Network Oriented Risk-assessment by In-situ Screening of Contaminated sites

NORISC

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Content

Guidance for using the Revitalisation Module

1. Introduction

The Revitalisation Module is based on multi-site management (MSM). Stakeholders apply MSM to select one or more contaminated sites for revitalisation and the suitable remediation option(s). The ultimate goal of MSM is to select the optimal "site-remediation option" combination(s).

The MSM is used for the following purposes:

- to summarise the investors' expectations from the "site- option" combinations,
- to characterise the sites,
- to characterise the available remediation options.

The input of MSM is the output of several single-site management (SSM) processes. (SSMs are based on the data provided by site investigation.) SSMs identify the sites and remediation options available for MSM.

By using MSM:
1) stakeholders rank the available remediation options and sites, and
2) select one or more sites and the related remediation option(s).
Since more than one remediation option may be identified for a particular site, the "site - remediation option" combinations (not only sites or options) should be ranked and selected from.

Each MSM questionnaire refers to a particular site and a related remediation option. If several remediation options are relevant for the same site, several questionnaires should be filled in for that particular site. In this case the questionnaires on the site will differ only in the characterisation of the available options.

All questions of the MSM questionnaire must be answered.

2. Guidance for filling in the questionnaire and input sheets of the revitalisation module

2.1. Investors' expectations from the site

This section of the questionnaire should be filled in only by private investors. State and municipal officials should not fill in this section.

1. Characteristics of the requested site

1.1 Extent of the site (m^2)

The minimum and maximum requested size of the site should be given.

1.2 Planned revitalisation function on the site

The function as a result of remediation should be given from Table 1.

TABLE 1. POSSIBLE FUNCTIONS OF THE SITE AFTER REMEDIATION AND THEIR CODE NUMBERS

Function of the site	Code number
Industrial and storage area	1
Agricultural area	2
Non-agricultural ecosystem	3
Playground, garden, sports area, park, recreational area	4
Residential area	5
Institutional area	6
Multifunctional area	7

1.3 Requested type of area

The type of area includes:

- the requested type of infrastructure (electricity, water supply, sewage, gas, road, rail, water transport route, air transport route, telephone wire, etc.) at the site;
- distance from a major city.

2. Total cost of remediation, EUR

The estimated minimum and maximum total cost of remediation should be provided (in EUROs).

3. Requested net financial profit, EUR

The minimum and maximum net financial profit (direct financial revenues minus total costs) requested from remediation should be provided (in EUROs).

2.2. Data of the sites and remediation options

1. Characterisation of the contaminated site

1.1 Name of the site

The official name of the site (as it appears in the official documents) should be provided. If this is not possible, the site should be described to make its identification possible. The names of the contaminating substances and the location of the contamination should be given. For example, "benzene contamination 2 km north-west from city X" or "toluene contamination in the east end of street Y in village Z".

1.2 Address of the site

The postal address and, if possible, land registry number of the site should be filled in. If no postal address exists, the location of the site should be identified as precisely as possible.

1.3 Co-ordinates of the site

The geographical co-ordinates with which the site can clearly be identified on a map should be provided.

1.4 Extent of the site (m^2)

The size of the requested site should be filled in (expressed in m^2).

1.5 Type of area

The type of area should be characterised by:

- selecting from the pop-up menu the requested type of infrastructure at the site;
- indicating the distance from major cities (if relevant) by using the pop-up menu.

1.6 Available infrastructure on the site

The type of the available infrastructure should be selected from the pop-up menu.

1.7 Type of area

The type of area includes:

- the requested type of infrastructure (electricity, water supply, sewage, gas, road, rail, water transport route, air transport route, telephone wire, etc.) at the site;
- distance from a major city.

2. Characterisation of the available option

2.1 Targeted levels of clean-up

Targeted levels of clean-up

The targeted levels of clean-up are the concentrations of contaminants to be achieved by remediation. The targeted level of clean-up for a contaminating substance may be 1) the national limit value or 2) a site-specific level. In the second case, the site-specific level of clean-up ensures the required levels of health risk and environmental risk. The required levels of risks should be determined by the stakeholder filling in the questionnaire. The required levels of risks depend on the intended use of the site after remediation.

The concentrations of the most important polluting substances to be achieved by remediation should be given in mg/m^3. The importance of the substances should be determined according to their quantity and hazardousness.

2.2 Clean-up method

A **clean-up** method consists of a particular set of remediation technologies with which a certain targeted level of clean-up can be achieved.

Table 1, Possible remediation technologies and their code numbers

Name of remediation technology	Code number
Biodegradable treatment	1
Controlled (natural) biodegradation	1.1
Stimulated (guided) aerobic biodegradation	1.2
Oxygen enhancement with air/oxygen	1.2.1
- bioventillation (soil, in situ)	
- enhanced bioremediation (soil, in situ, ex situ)	
- enhanced bioremediation (ground water)	
Soil loosening methods	1.2.2
- soil cultivation treatment (soil, in situ)	
- biobed treatment (soil, ex situ)	
- composting (soil, ex situ)	
- treatment with agricultural technics (soil, ex situ)	
Process in container	1.2.3
- slurry phase biological treatment (soil, ex situ)	
- bioreactors (ground water, ex situ)	
Intended / planned vaccine usage	1.2.4
Physical / chemical treatment	2.
Soil washing	2.1
- in situ	
- ex situ	
Aeration, soil vapor extraction	2.2
- soil aeration (soil, ground water, in situ)	

