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RISK REDUCTION, ENVIRONMENTAL MERIT AND COSTS

REC-METHOD, Phase 1

Nederlands Onderzoeksprogramma Biotechnologische In-situ Sanering

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CONTENT

CHAPTER 1

INTRODUCTION

In the scope of the NOBIS-project "Risk reduction, Environmental merit and Costs" (abbreviation REC, Dutch abbreviation RMK) the separate elements have been worked out in phase 1. This document serves as an discussion paper for this phase of the project. The report and the discussion in the workshop form the basis for the aim and activities in phase 2 of the project.
In this first, introductory chapter, the scope of this NOBIS-project, as well as the aims and ambitions are described.

1.1 Why the REC-project?

The assessment of (innovative) remediation concepts, strategies and techniques in the Netherlands is still largely based on a comparison of the expected end results in terms of final concentrations in soil and groundwater. There is however a growing awareness that it is necessary to optimize the efficiency of remediation alternatives from an integral viewpoint, taking into account risk reduction, environmental merit and costs as a function of time. This process of optimization can only be done, when an objective assessment procedure is available, which weighs alternative remediation options on these criteria. Such a procedure should also provide a tool to evaluate ongoing and already completed remediations, and can stimulate future development of new strategies and concepts. A lot of work has been done on the separate topics, however an integrated method is not yet available.

1.2 The REC-project within NOBIS

The objective of NOBIS is to develop, evaluate and demonstrate innovative strategies, methods, and techniques which will effectively help to control in-situ remediation by means of biotechnology (biorestoration). With a large scale application of the attained results a significant reduction in the costs of the soil clean-up operation will have to be achieved, taking sufficient risk reduction and environmental merit into account. A threatening stagnation in the solution of the soil clean-up problem can thus be counteracted. Therefore, for the selection of NOBIS projects, a tool is needed to evaluate projects with respect to risk reduction, environmental consequences and costs.
A project proposal, referred to as REC (Risk reduction, Environmental merit and Costs), was submitted to NOBIS in 1995, and the project started with a NOBIS contribution in january 1996.

1.3 Ambition

The aim of this REC-project is to develop an objective and quantitative assessment procedure with which the efficiency of remediation alternatives can be judged and optimized from an integral viewpoint, taking into account the elements Risk reduction, Environmental merit and Costs as a function of time.

The project will be executed in 2 phases. The current, first phase consists of 4 steps:
Step 1. Problem identification and definition of criteria
Step 2. First elaboration of criteria
Step 3. First testing of method, using a simple case
Step 4. Workshop in June 1996 with experts and users of the method (see Annexe E)

Based on the outcome of the discussions during the workshop and the level of acceptance by the users, the method will be further elaborated and tested during phase 2 of the project. This will result in an applicable REC-method, with clear instructions for use.

1.4 What is REC?

REC is the name for ***a decision support method*** to assess Risk reduction, Environmental merit and Costs.

Risk in this context is defined as health effects for human beings and adverse effects on ecosystems and infrastructure, as a result of exposure to soil contamination and as a result of the remedial activities itself.

Environmental merit is defined as the result of an integral assessment of environmental consequences of a remedial activity and the resulting new situation, compared to the environmental consequences of the situation before remediation.

Costs include the direct and indirect financial consequences of the contamination and remediation.

With the REC-method, the remedial options can be evaluated relative to each other or by itself. The REC-method doesn't take all the criteria in a decision making process into account. It provides for information only on the three defined criteria. Additional criteria can concern for example psychological, legal, political and social factors.

1.5 How can the REC-method be applied?

The REC-method serves three main purposes:

1. *Generation of innovative remedial strategies, concepts and techniques*
   Within NOBIS, the value of new developments in in situ soil remediation (a ***technology, concept or strategy***) can be assessed in terms of efficiency: does this new development lead to cost reduction, combined with sufficient risk reduction and a positive contribution to the environment? New developments can be compared to the existing alternatives.

2. *Comparison and optimization of remedial options*
   For the selection of a remedial option for a specific site, REC can be used to compare several remedial options, for example excavation combined with groundwater remediation, in situ bioremediation and isolation, containment and control. Also intensive in-situ bioremediation options can be compared to extensive ones.
   When a specific remedial option is considered, the REC-methodology provides for information, for example in a checklist with relevant parameters, about the direction for further improvement of this option with respect to cost reduction, risk reduction and environmental merit.

3. *Evaluation of ongoing and already completed remediation projects*
   By using the REC-method to evaluate ongoing and already executed projects, a systematic evaluation of experiences (in situ and otherwise) can be achieved.

These three main purposes are visualized in figure 1.1. The level of detail required for each purpose is also indicated. The necessary level of detail ranges from low detail, in case of generation of new remedial options, towards high detail when evaluating ongoing and executed remediation projects.

Fig. 1.1. Chronological order of the applications of the REC-model.

The proposed REC-method will be similar for each purpose but the number of aspects to be evaluated, and the depth of information required will vary in these stages.
For each purpose a relevant set of aspects is selected for each of the three criteria, Risk reduction, Environmental merit and Costs. Considerations for the selection of relevant aspects to cover the most significant influences on the REC-criteria are:
- transparency;
- ease of use and simplicity;
- measurability;
- discriminating power;
- relevancy
- support by experts and users.

At this stage of the project, the selection of relevant aspects is made for the application of the REC-method as a tool for comparison of remediation alternatives (purpose number 2). In the next phase the REC-method will be extended to other purposes mentioned.

1.6 Guide to the reader

This report of phase 1 of the REC-project serves as a discussion paper for the workshop on 21 June, 1996. In chapter 2, general aspects of the method, such as scale and time, and the relation between the criteria will be discussed. In the chapters 3 to 5, the separate criteria Risk reduction, Environmental merit and Costs will be worked out in detail. Every chapter starts with a summary, followed by an elaboration on definition and context of the criterium. Then the selection and operationalization of the relevant aspects for the criterium is discussed. Finally, the quantification of the separate aspects, and how to integrate these aspects into one integrated score for respectively risk reduction, environmental merit and costs is described.
In chapter 6, simple examples will be used to illustrate the proposed method.
Chapter 7 contains flow charts that describe the actions for application of the REC-method in general terms.

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GENERAL ASPECTS OF THE REC-METHOD

Before we elaborate on the general expressions of Risk reduction, Environmental merit and Costs, it is important to remind the reader of the scope of the development of the REC-method in this stage. The proposed REC-method aims at comparing and optimizing remedial options. It is assumed that all the options that are selected for the comparison can be executed in practise. This implies that all the options are within the boundary conditions of legislation, licenses and technical feasibility (i.e. not exceeding unacceptable risk levels, not exceeding unacceptable emission levels, etc.).

