, due to difficulties with the remediation, is very close to the original established direct risk values for the site.

These types of monitoring require expert judgement and are often very costly. Therefore, these types of monitoring are not described in the framework of these Guidelines.

4.3.2 The Aftercare

Aftercare is essential for sustaining the remediation results. If monitoring of the contamination provides enough information on the behaviour of the residual contaminant, the aftercare only focuses on the review, maintenance and support of the implemented mid/ long-term remedial and / or containment measures. This section describes the process of drafting a sustainable aftercare plan. Aftercare of a site consists of:

1. Inspecting, maintaining and replacing the physical measures that have been implemented on-site to prevent environmental risks from the residual site contamination
2. Inspecting, maintaining and enforcing the site-use restrictions

These activities are further described in this section.

1. Inspecting, maintaining and replacing physical measures

Before starting the aftercare program, the main features of the implemented physical measures should be inventoried and an inspection, maintenance and replacement program should be drafted. In most cases, the bid book or technical proposal from the contractor provides the essential information for drafting such program. The inspection, maintenance and replacement program consists of four parts:

- The tasks required to keep the implemented physical measures in an appropriate state
- Assignments and responsibilities for the above mentioned tasks
- Financial management of the inspection, maintenance and replacement
- The reporting of the tasks and the associated communication chain

A responsible party should be assigned for each task in the program. The budget for these tasks should be established and safeguarded as early as possible. The reporting and communication requirements for each task should be made clear.

2. Inspecting, maintaining and enforcing site-use restrictions

The enforcement of site-use restrictions is often the most difficult part of the aftercare. Over the years, the site ownership might change, the land pressure may increase and the precise reasons for the site-use restrictions can be quickly forgotten. In order to prevent this, it is essential that the party, responsible for enforcing the site-use restrictions regularly, communicates about the reasons for the site-use restrictions and related measures with the site users. The site users should also get informed of the potential effects if the site-use restrictions are not respected.

The responsible party should be in charge of maintaining the details of all stakeholders involved and regularly reviewing these details. If any changes take place, the new stakeholders should be informed about the site-use restrictions as well.

4.4 Organization of Monitoring and Aftercare

4.4.1 General

The main bottleneck of good monitoring and aftercare is to implement the monitoring and aftercare activities in such a way that it is appropriate over a prolonged period. For a proper monitoring and aftercare program, appointing the following four parties is essential:

1. **Accountable Party:** The party that bears the final responsibility, this is in most cases the funding agency and/ or the national implementing organization
2. **Responsible Party:** The party or parties that have the responsibility for the execution of monitoring and aftercare tasks
3. **Consulted Party:** The party or parties that have necessary information to contribute to sustain the monitoring and aftercare objectives
4. **Informed Party:** The party or parties that should be informed and that should be aware of the planned execution and / or results of the monitoring and aftercare program

Communication to all the stakeholders about the involved parties and their respective roles in the monitoring and aftercare will make all parties more aware and accountable for their parts and will improve the long-term effectiveness of the monitoring and aftercare measures.

The communication means can differ, but are for instance:

- Supplying all stakeholders with the site Monitoring and Aftercare Plan
- Providing all stakeholders with an overview of the involved parties, their contact details and respective roles and responsibilities within the monitoring and aftercare program
- Organizing monitoring and aftercare information meetings to share monitoring results and experiences and to raise capacity and awareness at regular intervals

4.4.2 Costs

For monitoring and aftercare to be successful, it is essential that sufficient funds are safeguarded as long as there are any residues of contamination on the site. The yearly budget has to be estimated at the start of Phase 5. The funding agency has to budget funds on an annual basis for:

- Adequate environmental sampling and sample analysis
- Unexpected events in relation to the environmental risk profile
- Adequate aftercare
- Unexpected events in relation to repairs, replacements of mid and long-term remediation installations

4.5 Reporting of Monitoring and Aftercare

An evaluation report of the site monitoring and aftercare should give the reader a short organized overview of the situation at the site, including an insight in the responsibilities of the various stakeholders. The evaluation report does not need to describe the remediation that was executed at the site in detail. Reporting the evaluation has to be done periodically (mostly annually) by the party that carries out the monitoring and aftercare activities.

The evaluation report of the monitoring and aftercare should be short and start with an introduction including:

- Contact details of parties responsible for monitoring and aftercare
- Site name and a short site characterization
- Short description of the site history, including references to the site Phase 1, 2, 3 and 4 reports
- Summary of the reasons and the objectives for the monitoring and aftercare

Besides the introduction, the evaluation report should have at least the following chapters:

1. Situation prior to the remediation giving the reader a general overview of the status of the contaminated site before the remediation. Information in this chapter can be obtained from the Phase 2 report but should at least include:
 - Description of the site prior to the remediation
 - Any decision of the authorities connected to the remediation
 - Description of the type of remediation executed
 - Remediation targets and results
 - Residual contamination
2. Monitoring and aftercare organization, objectives, requirements and interpretation
 - A list of the responsibilities and monitoring and aftercare tasks of each stakeholder (accountable, responsible, consulted and informed parties) with the:
 - The contact details
 - The monitoring and aftercare tasks
 - Yearly planning
3. Monitoring results, describing
 - The relevant locations of the monitoring points
 - The monitoring frequency and compounds (see Table 4.2)
 - The monitoring results and the evaluation of the results
 - A decision model if and what steps are necessary when monitoring values exceed the trigger or action values (see Table 4.3)
4. Aftercare results, describing:
 - The aftercare tasks (see Table 4.4)
 - The relevant locations of the aftercare
 - The site-use restrictions (type of plants that can be planted, maximum depth for excavation, use of groundwater etc.) and the risks when the site-use restrictions are not followed
 - The maintenance program and substitution program, including information on how an inspector determines if maintenance or substitution is necessary
 - The results of the maintenance and aftercare

5. A chapter with the conclusions and recommendations for the next year of Monitoring and Aftercare

The evaluation report contains at least the following appendices:

- Location of the site in a regional setting
- Site layout map showing
 - The presence of the residual contamination
 - The site-use restrictions
 - The mid / long-term remediation measures
 - The sensitive objects
- Table characterizing the residue of the soil and groundwater contamination
- Site layout map showing the exact position of the soil samples and the piezometers
- The analytical certificates of the sample analyses

The party that has to report the results of the monitoring and aftercare submits periodically (yearly) an evaluation report containing the same information as the first evaluation report, but each time updated with the most recent monitoring and aftercare results.

Table 4.2 The monitoring frequency and compounds the first years

Piezometer*	Location with respect to the groundwater plume	Responsible**	Frequency	Immobile CoC	Mobile CoC	Degradation products	pH, Redox, Ec, Nitrate, Sulphate and Oxygen
1	Up-gradient	-	Yearly	x	x		
2	Centre	-	Half yearly	x	x		x
3	Just down-gradient	-	Half yearly	x	x	x	x
4	Down-gradient	-	Yearly		x	x	
5	Far down-gradient	-	Biannual		x	x	
6	Lateral outside	-	Yearly	x	x	x	
7	Deep	-	Half yearly	x	x		
	Sensitive objects (domestic well)	-	Yearly		x		

* See Figure 4.4 for the indicated piezometers

** This will be project specific

Table 4.3 Monitoring program signal and threshold values

Monitoring subject	Signal value*	Action value*	If > Trigger value	If > Action value
Groundwater in centre of plume	-	-	<ul style="list-style-type: none"> • Increase monitoring frequency to 4 times per year • If persists place new piezometer downstream for additional supervision • Revise monitoring frequency 	<ul style="list-style-type: none"> • In case of surpassing 2 consecutive monitoring rounds • Re-assess remediation (return to phase 2)
House hold well	-	-	<ul style="list-style-type: none"> • Increase monitoring frequency to monthly 	<ul style="list-style-type: none"> • Close well • Supply drinking water from an alternative source • Return to phase 2 (Site Assessment)

* This will be project specific

Table 4.4 Aftercare program

Aftercare subject	Inspection program	Frequency	Responsible
Contact layer	Check presence of excavations and / large scale soil movement in the area	Monthly	Site care taker
On-site pump	Inspect all flow lines, connections and taps	Monthly	Contractor
Treat installation	Inspect all components of the installation	Monthly	Contractor
Site fence	Maintain in and outside a zone of 1 meter free of scrubs and bushes along the fence enclosing the site	Monthly during grow season Once during dry season / winter	Site care taker

5 References

FAO, 2009 – 2010: FAO Pesticide Disposal Series – Environmental Management Tool Kit for Obsolete Pesticides.

Volume 1: <ftp://ftp.fao.org/docrep/fao/011/i0473e/i0473e.pdf>

Volume 2: <ftp://ftp.fao.org/docrep/fao/011/i0474e/i0474e.pdf>

Volume 3: http://www.fao.org/fileadmin/templates/obsolete_pesticides/Guidelines/EMTK3web_nov_small.pdf

Volume 4: http://www.fao.org/fileadmin/templates/obsolete_pesticides/Guidelines/EMTK4xweb_nov_small.pdf

Tauw, 2015a: EMP Guidelines for Sustainable Management of POP pesticides contaminated sites, PHASE 3 the Site Remediation Assessment

Tauw, 2015b: EMP Guidelines for Sustainable Management of POP pesticides contaminated sites, PHASE 4 the Site Remediation Management

Tauw, 2015c: EMP Guidelines for Sustainable Management of POP pesticides contaminated sites, PHASE 5 the Site Monitoring and Aftercare

UNEP, 2011: Selection of Persistent Organic Pollutant Disposal Technology for the Global Environment Facility. https://www.thegef.org/sites/default/files/publications/POPs_Disposal_Final_low_1.pdf

UNIDO, 2010: Persistent Organic Pollutants: Contaminated Site Investigation and Management Toolkit. http://www.unido.org/fileadmin/user_media/Services/Environmental_Management/Stockholm_Convention/POPs/toolkit/Contaminated%20site.pdf