Name of remediation technology	Code number
- air injection + soil vapor extraction (ground water, in situ)	
- stripping (ground water, ex situ)	
Gas extraction by vacuum (in-well air stripping)	2.2.1
Chemical extraction	2.3
- solvent extraction (soil, ex situ)	
- acidic extraction (soil, ex situ)	
Chemical oxidation / reduction	2.4
Separation	2.5
- gravity separation (soil, ex situ)	
- filtering (ground water, ex situ)	
- distillation (ground water, ex situ)	
- reverse osmosis (ground water, ex situ)	
- membrane pervaporation (ground water, ex situ)	
Solidification / stabilization	2.6
- bituminization	
- emulsified asphalt	
- Pozzolan / Portand cement	
- soluble phosphates, liming	
- sludge stabilization	
Adsorption (with activated carbon)	2.7
Ion exchange	2.8
Coagulation and flocculation	2.9
UV oxidation (UV photolysis)	2.10
Thermal treatment	3.
Incineration	3.1
- rotary furnaces	
- infrared furnaces	
- fluidized bed furnaces	
- melting bed furnaces	
Pyrolysis (thermal degradation)	3.2
Thermal desorption	3.3
- low temperature (90-320 °C)	
- high temperature (320-560 °C)	
Isolation processes	4.
Gap-walling	4.1
Curtain walling	4.2
Hydraulic isolation (dike)	4.3
Upper isolation (covering)	4.4
Cleaning processes of steams and gases	5.
Adsorption by activated carbon	5.1
Oxidation	5.2
- thermal oxidation (incineration)	
- catalytic oxidation (CuO, MnO2, NiO, CrO, platinum, palladium)	

In *Annex 1,* there is a detailed list of in situ and ex situ remediation cleaning techniques for soil and groundwater with short description and an average of unit for cost. These information can be used for

estimation of the cost of the remediation process, however it is always more adequate to calculate the total cost using as many site specific data as possible instead of such generated average values.

2.3 Possible revitalisation functions of the site after remediation

The revitalisation functions of a site refer to the purposes for which the site can be used as a result of remediation. For example, following remediation the site can be used as a residential area whereas in its present state the site may be used only as an industrial area. The possible functions are shown in Table 2.

Table 2 Possible functions of the site after remediation

Industrial and storage area
Agricultural area
Non-agricultural ecosystem
Playground, garden, sports area, park, recreational area
Residential area
Institutional area
Multifunctional area

2.4 Impacts

The impacts of remediation include the avoided environmental and health risks and better land use. The impacts are expressed as indices of avoided risks and change in land value (see below). Some examples are provided below for calculating risk indices, nevertheless, the actual method depends on the practice of the particular country in which the questionnaire is filled in.

2.4.1 Index of avoided human health risk

As a result of remediation health risks will be avoided. Risks are caused by different substances to different types of receptors existing at different distances from the contamination. These differences should be taken into account in the estimation of health risks. The index of the prevailing health risk may be calculated as:

$$R = PEC/PNEC$$

where

R: risk,
PEC: actual concentration of the contaminant,
PNEC: “tolerable” concentration of the contaminant.

2.4.2 Index of avoided, detailed, quantitative risk

The index of detailed, quantitative risk includes both health risks and environmental risks. The index allows the characterisation of risks both in absolute terms and in comparison to risks at other sites (ranking of site-option combinations). Various methods exist for calculating the index of avoided,

detailed, quantitative risk. It should be ensured that the same method is used for all sites analysed within the same MSM process.

2.4.3 Index of the avoided, simplified, relative and qualitative risk

The calculation of the index of relative and qualitative risk is a simplified risk assessment. As a result of the process a score is generated for each site-option combination expressing the level of risk due to contamination (which will be avoided by remediation). The site-option combinations are ranked according to their scores. The method is able to characterise the sites in relation to all other sites (comparison), although the method is unable to characterise the sites in absolute terms.

For example, a method may be used assessing the risks to environmental media (groundwater, geological medium) and by risk-influencing factors (types, quantities and condition of contaminants, dissemination of contamination, receptors, etc.). The value of each factor is weighed and added for each environmental medium. The aggregate score represents the risk index of the site.

Various methods exist for calculating the index of avoided, simplified, relative and qualitative risk. It should be ensured that the same method is used for all sites analysed within the same MSM process.

2.4.4 Change in land value, EUR

As a result of remediation better land use will be possible, for example, the site can be used as a residential area instead of industrial area. The possibility of better land use increases the monetary value (price) of the site. The estimated increase in the value of the site should be provided in EUROs.

The change in land value may be estimated by using various methods. A possible method considers the following factors:

- the unit price (EUR/m^2) of uncontaminated sites in the neighbourhood which are used for the same purpose as the characterised site,

- the price ratio of contaminated and uncontaminated sites in another area (reference area). The price ratio of contaminated and uncontaminated land (P_{cr}/P_{ur}) is different for different land uses (industrial site, agricultural site, etc.).

The change in land value (i.e., the price increase as a result of remediation) at current prices may be estimated by using the following formula:

$$CV = E * P_u * (1-P_{cr}/P_{ur})$$

where:

CV: change in land value (EUR),
E: extent of the site (m^2),
P_u*:* unit price of uncontaminated site used for the same purpose in the neighbourhood (EUR/m^2),
P_{cr}*:* price of contaminated reference site (EUR/m^2),
P_{ur}*:* price of uncontaminated reference site (EUR/m^2).

To characterise an option the present value (PV) of the change in land value should be calculated. The PV is calculated by using the following formula:

$$PV = \frac{CV_i}{(1+r)^i}$$

where:

CV_i: change in land value in year i (C_0: current year),
r: general discount rate,
i: serial number of the year when the value change emerges.

2.5 Remediation cost, EUR

To characterise an option all incurred and planned costs clearly related to any remediation phase should be given (in EUROs). The costs of preparing, planning, implementing, and documenting each remediation phase, as well as all procedural and litigation costs related to the remediation process should be provided.