2.1 General expressions of R, E, and C

In defining *Risk reduction*, *Environmental merit* and total *Costs*, it is necessary to define the building blocks for these criteria. For an extensive elaboration of the definition and context of the criteria, we refer to the chapters 3, 4 and 5.

2.1.1 *Risk reduction*

The building block for Risk reduction is **Risk**, which refers to the adverse effects, that humans, the ecosystem, and infrastructure can suffer from exposure to soil pollutants. Risk will be expressed as a normalized 'total exposure' during a certain time frame.

Risk: $R = X_i \cdot t$ (1)

in which:

- R is Risk;
- X is normalized 'total exposure';
- i is remediation alternative i;
- t is time.

Total Risk is defined as the sum of Risk before, during and after remediation, all as a function of time, per object.

Total Risk: $TR = R_{before} + R_{during} + R_{after}$ (for a specific time frame, per object)

$$TR_i = X_{i,\ before} \cdot \frac{t_{before}}{t_{total}} + X_{i,\ during} \cdot \frac{t_{during}}{t_{total}} + X_{i,\ after} \cdot \frac{t_{after}}{t_{total}} \qquad (2)$$

in which:

- before is before remediation starts;
- during is during remediation;
- after is after remediation is completed.

Finally, **Risk reduction** refers to the impact of the remediation alternative on the total risk of a soil contamination for all objects. This means that to calculate this risk reduction, ***the total risk that would exist without remediation*** serves as a reference for the total risk for a specific remediation alternative. This total risk is referred to as TR_0 (Total risk, without remediation).
Then the final expression of risk reduction will be:

Risk reduction$_i$ = $TR_0 - TR_i$ (3)

A driving force of remediation is to ***optimize*** Risk reduction, relative to its functional use.

2.1.2 *Environmental merit*

The building blocks for Environmental merit are **Environmental influences**, which refers to the (potential) consequences of the remediation alternative related to the use of scarce commodities and the impact on environmental quality. Environmental influences can be expressed as a normalized 'quality-impact and use of scarce commodities' during a certain time frame. Environmental influences may be regarded as positive (i.e. improvement of soil and groundwater quality) and negative (i.e. emissions to water and air).

Environmental influences: $EI = (Q + U)_i \times t$ (4)

in which:
- EI is Environmental Influences;
- Q + U is normalized 'quality-impact and use of scarce commodities';
- i is remediation alternative i;
- t is time.

Total Environmental influence is defined per aspect as the sum of Environmental influences before, during and after remediation, all as a function of time. During the process of determining the building blocks of environmental merit, we separate the scores on positive and negative environmental influences. The combination and integration of these influences takes place in the final calculation of environmental merit. Total Environmental influence also separates scores on the regarded quality and scarcity aspects.

Total EI: $TEI = EI_{before} + EI_{during} + EI_{after}$ (for a specific time frame)

$$TEI_i = (Q + U)_{i,\ before} \times \frac{t_{before}}{t_{total}} + (Q + U)_{i,\ during} \times \frac{t_{during}}{t_{total}} + (Q + U)_{i,\ after} \times \frac{t_{after}}{t_{total}} \qquad (5)$$

in which:
- before is before remediation starts;
- during is during remediation;
- after is after remediation is completed.

Finally, **Environmental merit** refers to the integrated score of environmental influences, where the negative environmental influences are subtracted from the positive influences.

Environmental merit = $TEI_{i,\ positive\ aspects} - TEI_{i,\ negative\ aspects}$ (6)

A driving force for selection of remediation alternatives is optimizing environmental merit.

2.1.2 *Costs*

This section is a first proposal for the Cost-criterium. This has not yet been discussed extensively within the consortium. Consequently, changes are to be expected.

The building blocks for the Cost criterium are the **Financial expenses** directly or indirectly related to the remedial action. Besides this, **Changes in the value of assets** will be considered as costs. Both aspects will be expressed in monetary terms and need not to be normalized.

Financial expenses: $F = (\text{cash flow})_i \cdot t$ (7a)

Change in value: $V = (\text{asset increase or decrease})_i \cdot t$ (7b)

in which:

F	is Financial expenses;
V	is change in Value;
cash flow	is amount of money paid for investments and operating costs;
asset increase or decrease	is change in value of asset by remediation;
i	is remediation alternative i.
t	is time.

Total Financial expenses and change in value is defined as the sum of Financial expenses and changes in value before, during and after remediation, all as a function of time.

Total F&V: $TF\&V = F\&V_{before} + F\&V_{during} + F\&V_{after}$ (for a specific time frame)

$$TF\&V_i = F\&V_{i,\ before} \cdot \frac{t_{before}}{t_{total}} + F\&V_{i,\ during} \cdot \frac{t_{during}}{t_{total}} + F\&V_{i,\ after} \cdot \frac{t_{after}}{t_{total}} \qquad (8)$$

in which:

before is before remediation starts;
during is during remediation;
after is after remediation is completed.

Finally, **Costs** refers to the sum of expenses and changes in value, whereby, the change in the value of assets will (in most cases) be positive (i.e. a negative cost factor!).

Costs $= TF_{i(\text{positive sign})} + TV_{i(\text{negative sign})}$ (9)

A driving force for optimizing remediation alternatives is minimizing costs by minimizing the financial expenses and maximizing the increase of value of assets.

2.2 *Scale of assessment of criteria*

A second aspect that needs to be clarified in this chapter is the relation between the criteria Risk reduction and Environmental merit. Both criteria aim at relating the impact of soil contamination and the remedial activities to improvements for humans and the environment.
However, for the purpose of the REC-method, the following distinction is made between the focus of the two criteria:

Risks can only be assessed if specific objects are defined: in the scope of soil remediation objects on or in the immediate surroundings of the site will be regarded in the object-path-source oriented risk assessment. This means that the scale on which risk reduction is determined is limited to the area of influence of the contaminated site to be regarded. Risk reduction is evaluated at the fifth level (end point) of the general cause-effect chain that is represented in figure 2.1.
Environmental merit will be assessed by evaluating the influences of the contamination and its remediation on the use of scarce commodities and the potential impact on environmental quality that

has no direct relation to the contaminated site. In fact, environmental merit is based on an evaluation at the third level in the general cause-effect chain.[1]

human needs	→	human activities	→	use of the environment	→	change in environmental quality	→	consequences for man, animal and vegetation

Fig. 2.1. General cause-effect chain.