To ensure the addibility of the costs emerging in different years the present value (PV) of the costs of each remediation phase should be calculated. PV is calculated by using the following formula:

$$PV = \sum_{i=1}^{t} \frac{C_i}{(1+r)^i}$$

where:

C_i: cost in year i (C_0: current year),
r: general discount rate,
i: serial number of the year when costs emerge,
t: serial number of the last year when costs emerge.

2.5.1 Cost of site investigation and assessment

Site investigation is used to determine the level and spatial distribution of contamination on the site. The PV of all costs related to site investigation and assessment should be calculated, added and filled in here.

2.5.2 Cost of clean-up

During the clean-up phase of remediation a certain portion of the contamination is removed to achieve the targeted levels of clean-up for the contaminants. The PV of all costs related to the clean-up phase should be calculated, added and filled in here.

2.5.3 Cost of follow-up monitoring

After the clean-up phase the state of the site should be monitored continuously for a certain period. Monitoring is necessary to find out the possible appearance and transfer of contaminants. The PV of all costs related to follow-up monitoring should be calculated, added and filled in here.

2.5.4 Total cost of remediation

The amounts in Questions 2.5.1, 2.5.2, and 2.5.3 should be added and their sum should be provided here.

2.6 Results of the simplified cost-benefit analysis

The simplified cost-benefit analysis compares the beneficial impacts (avoided risks) with the total costs of remediation. Financial analysis, however, considers only the direct financial costs and benefits related to remediation (see Question 2.7). The ranking of the option-site combinations may be based primarily either on cost-benefit analysis or on financial analysis depending on the preferences of the stakeholders. State budget officials and city developers rank the combinations primarily on the basis of the cost-benefit analysis. Investors, however, rank the options based on the results of the financial analysis. Carrying out both types of analyses allows the ranking of the combinations according to different preferences.

To carry out the simplified cost-benefit analysis:

1) one of the risk indices (from Questions 2.4.1, 2.4.2 or 2.4.3) should be selected;

2) the value of the selected risk index should be divided by the total cost of remediation (2.5.4) in the following way (see also Question 2.6.1):

Cost-benefit index = value of risk index / total cost.

2.6.1 Selected index of risk/total remediation cost

The value of the selected risk index (from Questions 2.4.1, 2.4.2 or 2.4.3) should be provided on the dotted line of the 2nd column (titled "Question").

The value of "risk index / total cost" should be given in the 3rd column (titled "Answer"), as well as in the module software at input sheet "Characterisation of the contaminated site" / "Options". The "risk index / total cost" ratio may be given for more than one risk index, if the ratios weighted average is used for ranking the options (see 2nd bullet of the description of Question 2.6.2).

2.6.2 Priority number based on cost-benefit analysis

A priority number should be given to each "site - remediation option" combination to allow the ranking of the combinations. Priority numbers express how "good" each combination is in relation to the others. Priority numbers may be calculated in two different ways.

- In the first case, a certain type of "risk index / total cost" (for example, "index of avoided human health risk/total cost") is selected and used as the priority number for each site. In this case the "site - remediation option" combinations are ranked according to that single type of priority numbers.

- In the second case, all three types of "risk index / total cost" are used for ranking the sites. All three types of indicators should be weighed and considered for each site.

To allow comparison of the sites within the country/region/city the priority numbers for all "option & site" combinations should be calculated with the same method.

2.7 Results of the financial analysis

2.7.1 Change in land value/total remediation cost

The change in land value (2.4.4) should be divided by the total remediation cost (2.5.4).

2.7.2 Net financial profit, EUR

Net financial profit means direct financial revenues minus total costs. The present value of the expected net financial profit of remediation should be calculated by the investor and given in EUROs.

Direct financial revenues include: revenues from site utilisation and / or revenues from the difference between the price of the cleaned-up site and the price of the contaminated site (if the cleaned-up site is sold). Note that wider social impacts and indirect benefits, like avoided risks, are not included in direct financial revenues.

Direct costs include: investment costs and operation costs of remediation. If the stakeholder filling in the questionnaire is an investor, direct costs also may include the cost of purchasing the land as well as costs related to obtaining a loan and other direct costs.

3. Annex 1: Remediation technologies

The remediation technology to be applied at the site should be identified and selected.

In *Vik and Bardos (2002)*[*] according to *Martin and Bardos (1996),* remediation technologies may be defined according to the type of the applied treatment processes:

- **Biological (B):** contingent on the use of living organisms;
- **Chemical (C):** destroy, fix or concentrate toxic compounds by using one or more types of chemical reaction;
- **Physical (P):** separate contaminants from the soil matrix by exploiting physical differences between the soil and contaminant (for example, volatility) or between contaminated and uncontaminated soil particles (for example, density).
- **Solidification/stabilisation (S):** processes immobilise contaminants through physical and chemical processes (Solidification processes are those which convert materials into a consolidated mass. Stabilisation processes are those in which the chemical form of substances of interest is converted to a form that is less available).
- **Thermal (T):** exploit physical and chemical processes occurring at elevated temperatures.

Remediation solutions also refer to the place where the action takes place:

- On site
    - In situ
    - Ex situ
- Off site
    - Ex situ

[*] VIK, E.A. and BARDOS, P. (2002): Remediation of Contaminated Land Technology Implementation in Europe, A report from the Contaminated Land Rehabilitation Network for Environmental Technologies, Version: October 2002, SFT: Federal Environmental Agency – Austria, www.clarinet.at

Technology	Description	Type	Volume unit	Unit cost (Euro)
(On site) In situ				
Bioremediation	Remediation by altering conditions, typically by flushing (see below) to optimise biodegradation rate. Examples include the addition of nutrients, oxygen, etc.	B	Ton soil	20-200
Biosparging / Air sparging	Injecting air (or other gases) into the saturated zone to strip volatile contaminants and/or stimulate biodegradation. The latter process is often termed "biosparging".	B P C	m^3 groundwater	65-75
Bioslurping	Multiphase extraction of groundwater, free-phase contamination and soil gas to achieve bulk contaminant removal and supply oxygen for enhanced biodegradation.	B P	Ton soil	30-90
Bioventing	Movement of air or other gas through soil to stimulate biological destruction of contaminants, possibly in combination with their removal in the gas phase (c.f., soil vapour extraction)	B P	Ton soil	25-80
Chemical destruction	Use of highly reactive reagents to convert contamination to environmentally acceptable end-products in situ. An example is the use of Fenton's reagent (iron-catalysed hydrogen peroxide).	C	m^3 soil	50-110
Electro-remediation	Use of electric fields to move or contain contaminants.	P C		
Flushing	Enhanced pump and treat to remove contaminants, for example addition of surfactants or solvents to re-circulated water.	P C	m^3 groundwater	30-50
Hydrofracture	Hydraulic or pneumatic techniques to induce fracturing of subsurface zones to increase permeability for other remediation treatments.	P		
In situ heating	Use of steam or microwaves (radio-frequency heating) to heat the soil, for example to increase the range of contaminants recoverable by soil vapour extraction.	T		
Landfarming	Cultivation of surface soils (typically the top 50cm) to stimulate biodegradation. Usually includes the addition of various amendments (e.g., fertiliser) - unlikely to easily find regulatory approval under current circumstances.	B	Ton soil	10-50
Natural attenuation	Monitored use of naturally occurring in situ processes to remediate contamination without enhancement. Often, and more accurately, called monitored natural attenuation (MNA).	B P C		Monitoring cost

Technology	Description	Type	Volume unit	Unit cost (Euro)
(On site) In situ				
Permeable reactive barriers	A single or combination of biological, chemical or physical process(es) in a specific portion of the subsurface that treats a carrier as it passes through but does not unacceptably impede flow.	B P C	Ton soil	25-410
Phyto-remediation	Use of plants to recover contaminants and/or stimulate in situ biodegradation and stabilisation.	B		
Pump and treat	Treatment mediated by the pumping of groundwater. The term “Pump and Treat” is sometimes specifically used to mean technologies where groundwater treatment is undertaken above ground. However, in practice the term is also used to refer to true in situ processes involving groundwater pumping.	P	m^3 groundwater	30-50
Soil vapour extraction (SVE)	Movement of air or other gas through unsaturated soil to remove contaminants through enhanced volatilisation. Sometimes called “venting “ or “stripping”.	P	Ton soil	25-130
Stabilisation/ Solidification	In situ mixing (e.g., by augering) of chemical agents into the soil to solidify the ground or otherwise reduce mobility of contaminants.	S	Ton soil	25-130
Vitrification	Use of high temperature to melt subsurface minerals. Organic contaminants are thermally destroyed; inorganic contaminants are immobilised in the glassy residue.	S T		

Technology	Description	Type	Volume unit	Unit cost (Euro)
(On site or Off site) Ex situ				
Biopiles	Excavated soil is built into a heap within which is a network of perforated pipes to aerate the soil.	B	Ton soil	50-200
Bioreactors	Soil (dry or slurried) is treated in an enclosed reaction vessel to which nutrients, air water and microbes are added as necessary. Bioreactors are also used to treat groundwater.	B	Ton soil	20-80
Biological treatment beds	Shallow cultivation, where contaminated soil is cultivated in a contained treatment bed on a specially prepared area of a contaminated site	B	Ton soil	10-100
Chemically enhanced soil washing	Physical processes are integrated with chemical processes such as leaching or extraction.	C P	Ton soil	100-300
Chemical Leaching/ Chemical extraction	Transfer of contaminants from the soil into an aqueous solution. The soil is dewatered and the aqueous solution plus contaminants is further processed.	C	Ton soil	100-1000
Groundwater treatments (non-biological)	Various including: air stripping, carbon adsorption, chemical oxidation, filtration, ion exchange, neutralisation, precipitation, reverse osmosis, steam stripping.	C P	m^3 groundwater	???
Incineration	High temperature destruction of contaminants (eg. in rotary kiln incinerators or fluidised bed systems). Main pre-treatment is to obtain suitable particle size. Thermal desorption occurs during incineration. An ex situ process.	T	Ton soil	300-1400
Soil washing	Primarily a physical technique involving size separation and washing of contaminants using aqueous based solutions.	P	Ton soil	30-150
Solvent extraction	Uses non-aqueous solvent to transfer contaminants from soil into solution.	C		
Stabilisation/ Solidification	Mixing of chemical agents into the soil to solidify the ground or otherwise reduce mobility of contaminants.	S	Ton soil	50-200
Thermal desorption by combustion of organics in vapour phase	Two stage process comprising low temperature transfer of contaminants from soil to vapour phase via volatilisation followed by destruction or removal of contaminants from gas stream. Ex situ process needs extensive pre-treatment e.g. screening, de-watering, neutralisation, blending. Partial combustion often occurs during process.	T	Ton soil	25-220
Thermal desorption by condensation	Heating of soil to volatilise volatile metals (so far principally mercury), which is then condensed from exhaust gases downstream.	T	Ton soil	25-220
Vitrification	Excavation of soil, transport to (usually off site) facility. Soil plus other materials used for glass making (silica, fusing agents) are placed in a smelter, which heats to about 1500 ^{o}C. Molten material is continuously removed and cooled to produce granular solids or monolithic mass.	S T	Ton soil	55
Windrow turning	Piles of contaminated soil often mixed with organic materials such as bark are turned on a regular basis to aerate the soil and improve the soil structure.	B	Ton soil	10-100

4. Annex 2: QUESTIONNAIRE ON CONTAMINATED SITE

MULTI SITE MANAGEMENT

QUESTIONNAIRE ON CONTAMINATED SITE

MSM

Serial No of option: …….