Since risk reduction as well as environmental merit are both based on the cause-effect chain, it can be expected that these criteria are not independent. However, in the development of REC, we aim at preventing double-counting of aspects.
Another result of assessing environmental merit at the third level is that the scale on which environmental merit is regarded is not limited or related to the site. The difference in scales for risk reduction and environmental merit is illustrated in figure 2.2.

Fig. 2.2. Scale difference between Risk reduction and Environmental merit.

[1]In the operationalization of Environmental merit it appears to be necessary to take site specific factors into account for the quantification. However, the ***evaluation*** of environmental influences will be independent from the site.

2.3 **Time: discounting**

As can be seen in the general expressions in paragraph 2.1., Risk reduction, Environmental merit and Costs are all functions of time. In the comparison of remediation alternatives (the focus of phase 1), alternatives with different total time and timing will be compared. Questions that need to be answered are:

- How do we compare alternatives that both arrive at the same exposure-risk at the end, but differ significantly in the remediation time necessary to achieve this (comparing intensive and extensive remediation)?
- How do we compare short term higher exposure with long term lower exposure?
- How do we compare alternatives that both extract the same amount of clean groundwater, but in a different time frame?
- How do we compare alternatives that have the same total costs, but differ significantly in the way these costs are spread in time?

These questions all refer to the theory of discounting.

2.3.1 *Discounting costs*

It is accepted in daily practise of soil remediation that the costs (restricted to financial expenses) for different remedial alternatives are discounted, before the cost-comparison takes place. The ministry of VROM has defined a simplified method to calculate the Nett Present Value, and establishes every year the discount rate (being the difference between interest and inflation).

Discounting takes into account the time-value of money: it can be interpreted as the total amount of money that must be reserved in year 0 to provide for all the financial expenses from year 0 to the end of the remediation. The total amount reserved must be invested (i.e. put in the bank) for the established interest rate, and specific prices are supposed to have the same inflation rate as was selected in the calculation.

One of the most important effects of discounting is that expenses in the long run (dependent on the interest and inflation rate approx. 15 - 20 years) do not contribute any more to the Nett Present Value. Two alternatives that have the same cash-flow profile and take 20 respectively 40 years will therefore be regarded as having the same Costs.

Discounting can also be applied to the changes in asset value: the increase or decrease of value can be regarded as a cash inflow or cash outflow (for example if the mortgage is directly related to the value of the property).

The economic theory on discounting can be applied in the REC-method to make the financial expenses as well as the changes in asset value of different alternatives comparable.

It is proposed to use discounted costs in the REC-method.

2.3.2 *Discounting risks*

To answer the question whether or not risks must be discounted too, we will look for rationales behind the time-value of risks. Some simple examples will be used to discuss this topic. A distinction must be made between the toxicological and psychological answer.

Example 1
From a toxicological point of view, it is not possible to discriminate between the following two situations:

A is exposed at a certain level A_1 from year 1 to 10.
B is exposed at the same level A_1 from year 11 to 20,

assuming that A and B are at the same age, when the exposure takes place.
However, from a psychological point of view, it is likely to expect that A ***perceives*** the situation more seriously (higher risk) than B in year 0.

Example 2
A second situation in which it is not possible to discriminate on toxicological grounds is the following:
The exposure of humans and the ecosystem on a specific site are assessed at H_1 and E_1 respectively. Two remedial options are considered:

A1 Start with (intensive) in situ remediation in year 0; arrive at final situation in year 5, exposure at final situation is 0.75 H_1 and 0.75 E_1.
A2 Start with (extensive) in situ remediation in year 5; arrive at final situation in year 15, exposure at final situation is 0.25 H_1 and 0.25 E_1.

For a total time frame of 15 years the total Risk (according to relation 2) is:

$$TR = t_{before}/Tt \times X_{before} + t_{during}/Tt \times X_{during} + t_{after}/Tt \times X_{after}$$

A1: $0/15 \times (H_1+E_1) + 5/15 \times 0.875\ (H_1+E_1) + 10/15 \times 0.75\ (H_1+E_1) = 0.79$
A2: $5/15 \times (H_1+E_1) + 10/15 \times 0.625\ (H_1+E_1) + 0/15 \times 0.25\ (H_1+E_1) = 0.75$

As long as the exposure of humans and the ecosystem is below specific evaluation criteria (that are considered to be boundary conditions for all remedial alternatives), and the Total risk is more or less the same, it is not possible to discriminate between options A1 and A2.

However, from a psychological point of view, it is possible that option A1 is perceived as lower risk, because within this alternative the risk reduction starts immediately. Note that is the total time frame that is evaluated has a large impact in this case on the total risk. If we consider a time frame of 50 years, option A2 will end up with considerable lower Total risk than option A1. We will come back to the aspect of total time frame in paragraph 2.3.4.

Example 3
In the last example the following options are compared:

B1 Human exposure in year 0 is H_1, remediation starts at year 8, final situation will be achieved in year 20 at 0.1 H_1.
B2 Human exposure in year 0 is H_1, remediation starts at year 0, final situation will be achieved in year 5 at 0.7 H_1.

The total risk in the time frame of 20 years will be:

B1 = 0.73
B2 = 0.74

If a longer time frame will be considered, option B1 will be preferred.

Applying discounting-principles on risks has the advantage that the perception of people that risks now are more important than risks tomorrow is quantified. It is not clear what discount rate describes this process adequately.
However, if risks would be discounted, options that decrease risks in the beginning of the considered time frame will be favoured above options that take more time but arrive at lower exposure levels. The remaining risk levels at year 20 or later in time do not contribute any more to the total assessment of risk reduction. This is not in line with the long-term perspective of soil remediation, and the concept of 'sustainability'.

As was explained in chapter 1, REC doesn't take all the relevant evaluation criteria for remediation alternatives into account. The social, political and psychological aspects were considered to be too case-specific to incorporate into an objective, quantitative method. Therefore, in this phase of the project, risks will not be discounted.

2.3.3 *Discounting environmental influences*

As can be seen in the general expression for Environmental merit, the building blocks are also a function of time. Is it necessary to evaluate the use of scarce commodities in year 1 different from the use in year 10? And are emissions that may have influence on environmental quality more serious in year 1 than in year 5?

A distinction must be made between the use of scarce commodities and the potential influencing of environmental quality. It can be supported that in case of use of scarce commodities, it is the use itself that matters, not the moment or speed in which this happens.
In case of aspects that may influence environmental quality, it is more likely that the distribution of the emissions in time, does actually determine the extent to which environmental quality is influenced. Since we have chosen to evaluate *potential* influence on the environment, it is not necessary to take the time-value of environmental influences into account. However, this will remain a topic for discussion.

2.3.4 *Total time frame to be regarded*

As was already mentioned in one of the examples of paragraph 2.3.2, the total time frame that will be considered may have significant impact on the final quantification of the criteria that do not use discounting principles. It is possible to define several time frames that may be considered, such as:

1. the time of the most-time consuming alternative: $t_{total} = t_{longest\ alternative}$ (minimal time frame);
2. one generation: $t_{total} = t_{30\ years}$;
3. lifetime: $t_{total} = t_{70\ years}$;
4. a century: $t_{total} = t_{100\ years}$.

It is recommended to investigate, case by case, if increasing the time frame has significant impact on the REC-scores.

2.4 **Process to arrive at integrated score within one criterium**

The process to arrive at an integrated score on the criteria Risk reduction, Environmental merit and Costs is similar, and will be discussed here in general terms.
This process is presented in figure 2.3.

Fig. 2.3. Overview of process of defining REC-criteria.

First the criterium needs to be defined and positioned into the context. The philosophy behind the criterium must be described. Then the relevant aspects that need to be incorporated in the criterium are selected and motivated. The selected aspects will be operationalized: it must be described in detail how to assess the aspect in a quantitative way.
The final step is to integrate the separate, quantified aspects into one criterium. In this final step, weighting of the aspects is introduced. It is customary to distinguish between two types of weights: technical weights, which represent established and scientifically sound evidence, and policy weights, which are the result of subjective evaluations. The first type of weights is often used to integrate pieces of information with a technical nature. Weights can usually be related to the state of the art, science or to accepted practice and be often set in an uncontroversial way. On the other hand, the weights applied to entire evaluation sectors usually represent policy priorities an need to be assessed by the users. In REC, all type of weights will be made transparent and available for user changes.

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RISK REDUCTION

3.1 Summary

In this chapter a proposal for an assessment procedure for 'risk reduction' is described. The philosophy behind this criterium is to determine the total impact of the remediation strategy and method on the total risk for different objects such as humans, ecosystem, infrastructure and so on. The approach will be object-path-source oriented: starting with a site specific description of objects, their behaviour, site specific information and finally, the relation to the contamination present in soil and groundwater. Although the REC-method tries to integrate all risk aspects in one criterium, in this stage of the project we focus on exposure to the soil contamination and not on the risk for calamities. At this moment, the following aspects are identified to be considered in Risk reduction: people at the site or in the surroundings, remedial workers, ecosystem, infrastructure (underground cables & pipes), and other objects that need to be protected like vegetation and cattle.

The first step in the risk reduction assessment is to define the threatened objects. This starts by an inventory of objects on the site and in the immediate surroundings. Separate areas may be distinguished, representing a different type of exposure for objects. The exposure scenario for the people on or around the site and the remedial workers need to be defined as precisely as possible, taking into account the 'expected' behaviour, given the present lay out of the site.
If one of the remedial alternatives does not start at t = 0, or doesn't contain the contamination, it must be checked whether or not other objects will be threatened in the future, given the time span to be evaluated (i.e., system boundaries for risk reduction assessment).

Once the exposure scenario's for the several groups are defined, it is necessary to establish the concentration of contaminants in the contact media for the different objects. This can be achieved by measuring (for t = 0) or calculation with exposure models, (necessary to predict concentrations in contact media during the course of the remediation). Assessment of risk reduction for people on the site and remedial workers will be based on comparison of actual exposure. Assessment of risk reduction for the ecosystem will be based on an estimation of percentage species at risk in a certain surface area.
To end up with risk reduction, it is necessary to define an anchor point which serves as a reference for the total risk (TR_0). Comparison of this anchor point with the total risk (TR) results in risk reduction of a specific remedial option. The quantified scores on risk reduction for several alternatives can than be compared.
The anchor point is defined as the total risk at the time of the REC-assessment (t = 0), taken into account the total time frame that is regarded, without remediation.

The assessment of the total risk demands an integration of several risk indices, such as risk for people on or in the surroundings of the site, remedial workers, the ecosystem, underground infrastructure and other objects. The procedure to assess the separate risk indices must take into account that the indices will be added. This means that, if all the aspects are evaluated as equally important, the numerical values of the separate indices must represent the risk weighed to the other indices. It must therefore be defined what level of exposure of people during what time is evaluated as important as a certain level of exposure of the ecosystem.
By implementing weight factors in the formula to calculate the final risk reduction it is possible to insert additional preferences to evaluate the separate risk indices differently.

3.2 Definition and context

3.2.1 *Definition of Risk and Risk reduction*

Before relevant aspects in the scope of the subject risk reduction can be identified, the term risk has to be defined. Based on the results of discussions with participants of the REC-project and on internal discussions, the following definition is proposed:

Risk: all forms of exposure related to the regarded soil contamination, both as a result of the contamination itself and as a result of the execution of the evaluated remediation alternative, which may lead to negative effects on the health of people living in the affected area, on the health of workers involved *in the realisation of the regarded remedial option, on the state of the ecosystem or on the state of other objects, and which is regarded as not expressible in costs.*

With the presented risk definition, the following remarks have to be made:

- The used definition implies that not only risks related to exposure to contaminants should be regarded, but also risks resulting from exposure to calamities such as traffic accidents, explosions and collapses, both due to the soil contamination itself and to the execution of the remedial option. It should be realised that the first class of exposure has a *chronic* character and has to be judged based on its intensity (amount of exposure relative to accepted thresholds), while the latter class has an *incidental* character and has to be judged based on its likelihood of occurrence.

- It is important to prevent an overlap with the REC-element *cost reduction. It is necessary to separate risks that can be expressed in costs (for example the replacement of a tree) and risks that can not be expressed in costs*: negative health effects to people and to workers (they are not replaceable). Therefore, in the criterium risk reduction only those aspects are incorporated that cannot be expressed in costs.

3.2.2 *The object-path-source orientation*

In the assessment of Risk reduction, the line of thinking will be from object through pathways to sources of exposure. This implies that the Risk reduction assessment procedure starts with the identification of relevant objects that are under consideration. After identification the objects must be defined: a site specific characterization of the behaviour of objects must lead to a reliable, representative exposure scenario. Then the impact of several sources of exposure (water, air, food and soil contamination), related to the objects is evaluated. If possible, site specific measurements of contact media will be used, combined with predictions of the future exposure.