I Investor's expectations from the site

Number of question	QUESTION	ANSWER
1	Characteristics of the requested site	
1.1	Extent of the site (m^2)	
1.2	Planned revitalisation function of the site	
1.3	Requested type of region	
1.4	Requested infrastructure on the site	
2	Planned maximum total cost of remediation, EUR	
3	Requested net financial profit, EUR	

II DATA OF THE SITES AND REMEDIATION OPTIONS

Number of question	QUESTION	ANSWER
1	**Characterisation of the contaminated site**	
1.1	Name of the site	
1.2	Address of the site	
1.3	Co-ordinates of the site	
1.4	Extent of the site (m^2)	
1.5	Number of the available options (incl. Option No. 0)	
1.6	Available infrastructure on the site	
1.7	Type of region	

II DATA OF THE SITES AND REMEDIATION OPTIONS (CONTINUED)

Number of question	QUESTION	ANSWER
2	**Characterisation of the available option**	
2.1	Targeted level of clean-up	
2.1.1	Targeted level of clean-up for ……, mg/m^3	
2.1.2	Targeted level of clean-up for ……, mg/m^3	
2.1.3	Targeted level of clean-up for ……, mg/m^3	
2.1.4	Targeted level of clean-up for ……, mg/m^3	
2.1.5	Targeted level of clean-up for ……, mg/m^3	
2.1.6	Targeted level of clean-up for ……, mg/m^3	
2.1.7	Targeted level of clean-up for ……, mg/m^3	
2.1.8	Targeted level of clean-up for ……, mg/m^3	
2.1.9	Targeted level of clean-up for ……, mg/m^3	
2.1.10	Targeted level of clean-up for ……, mg/m^3	
2.2	Clean-up method	
2.3	Possible revitalisation functions of the site after remediation	
2.4	Impacts/benefits	
2.4.1	Index of avoided human health risk	
2.4.2	Index of avoided, detailed, quantitative risk	
2.4.3	Index of the avoided, simplified, relative and qualitative risk	
2.4.4	Change in land value, EUR	
2.5	Remediation cost	
2.5.1	Cost of site investigation and assessment, EUR	
2.5.2	Cost of clean-up, EUR	
2.5.3	Cost of follow-up monitoring, EUR	
2.5.4	Total cost of remediation, EUR	
2.6	Results of the simplified cost-benefit analysis	
2.6.1	Selected risk index for calculating priority number based on cost-benefit analysis: ……..	Value of selected risk index:
2.6.2	Priority number based on cost-benefit analysis	
2.7	Results of the financial analysis	
2.7.1	Change in land value/total remediation cost	
2.7.2	Net financial profit, EUR	

5. Annex 3: Background information related the filled in questionnaire

Introduction

This background information provides a possible example of characterising sites and calculating risk indices, costs and other figures for the multi-site management (MSM) of NORISC. The data in the background information have been taken from the final report of a site investigation carried out in Hungary in 2001. The description of the calculations serves illustrative purposes, in other words, for characterising sites it is not compulsory to apply the methods described here. It is, however, compulsory is to apply a uniform calculation methodology for all sites covered by the same MSM process. For example, the calculations should be carried out in a unified way for all sites in a particular country, region or city.

1. Characterisation of the contaminated site

The site is a petrol station at the western edge of a major Hungarian city, Székesfehérvár. The site is classified as an "institutional area". The site is surrounded by a sports ground, a car shop and a service station, a hobby department store, and a furniture department store with a parking lot. The distance between the petrol station and the nearest building of the nearby housing estate is about 200 metres.

2. Characterisation of the available options

Targeted levels of clean-up
At the site groundwater is contaminated by hydrocarbons; the contaminations is delineated for all components from all sides of the site. The concentrations of pollutants in the soil do not reach the national limit values, thus, targeted levels of clean-up are determined only for groundwater.

Three remediation options have been identified for the site:

- *Option 0:* no remediation. In this case the targeted levels of clean-up correspond to the current concentration of pollutants.

- *Option 1:* excavation of the polluted soil and clean-up of groundwater. In this case remediation lasts for three years. The elements of this method include aeration, soil vapour extraction, air injection and soil vapour extraction (groundwater, in situ treatment), stripping of groundwater (ex situ), adsorption with activated carbon, and ex situ soil remediation. For this option the targeted levels of clean-up are shown in Table 1.

2. Table Targeted levels of clean-up for contaminants in Option 1

Pollutant	Targeted level of clean-up (µg/l)
TPH	4000
Benzene	15
Toluene	150
Ethyl-benzene	150
Xilene	100

- *Option 2:* groundwater clean-up combined with aeration and soil vapour extraction, and, if necessary, in situ biological treatment of soil. In this case the petrol station can continue its operation but remediation will last for six years. The elements of this method are as follows: aeration, soil vapour extraction, air injection and soil vapour extraction (groundwater, in situ treatment), stripping of groundwater (ex situ), adsorption with activated carbon, and in situ soil remediation. For this option the targeted levels of clean-up are shown in Table 2.

3. Table Targeted levels of clean-up for contaminants in Option 2

Pollutant	Targeted level of clean-up (µg/l)
TPH	2000
Benzene	20
Toluene	80
Ethyl-benzene	80
Xilene	80

Calculation of risk indices

Index of avoided human health risk

The index of avoided human health risk may be calculated in several ways. Although, the index has not been calculated for the options presented above, as an illustration, a calculation of risk indices is presented below for the targeted levels of clean-up shown in Table 3.