3.2.3 *Short description of national developments*

In the past decade a lot of work was done on the development of risk assessment procedures and methodologies. The extensive work of the RIVM in the projects for derivation of intervention values has lead to an increased awareness of the importance of risk based standards and risk based decision making. The development of the exposure model CSOIL (in close cooperation with Shell and DSM, ECETOC) has lead to several applications in practise, and has been used in the definition of the method for assessment of urgency of remediation.
Risk assessment is also one of the corner stones of the BSB approach (remediation of industrial sites currently in use). However it must be stressed that in this priority setting a combination is made between 'environmental risk assessment' and 'financial and legal risk assessment' (liability).
The VNG assigned the RIVM to work out a method for the evaluation of soil quality in relation to construction and building licenses.
In the Soil Protection Act, the use of risk assessment in soil investigation and soil remediation is embedded, for example in describing the method for determination of urgency, and by setting boundary conditions for Isolation, Containment and Control alternatives, based on risk assessment.
There are several computer applications available nowadays, such as SUS (Sanerings Urgentie Systematiek, Van Hall Institute), CSOIL6.3 (Tauw), and HESP (Shell). In the development of the risk reduction criterium we will use the existing knowledge as good as possible. However, since we adopt the object-path-source approach, adjustments of these models will be necessary.

3.2.4 *Short description of international developments*

It is commonly accepted in most countries, that risks for humans and the ecosystem from soil contamination is not allowed. As a consequence, soil remediation is needed, when it is shown that a contaminated site does present an actual risk. Therefore, a risk assessment is needed to evaluate the need and urgency of a remediation for a situation of soil contamination.

The concept of risk assessment of a soil contamination is similar for most countries, whereas the practical implementation may vary for the different nations. Unacceptable risk for humans exists, if human exposure at the site, that is caused by the soil contamination, does exceed a human toxicological standard. In a similar way, risks for the ecosystem can be assessed.

Consequently, in the different countries exposure models are developed to estimate human exposure from a soil contamination. Known models are: the Dutch CSOIL model, the HESP model, the German UMS model, the CLEA model from the UK, and the RBCA for the US and Canada. Some of them are very well described and available as a computer application, whereas others are still in an experimental stage. They share the concept of exposure assessment and toxicological standards, but do differ for the sub models calculating exposure and toxicological endpoints. Most kind of differences are relevant as the different countries do show a different environmental policy, and different type of behaviour that influences human exposure.

In conclusion it can be stated, that the concept of risk assessment of contaminated soil is generally identical all over the world. By the use of exposure models, that are scientifically well established, a major part of the risk assessment for humans is similar for most countries. Differences are to be expected, caused by different environmental regulations, human behaviour and country specific data on meteorological situation, and so on. Therefore, for calculation of risk reduction by soil remediation, acceptance of the method will be significant when using the general concept of exposure exceeding an unacceptable risk level. However, it will be essential that the REC-method provides for freedom to adapt the risk reduction assessment procedure to national standards, values and norms.

3.3 **Identification of relevant aspects for Risk reduction**

Given the object - path - source orientation of the risk reduction assessment, it is necessary to start with the identification of threatened objects on the site and in the immediate surroundings, expected to be affected by the soil contamination.
According to the risk definition, the following classes of threatened objects are judged as important:

1. people living or working in the system;
2. workers involved in the evaluated remediation alternative;
3. ecosystem situated in the system;
4. specific constructions/infrastructure for which damage may pose a risk for humans or the ecosystem;
5. individual flora or fauna that is needed to be protected separately.

With respect to the assessment of the relevance of each object for the evaluation process, the following decision schemes will be used:

1. *People living or working in the system*

```
                              +))))))))))))))))),
                              *People in system?/))< no, not relevant
                              .))))))))0))))))))-
                                       ?
                                      yes
                        +))))))))))))))2))))))))))))),
                        * relevant subpopulation ?  *
                        .)))0))))))))))))))))))))0)))-
                   +))))))))-                  .)))))))),
                   ?                                     ?
                  yes                                    no
+))))))))))))))))2))))))))))),        +))))))))))))))))2))))))))))))))))),
*Exposure of this subpopula-  *          *Exposure of an applicable** stan- *
*tion will be quantified*     *          *dard population will be quantified*
.))))))))))))))))))))))))))))))-        .))))))))))))))))))))))))))))))))))-
             *: scenarios a.o. living, working, agriculture, etc;
             **: standard population dependent on scenario.
```

2. *Workers involved in the evaluated remediation alternative*

```
                  +))))))))))))))))))),
                  *Workers exposed to /))< no, not relevant
                  *soil contamination?*
                  .)))))))))0)))))))))-
                            ?
                           yes
                +)))))))))))2))))))))))))),
                *Exposure fully countered/))< yes, not relevant
                *by protection measures? *
                .))))))))))))0))))))))))))-
                            ?
                            no
         +))))))))))))))))))2)))))))))))))))))),
         *Exposure to workers will be quantified*
         .))))))))))))))))))))))))))))))))))))))-
```

3. *Ecosystem situated in the system*

```
                              +)))))))))))))))))),
                              *Ecosystem relevant/))< no, not relevant
                              .)))))))))0))))))))-
                                        ?
                                       yes
                              +)))))))))2)))))))),
                              *Can this ecosystem*
                              *be specified?     *
                              .))0)))))))))))))0))-
                     +)))))))))))-            .))))))))))))),
                     ?                                      ?
                    yes                                     no
       +))))))))))))))2))))))))))))),       +)))))))))))))2))))))))))))),
       *Exposure of this specific  *           *Exposure to a "standard"   *
       *ecosystem will be evaluated*           *ecosystem will be evaluated*
       .))))))))))))))))))))))))))))-       .))))))))))))))))))))))))))))-
```

4. *Other objects*

Constructions

```
                        +)))))))))))))))))))))))))))))))))))),
                        *Are there any specific constructions/))< no, not relevant
                        *that deserve protection?             *
                        .))))))))))))))))))0)))))))))))))))))-
                                           ?
                                          yes*
                        +))))))))))))))))))2)))))))))))))))))),
                        *exposure to these constructions will*
                        *be evaluated                         *
                        .)))))))))))))))))))))))))))))))))))))-
```

Specific plant and animal species or individuals

```
                        +)))))))))))))))))))))))))))))))))),
                        *are there specific plant or animal/))< no, not relevant
                        *species or individuals that       *
                        *deserve protection?               *
                        .))))))))))))))))))0))))))))))))))))-
                                           ?
                                          yes*
                            +))))))))))))))2)))))))))))))))),
                            *exposure to these species or  *
                            *individuals will be quantified*
                            .))))))))))))))))))))))))))))))-
```

*: only relevant if negative effects to the object are regarded as not expressible in costs.

System area

After evaluation of the potentially threatened objects, and before determining the exposure scenario for each object in detail, it is necessary to check whether or not there can be additional objects identified, that may be at risk in a future situation. This may take place in cases, where the remedial activities will take place after a certain 'delay period' in which spread of the contamination may lead to exposure for new objects. Another possibility is that one of the remedial options doesn't contain the contamination (fully). In these instances it is necessary to define the system area for the assessment of risk reduction.

It depends on the level of detail of the REC-assessment, and on the available information how the system area is determined. First, a rough evaluation of the surroundings is made, to find out if there are sensitive objects that may be at risk in the future. If this is the case, it may be useful to make a rough estimation of the spread of the contamination within the regarded time period.

Types of exposure including background exposure

In order to be able to consider the relevance of exposure reduction by soil remediation related to the total exposure, we propose to include background exposure into the REC-assessment procedure, as far as possible. By background exposure is meant the industry or activity specific background exposure (such as benzene at gasoline stations or chlorinated solvents at dry cleaning shops) as well as the background exposure by other sources (via food, air, etc.). This will probably be worked out in phase 2 of the project.

The exposure posed to the discerned threatened objects can be expressed in a general scheme as presented below. The discerned types of exposure and relevant exposure routes will be briefly discussed in the following text.

```
                          +))))))))))))))))))))),
                          *   exposure to soil   *
                          *   contamination      *
                          .)))))))))))?))))))))))-
             +))))))))))))))))))))0)))2)))))))))))))0))))))))))))))))),
 +))))))))))?))))))))),   +)))))))?))))))),   +)))))?))))))),   +))))))?))))))),
 *People living & wor-*   *Worker involved*   *Ecosystem in*   *Other objects *
 *king in system area *   *in remediation *   *system area *   *in system area*
 .))))))))))>)))))))))-   .)))))))>)))))))-   .)))))>))))))-   .))))))>)))))))-
             .))))))0))))))))))))))2)))))))))))))))))2))))))))))0))))))-
       +)))))))))))>))))))))))),                    +)))))))))))>))))))))))))),
       *   exposure to         *                      *   exposure to effects   *
       *   external sources    *                      *   of soil remediation   *
       .)))))))))))))))))))))))-                    .)))))))))))))))))))))))))-
```

Given the discerned sources, the following possible forms of exposure can be discerned, which may be applicable to one or more of the discerned threatened objects:

1. exposure to contaminants originated from the soil contamination;
2. exposure to contaminants liberated due to the execution of the remedial option;
3. exposure to contaminants originated from external sources;
4. exposure to calamities due to the soil contamination;
5. exposure to calamities due to the execution of the remedial option;
6. exposure to direct effects of the execution of the remedial option such as lowering of the groundwater table and excavation of soil.

In the scope of the evaluation of added risk, a separate form will be regarded:

7. exposure to calamities due to external sources.

The relevance and a first indication of the possibility for quantification of each exposure type for each discerned class of vulnerable objects is listed in table 3.1. This table will form the base of the operationalization and quantification of risk reduction for the selected aspects (objects).

Table 3.1. Discerned exposure types in phase 1.

exposure type	people	workers	ecosystem
1	exposure model; toxicological standards	exposure assessment; toxicological standards	exposure assessment; ecotoxicological standards
2	exposure assessment	exposure assessment; toxicological standards	1
3	statistics	statistics	statistics
4	-	-	-
5	statistics	statistics	-
6	-	-	assessment
7	statistics	statistics	-

-: judged as less relevant or not relevant;
1: assumed to be insignificant compared to exposure type 1.

3.4 Operationalization of selected aspects

3.4.1 *Detailing general expression Risk reduction*

Given the aim of the REC-project, the required procedure must enable quantification of the total risk for possible remedial options compared to Total risk TR_0.
Risk reduction was defined in paragraph 2.1.1. as:

Risk reduction = $TR_0 - TR_i$ (3)

in which:

Risk: $R = X_i \, A \, t$ (1)

in which:

R is Risk;
X is normalized 'total exposure';
i is remediation alternative i;
t is time.

In this paragraph, X must be operationalized.

As mentioned before, two types of risks are of importance:

1. risks related to exposure to contaminants;
2. risks related to exposure to certain calamities.

Exposure to contaminants can be quantified as follows:

$X_{exposure\ contaminants} = RIndex \, A \, n$

in which:

RIndex is a risk index, equal to the amount of exposure, divided by an applicable toxicological threshold value (RIndex = Exposure/Toxicological threshold value);
n is the number of exposed objects.

Exposure to calamities can be quantified as:

$$X_{\text{exposure calamities}} = L \times S$$

in which:

- L is likelihood of occurrence calamity;
- S is "seriousness factor".

In this stage, this paper will further focus on exposure risks. Risks for calamities can be discussed in a phase II of the project.

3.4.2 *Quantification of exposure (X) to contaminants*

In the following text, applicable formulas will be discussed for people, workers and the ecosystem. Subsequently, the potential of integration of these formulas will be regarded.

People living or working in the system

For this group, the exposure to contaminants originated from the soil contamination could be quantified, using the following formula:

$$X = RIndex \times n$$

in which:

- RIndex is exposure/TDI;
- n is number of exposed individuals at the site.

The first step is to define the applicable exposure scenario given the site specific situation. This exposure scenario is used for the calculation (thereby using the formularium of exposure models). If a zoning into areas with different exposure situations could be made and/or subgroups can be discerned, this formula can be separated into elements for each zone and/or subgroup (for example children and adults, working and living area, and so on).

Workers involved in the evaluated remediation alternative

With respect to the quantification of the exposure of workers, it could be assumed that protection equipment is fully effective, implying that only exposure due to inhalation of dust and vapours in class 1T remediation zones and exposure to vapours in class 2T remediation zones has to be taken into account. Such exposure will probably mainly be limited to remediations involving excavation of contaminated materials.

For workers, the exposure to contaminants during the remedial work could be quantified once the exposure scenario is defined, taking into account a proper evaluation value, for example the MAC-value. The MAC-value is commonly accepted to describe allowable exposure for working individuals. The MAC-value accounts for lower vulnerability, lower exposure time fractions and a lower total exposure period for workers compared to people (40 years instead of 70).

Thus, the exposure to soil contamination during the remediation could be quantified as follows:

$$X = RIndex \times n$$

in which:

- RIndex is exposure/MAC;
- n is number of exposed workers.