4. Table, Targeted levels of clean-up for calculating human health risk indices (example)

Pollutant	Targeted level of clean-up (µg/l)
TPH	2880
Benzene	10
Toluene	100
Ethyl-benzene	100
Xilene	70

The risk assessment for soil and groundwater has been carried out at the two most seriously polluted points of the site. The values of the health and cancer risk indices have been summarised at the two sampling points for different environmental media (air, soil, and groundwater) and for different receptors (local employees, remediation staff, and residents) located in different distances from the

sampling points. The risk indices have been aggregated for all environmental media in the case of different receptors; the results are shown in Table 4 and 5.

5. Table, Aggregated risk index of cancer and health risk index for different receptors at the 1st sampling point

	Probability of cancer (additional risk)			Health risk index (exceeding toxicological threshold)		
	Within contaminated area	Outside of contaminated area		Within contaminated area	Outside of contaminated area	
	0 m	50 m	150 m	0 m	50 m	150 m
Pollutants	Local workers and remediation staff	Local workers	Residents	Local workers and remediation staff	Local workers	Residents
BTEX	2.3E-05	6.20E-06	3.20E-06	0.87	0.241	0.101
Aromatic	2.3E-05	6.20E-06	3.20E-06	3.71	1	0.44
TPH	-	-	-	0.71	0.3	0.1
Total	4.6E-05	1.24E-05	6.40E-06	5.29	1.54	0.6411
Tolerable level:		1.0E-06			1.0	

6. Table, Aggregated risk index of cancer and health risk index for different receptors at the 2nd sampling point

	Probability of cancer (additional risk)			Health risk index (exceeding toxicological threshold)		
	Within contaminated area	Outside of contaminated area		Within contaminated area	Outside of contaminated area	
	0 m	50 m	150 m	0 m	50 m	150 m
Pollutants	Local workers and remediation staff	Local workers	Residents	Local workers and remediation staff	Local workers	Residents
BTEX	5.1E-5	1.4E-5	7.2E-6	1.7	0.46	0.2
Aromatic	5.1E-5	1.4E-5	7.2E-6	1.7	0.47	0.2
TPH	-	-	-	0.51	0.16	0.076
Total	1.0E-04	2.8E-05	1.40E-5	3.91	1.09	0.476
Tolerable:		1.0E-06			1.0	

Risks are caused by different substances and at the same time, different types of receptors exist at different distances from the contaminated area. Therefore, the aggregated risk indices have been calculated as the weighted average of risk indices relating to different receptors. In this sample case the weights are the number of people exposed to the respective risk indices (see last row in Table 6). The level of risk additional to the tolerable level of risk has been calculated by deducting the level of tolerable risk (1.0E-06 and 1.0 respectively) from the levels of the actual cancer and health risk indices.

The additional level of risk is the risk to be avoided by remediation.

7. Table Summary data for calculating the indices of avoided risk

	Probability of cancer (additional risk)			Health risk index (exceeding toxicological threshold)		
	Within contaminated area	Outside of contaminated area		Within contaminated area	Outside of contaminated area	
	0 m	50 m	150 m	0 m	50 m	150 m
Pollutants	Local workers and remediation staff	Local workers	Residents	Local workers and remediation staff	Local workers	Residents
Total (1st sampling point)	4.6E-05	1.24E-05	6.40E-06	5.29	1.54	0.6411
Total (2nd sampling point)	1.0E-04	2.8E-05	1.40E-5	3.91	1.09	0.476
Number of people exposed	4	10	30	4	10	30
Tolerable level:		1.0E-06			1.0	

Based on the data in Table 6 the weighted risk index of cancer has been calculated as follows:
[4 * (4.6E-05 + 1.0E-04) + 10 * (1.24E-05 + 2.8E-05) + 30 * (6.40E-06 + 1.40E-5)] / (4 + 10 +30] = 3.64E-05

The weighted health risk index has been calculated as follows:
[4 * (5.29 + 3.91) + 10 * (1.54 + 1.09) + 30 * (0.6411 + 0.476)] / (4 + 10 +30] = 2.18

As mentioned above, the risks to be avoided as a result of remediation have been calculated by deducting the levels of tolerable risk from the actual average cancer and health risk indices (Table 7):

8. Table Indices of avoided human health risk

Risk of cancer to be avoided:	3.64E-05 - 1.0E-06 = 3.54E-05
Health risk to be avoided:	2.18 – 1.0 = 1.18

The index of avoided risk of cancer and the index of avoided human health risk are considered as the estimated benefits of remediation.

Index of avoided detailed, quantitative risk
Several methods may be applied to calculate the index of avoided detailed, quantitative risk. Due to insufficient data, the index has not been calculated.

Index of the avoided simplified, relative and qualitative risk
The relative risk index has been calculated for the options. The calculation has been carried out by considering several factors including, for example, the hazardousness and concentrations of pollutants, the targeted levels of clean-up for pollutants, the quantity of contaminated groundwater, and the types of endangered water resources.

The applied method assesses the different aspects of the site by environmental media and by risk influencing factors. The assessed environmental media are groundwater, soil, surface water, and air. The assessed risk influencing factors are as follows: characteristics of the contamination, amount of pollution in the different environmental media, naturally existing protection of the site, and types of receptors.

The value of each factor has been multiplied by the weight of the factor. The results are summarised by environmental media. The impacts of the hazardous substances have been taken into account together. The following data of each hazardous substance have been taken into account and aggregated to calculate the relative risk index:

- concentration of hazardous substance in soil,
- concentration of hazardous substance in surface water,
- targeted value of clean-up in the soil,
- targeted value of clean-up in groundwater.

The result of the calculations is an index characterising the hazardous substances. The index is calculated on the basis of the number of the hazardous substances, the substances' "risk values", the substances' concentrations, and their targeted values of clean-up. (The index may be calculated both for soil and for groundwater, nevertheless, in this case the index has been calculated only for groundwater.)

The steps of the calculation method are as follows:

1. step: the "risk values" (V) expressing the hazardousness of substances are determined by experts.

2. step: For each hazardous substance the ratio of the substance's concentration (K) and the respective targeted value of clean-up (D) is determined:

$$\frac{K}{D}.$$

3. step: the logarithms of the ratios are calculated:

$$\ln\left(\frac{K}{D}\right).$$

4. step: each logarithm is multiplied by the risk value of the hazardous substance:

$$V \cdot \ln\left(\frac{K}{D}\right).$$

The results are summed and divided by the number of the hazardous substances to obtain average logarithmic points both for soil and groundwater:

$$\frac{\sum V \cdot \ln\left(\frac{K}{D}\right)}{N}.$$

The average logarithmic points are weighed for each environmental medium and the resulting points are added to receive an aggregate risk indicator for all media.

In the further steps several other data are used by the calculation process, for example:

- the volume of contaminated soil (m3),
- the volume of contaminated groundwater (m3),
- types of groundwater and surface water that can be affected by the contamination in 50 years,
- types of lands (residential, agricultural, etc.) that can be affected by the contamination in 50 years.

All answers to the above questions are weighted for all environmental media. The resulting points and the average logarithmic points are used to calculate an overall risk index for the site. The risk index characterises the risk caused by all hazardous substances for all environmental media. The indices of the avoided simplified, relative and qualitative risk of Option 1 and 2 are shown in Table 8.

The indices for the two options have the same value due to the following reasons:

- the characteristics of the site and the contamination are the same;
- the two options differ only in their average logarithmic points, however, both points fall in the same category of hazardousness.

9. Table *Index of the avoided simplified, relative and qualitative risk in Option 1 and 2*

Option 1	Option 2
407	407

Change in land value

Similarly to the risk index calculation, several methods exist to estimate the change of the site's value (land value). (See the description of the applied method in the Guidance.) The estimation has been based on the assumption that the price of a contaminated institutional site is 50 per cent lower than that of an uncontaminated institutional site.

As a result of Option 1 and Option 2 the classification of the site ("institutional site") will not change. However, the value of the cleaned-up site will increase as a result of clean-up. At current prices the change in land value is the same in the two options, however, the PV of the change are different because the durations of Option 1 and 2 differ (see the description of the formula for calculating the PV in the Guidance). To calculate the PV of the change in land value the prices have been adjusted by the estimated annual inflation rates and discount rates. The PV of estimated changes in land value are shown in Table 9.

10. Table *Present values of changes in land value as a result of Option 1 and 2 (EUR)*

Option 1	Option 2
64,685	66,569

Remediation cost

The remediation costs of Option 1 and 2 have been taken from the final report of the site investigation. The costs of remediation at current prices have been calculated for each year by adding the costs of investigation, clean-up, and follow-up monitoring in the respective years. To calculate the present values of costs of each year the figures have been adjusted by the estimated annual inflation rates and by estimated discount rates then the adjusted costs have been added. (See the description of the formula for calculating the PV in the Guidance.)

The PV of the costs of Option 1 are less than those of Option 2 because in Option 1 the targeted values of clean-up are less stringent than in Option 2. In addition, the duration of Option 1 is shorter than that of Option 2. However, Option 1 includes the demolition of the petrol station to allow the excavation of the contaminated soil, which increases the costs of Option 1. The estimated present values of the two options' remediation cost are shown in Table 10.

11. Table Estimated present values of the remediation cost of Option 1 and 2 (EUR)

Option 1	Option 2
927,907	1,023,256

Cost-benefit analysis and priority numbers

The benefits of the options are reflected by the indices of avoided relative risk. The cost-benefit ratios of the two options have been calculated by dividing the index of avoided relative risk by the total cost of remediation. The cost-benefit ratios serve as the priority numbers of the two options (see Table 11). The ratios of the change in land value and total remediation costs have also been calculated (see Table 11).

The net financial profit has been calculated as the difference of direct financial revenues and direct costs (assuming that after remediation a petrol station will be operated at the site then the site will be sold). The different priority numbers are shown in Table 11.

12. Table Priority numbers of the options

Priority number	Option 1	Option 2
Index of avoided relative risk / total cost of remediation	0.000438622	0.00039775
Change in land value / total cost of remediation	0.069710401	0.06505605
PV of net financial profit (EUR)	10,191,634	9,603,513

Based on the first two rows of Table 11, Option 1 is preferable to Option 2. If the stakeholder is an investor, whose primary requirement is financial profit, Option 1 will also be preferable to Option 2.

The investor's expectations from the site

In this description the data related to the investor's expectations are assumptions and serve illustrative purposes.