Ecosystem situated in the system area

Due to a lack of a quantitative, species-specific model for the exposure of ecosystems to soil contamination and the lack of a system for the judging of the value of different ecosystem types, a species-specific or ecosystem-specific exposure-assessment is not yet possible.

In the assessment of ecological risks, a number of aspects are important, which follow the same conceptual approach as the evaluation of human exposure:

$$Risk_{ecosystem} = Exposure_{ecosystem}/Toxicological\ threshold_{ecosystem}.$$

Exposure ecosystem

Although there is an immediate contact between soil species and soil contamination, the exposure of an ecosystem is related to the ***accessibility*** of the area. In case there is an intensive exchange between parts of the ecosystem (for example via the food chain) and the possibilities for a high variety in soil species are large, the accessibility of the area is evaluated as large. In fully accessible areas, such as natural reserves, the total number of types of flora, fauna and microorganism per m^2 is large, and maximal contact between species and the soil contamination is possible. In less accessible areas such as urban areas or industrial areas, the disturbing factors as underground infrastructure, pavement, and so on lead to a smaller number of different species per m^2. The total surface area that can be contaminated before a specific number of species is at risk is therefore larger in less accessible areas. The critical surface to arrive at a certain degree of "ecological accessibility", has been set (urgency determination, Soil Protection Act) at 50 m^2 for natural areas, 5,000 m^2 for urban and agricultural areas and 500,000 m^2 for industrial, barren and city areas.

Toxicological threshold ecosystem

It is proposed to assess the effects soil contamination has on the potential, relative number of species, using available HC_{50} values. For a number of contaminants, HC_{50} values have been derived. If one assumes that for each contaminant, the concentration/HC function has the same shape, we can derive a concentration/threatened species function for each contaminant for which a HC_{50} value is available, describing the concentration in soil versus the percentage of species protected. The number of species at risk will be divided by 50, which is proposed to be taken as the threshold for ecosystems (comparable to TDI for humans).
Thus, the exposure to soil contamination could be quantified as follows:

X = RIndex Â n

in which:

RIndex is % unprotected species/50;
n is influenced surface/critical surface (50, 5,0000 of 500,000 m^2).

The ecological exposure index can be calculated as follows:

- for natural areas:

X = % unprotected species/50 Â influenced surface (m^2)/50 (m^2)

- for urban and agricultural areas:

X = % unprotected species/50 Â influenced surface (m^2)/5,000 (m^2)

- for industrial, barren and city areas:

X = % unprotected species/50 Â influenced surface (m^2)/500,000 (m^2)

3.4.3 *Exceeding toxicological thresholds*

A potential problem with the quantification could be the comparison of exposure situations where threshold values such as TDI (for people), MAC (for workers) and HC_{50} (for ecosystems) are exceeded with situations in which these values are not exceeded. However, as a general rule, remedial options which will lead to situations in which exceedence of thresholds such as TDI, MAC or HC_{50} may remain, are regarded as not acceptable. However, the time necessary to achieve an exposure level below the mentioned thresholds can differ for several options. This needs further attention in the determination of risk reduction. In the presented proposal for quantification, risk reduction above threshold values is weighted equally to risk reduction below threshold values. This aspect can be tackled by implementing an additional weight factor in the formula.

3.4.4 *Exposure to mixtures of compounds*

In the operationalization of the assessment of mixtures of chemical compounds, it is proposed to subscribe the Dutch method of defining actual risks for humans and the ecosystem. There it is assumed, that toxicity of mixtures is additive for different groups of compounds, with toxic resemblances, such as PAHs, chlorophenols, and others. Accordingly, all RIndexs of all chemicals within such a predefined group are to be summed up. Exposure (X) must then be calculated using the total of RIndexs, for humans and the ecosystem, separately. For the different groups of mixtures, one must follow the total procedure of integration to obtain the total Risk reduction per group.

3.4.5 *Overview of inputs in quantification*

In table 3.2 , an overview is given of the inputs used with the proposed assessment of risks to people living or working in the system area, workers involved in the remediation and the ecosystem.

Table 3.2. Overview of inputs used with the proposed risk quantification assessments.

vulnerable object	toxicological threshold	n	t
people	TDI	number of people	total time
workers	MAC	number of workers	remediation period
ecosystem	HC_{50}	influenced area/critical surface	total time

3.5 **Integration of the quantified aspects**

Before integration of the quantified aspects, the total exposure as a function of time (X) has to be transformed to Risk, by multiplying the exposure with the time period of this exposure (see formula 1). To arrive at risk reduction, the total risk (TR) is subtracted from the anchor point, defined as the total risk that would occur if the exposure at t = 0 would maintain during the total time span. The risk reduction for the separate aspects can thus be calculated.

With respect to the integration of the risks for exposure of people, workers and the ecosystem to contaminants, one must add the risk reduction for the separate aspects that are evaluated, as the underlying toxicological threshold that is used to normalize the exposure are regarded as having the same societal meaning. However, it can be expected, that the user of REC wants to weigh the separate aspects differently. Therefore, additional weight factors are to be inserted in the next expression:

$$\text{Risk reduction} = E0 - (E_{before} A t_{before}/Tt + E_{during} A t_{during}/Tt + E_{after} A t_{after}/Tt$$

$$E0 = W_p\, A\, E0_{people,\ before\ remediation}\, A\, Tt/Tt + W_e\, A\, E0_{ecosystem,\ before\ remediation}\, A\, Tt/Tt$$

$$E_{before} = W_p\, A\, E1_{people,\ before\ remediation}\, A\, a/Tt + W_e\, A\, E1_{ecosystem,\ before\ remediation}\, A\, a/Tt$$

$$E_{during} = W_p\, A\, E1_{people,\ during\ remediation}\, A\, b/Tt + W_w\, A\, E1_{workers,\ during\ remediation}\, A\, b/Tt + W_e\, A\, E1_{ecosystem,\ during\ remediation}\, A\, b/Tt$$

$$E_{after} = W_p\, A\, E1_{people,\ after\ remediation}\, A\, c/Tt + W_e\, A\, E1_{ecosystem,\ after\ remediation}\, A\, c/Tt$$

in which:

W_p is weight factor, people;
W_w is weight factor, workers;
W_e is weight factor, ecosystem;
Tt is total time;
a is time before remediation starts (after t = 0);
b is remediation time;
c is remaining time period (a + b + c = Tt).