OPTION No. 1

MULTI SITE MANAGEMENT

QUESTIONNAIRE ON CONTAMINATED SITE

MSM

Serial no. of option: 1

I Investor's expectations from the site

Number of question	QUESTION	ANSWER
1.	Characteristics of the requested site	
1.1	Extent of the site (m^2)	3300 m^2
1.2	Planned revitalisation function on the site	Petrol station
1.3	Requested type of region	Industrial, max. 60 km from capital city
1.4	Requested infrastructure on the site	1, 2, 3, 5, 9
2.	Planned maximum total cost of remediation, EUR	950,000
3.	Requested net financial profit, EUR	10,000,000

II DATA OF THE SITES AND REMEDIATION OPTIONS

Number of question	QUESTION	ANSWER
1	**Characterisation of the contaminated site**	
1.1	Name of the site	Petrol station on the western edge of the city of Székesfehérvár, Hungary: hydrocarbon contamination in the soil and groundwater
1.2	Address of the site	Petrol station, X street, Székesfehérvár, Hungary
1.3	Co-ordinates of the site	x (horizontal co-ordinate), y (vertical co-ordinate)
1.4	Extent of the site (m^2)	3500 m^2
1.5	Number of the available options (incl. Option No. 0)	3
1.6	Available infrastructure on the site	1, 2, 3, 5, 9
1.7	Type of region	Industrial, 60 km from capital city

OPTION No. 1

II DATA OF THE SITES AND REMEDIATION OPTIONS (CONTINUED)

Number of question	QUESTION	ANSWER
2	**Characterisation of the available option**	
2.1	Targeted level of clean-up for groundwater	
2.1.1	Targeted level of clean-up for benzene, mg/m^3	15
2.1.2	Targeted level of clean-up for toluene, mg/m^3	150
2.1.3	Targeted level of clean-up for xylene, mg/m^3	100
2.1.4	Targeted level of clean-up for ethyl-benzene, mg/m^3	150
2.1.5	Targeted level of clean-up for TPH, mg/m^3	4000
2.1.6	Targeted level of clean-up for ……, mg/m^3	
2.2	Clean-up method	air injection + soil vapour extraction (groundwater, in situ); stripping (groundwater, ex situ)
		adsorption with activated carbon
		other: soil remediation (ex situ)
2.3	Possible revitalisation functions of the site after remediation	institutional area
2.4	Impacts/benefits	
2.4.1	Index of avoided human health risk Risk of cancer Health risk	n.a.
2.4.2	Index of avoided, detailed, quantitative risk	n.a.
2.4.3	Index of the avoided, simplified, relative and qualitative risk	407
2.4.4	Change in land value, EUR	64,685
2.5	Remediation cost, EUR	
2.5.1	Cost of site investigation and assessment	15,200
2.5.2	Cost of clean-up	888,899
2.5.3	Cost of follow-up monitoring	23,808
2.5.4	Total cost of remediation	927,907
2.6	Results of the simplified cost-benefit analysis	
2.6.1	Selected index of risk/total remediation cost: Selected index: avoided, simplified, relative and qualitative risk	407
2.6.2	Priority number based on cost-benefit analysis	0.000438622
2.7	Results of the financial analysis	
2.7.1	Change in land value/total remediation cost	0.069710401
2.7.2	Net financial profit, EUR	10,191,634

OPTION No. 2

MULTI SITE MANAGEMENT

QUESTIONNAIRE ON CONTAMINATED SITE

MSM

Serial no. of option: 2

I Investor's expectations from the site

Number of question	QUESTION	ANSWER
1	Characteristics of the requested site	
1.1	Extent of the site (m^2)	3300 m^2
1.2	Planned revitalisation function on the site	Petrol station
1.3	Requested type of region	Industrial, max. 60 km from capital city
1.4	Requested infrastructure on the site	1, 2, 3, 5, 9
2.	Planned maximum total cost of remediation, EUR	950,000
3.	Requested net financial profit, EUR	10,000,000

II Data of the sites and remediation options

Number of question	QUESTION	ANSWER
1	**Characterisation of the contaminated site**	
1.1	Name of the site	Petrol station on the western edge of the city of Székesfehérvár, Hungary: hydrocarbon contamination in the soil and groundwater
1.2	Address of the site	Petrol station, X street, Székesfehérvár, Hungary
1.3	Co-ordinates of the site	x (horizontal co-ordinate), y (vertical co-ordinate)
1.4	Extent of the site (m^2)	3500 m^2
1.5	Number of the available options (incl. Option No. 0)	3
1.6	Available infrastructure on the site	1, 2, 3, 5, 9
1.7	Type of region	Industrial, 60 km from capital city

OPTION No. 2

II Data of the sites and remediation options (Continued)

Number of question	QUESTION	ANSWER
2	**Characterisation of the available option**	
2.1	Targeted level of clean-up for groundwater	
2.1.1	Targeted level of clean-up for benzene, mg/m^3	20
2.1.2	Targeted level of clean-up for toluene, mg/m^3	80
2.1.3	Targeted level of clean-up for xylene, mg/m^3	80
2.1.4	Targeted level of clean-up for ethyl-benzene, mg/m^3	80
2.1.5	Targeted level of clean-up for TPH, mg/m^3	2000
2.1.6	Targeted level of clean-up for ……, mg/m^3	
2.2	Clean-up method	air injection + soil vapour extraction (groundwater, in situ); stripping (groundwater, ex situ)
		adsorption with activated carbon
		enhanced bioremediation of soil (in situ)
2.3	Possible revitalisation functions of the site after remediation	institutional area
2.4	Impacts/benefits	
2.4.1	Index of avoided human health risk Risk of cancer Health risk	n.a.
2.4.2	Index of avoided, detailed, quantitative risk	n.a.
2.4.3	Index of the avoided, simplified, relative and qualitative risk	407
2.4.4	Change in land value, EUR	66,569
2.5	Remediation cost, EUR	
2.5.1	Cost of site investigation and assessment	15,200
2.5.2	Cost of clean-up	999,584
2.5.3	Cost of follow-up monitoring	8,472
2.5.4	Total cost of remediation	1,023,256
2.6	Results of the simplified cost-benefit analysis	
2.6.1	Selected index of risk/total remediation cost: Selected index: avoided, simplified, relative and qualitative risk	407
2.6.2	Priority number based on cost-benefit analysis	0.00039775
2.7	Results of the financial analysis	
2.7.1	Change in land value/total remediation cost	0.06505605
2.7.2	Net financial profit, EUR	9,603,513