Two arguments are applicable in weighing the relevance of the different objects: population, remedial workers, and ecosystem. First, differences in maximal tolerable exposure are normalized by the distinct toxicological threshold values (TDI, MAC, resp. HC_{50}), and number of exposed humans versus critical surface area for the ecosystem. Accordingly, differences in environmental policy is taken care of, and all three objects can be weighed equally. Additional weight factors should therefore embody social choices on the differences between the objects. The second argument is the minor likelihood of combinations with equal relevance for the humans and ecosystem. For example: for a excavation option in a densely populated area the population and workers will show a equally high relative exposure risk, whereas risk for the ecosystem could be assumed to be rather low. Vice versa, high risk for the ecosystem can be expected in a natural reserve with a rather low risk for the population and remedial workers. Hence, whether humans or the ecosystem will define the total risk for all subjects into a great extent in most cases. Additional weight factors can be expected not to be discriminating.

3.6 Overview of selected, operationalized and quantified aspects for Risk reduction

In table 3.3, an overview is given of the elaborated aspects in this chapter.

Table 3.3. Overview of aspects for Risk reduction.

identified object	selected	operational	quantified	integrated
general population	phase I	yes	yes	yes
remedial workers	phase I	yes	yes	yes
ecosystem	phase I	yes	yes	yes
infrastructure	phase II	no	no	no
other objects that need to be protected	phase II	no	no	no
background exposure	phase II	no	no	no
calamities	phase II	no	no	no

HOOFDSTUK 4

ENVIRONMENTAL MERIT

4.1 Summary

In this chapter a proposal for the assessment for 'environmental merit' is described. The proposed definition of environmental merit in this chapter is: ***the outcome of an integral evaluation of potential environmental influences of the contamination and its remediation, whereby these potential influences are not restricted to a specific site.*** Environmental merit will be based on the quantification of 'use of the environment', thereby not including the actual effects of this 'environmental use'. This choice avoids detailed discussion on the environmental effects. The term 'environmental influences' relates to scarcity of commodities and potential influence on environmental quality. The proposed procedure only covers the most substantial environmental influences, and uses data that are available in the daily practise of soil remediation.

The improved soil- and groundwaterquality and prevention of future spreading is regarded as positive inlfluence. The use of scarce commodities (soil, groundwater, drinkingwater, space and energy) and influences on the environmental quality (air and water emissions), are identified as negative aspects. Some aspects of remediation activities are considered to be not relevant for the environmental merit calculation, such as the use of chemicals and other materials.

Some aspects have been operationalized by an equivalent-definition. This has been done for: the actual improvement of soil and groundwater quality, the prevention of future soil and groundwater contamination, the use of clean soil and groundwater and emissions to the surface water and air. For the calculation of the prevention of future soil and groundwater contamination a rough estimation of spreading is made: a calculation of maximum potential spreading gives an overestimation of the actual environmental influence. Other influences are operationalized in the following units: drinkingwater in m^3, energy in MJ and space in m^2.

The integration of the operationalized aspects is executed in two steps. First by combining the aspects with the same unit: the different soil and groundwater aspects. Then the different scores have been standardized by relating them to a default situation with a most desirable and least desirable outcome on every aspect. The weighing of the different aspects is not done in this report, because further research is needed on this point. The weighing can be done by the users of the method.

4.2 Definition and context

In this paragraph we will elaborate on the concept and definition of Environmental merit. Also, the relevant developments in the Netherlands and abroad will be discussed.

4.2.1 *Definition of environmental influences and Environmental merit*

Before identifying the relevant aspects for the assessment of environmental merit the criterium itself has to be defined. The proposed definition must be regarded as a working definition:

Environmental merit is the outcome of an integral evaluation of potential environmental influences of the contamination and its remediation, whereby these potential influences are not restricted to a specific site.

As was already explained in chapter 2, a choice has been made to relate environmental merit directly to the causes (past or present human activities) at the third level of the cause-effect relation ship, the so called 'use of the environment'.
This choice is motivated as follows:

- It makes the method applicable for the practice of remediation nowadays, because it is easier to relate environmental merit to the direct outputs of the remediation than to relate it to real effects on the environment. Uncertainties about the likelihood of occurrence (for example the greenhouse effect), and the impact of time and place of emissions on the actual environmental quality make an actual environmental assessment very complex.

- By using the REC-method to compare and optimize alternatives, general insight in the environmental influences of remediation activities to the user provides for information to assess if there are major differences between alternatives, and what activities cause these differences. This can be done without a detailed discussion on the environmental effects.

As can be seen in the definition, environmental merit only accounts for those environmental influences that have no direct relation with objects near the site, to prevent obvious overlap with Risk reduction. This means that it is assumed that the place where the outputs of the remediation take place is regarded as irrelevant for the assessment of environmental merit. Note that if emissions on the site lead to health risks, this will be included in the assessment of Risk reduction.

First we will elaborate on the term 'environmental influences', because these are the building blocks of the criterium environmental merit. Environmental influences will be regarded from two perspectives:

1. *Scarce commodities*
   This perspective relates to the concept that cycles of materials should be closed because of the scarcity of (raw) materials. This perspective is often referred to as 'Sustainable development' or 'responsibility for future generations'.

2. *Environmental quality*
   This perspective relates to the effect of emissions (solid, liquid or gas) on the environment on a local, regional and global scale.

Both perspectives will be taken into account in the evaluation of aspects to be included in Environmental merit.

Since one of the boundary conditions for this project is formed by the practical applicability of the method it will not be possible and desired to account for all causes of environmental influences. So in this stage of the development of the REC-method the aim is to incorporate the ***most substantial environmental influences***.

4.2.2 *Short description of national and international developments*

There is a growing awareness on the relevance of the environmental impact of remediation in the Netherlands. Several reports have been made in trying to assess the environmental impact of remediation. Some of these reports focus mainly on the environmental impact of remediation techniques, like reports from TAUW and POSW (LCA application for the selection of remedial option for sediment remediation), while others make a more integral calculation of environmental, social and financial criteria, like studies from the universities of Twente (vergelijking saneringsopties), Delft and Rotterdam (both consider environmental efficiency) and a study from TAUW (milieurendement). Many of these investigations are not adjusted to the data availability of the normal practice of remedial investigations, and therefore hard to apply. Other reports concentrate on a decision model for remediation options, like Bosland (RIVM/IVM). Methods that are based on the current remediation practice and partly consider environmental efficiency, are "Beoordelingsmethodiek voor saneringsvarianten" (TAUW) and "Rendement van saneringsvarianten" (Province Utrecht). There are also reports that concentrate on one of the aspects of REC, risk reduction, such as "risicorendement" (TAUW). A similar scope as REC has the feasibility study "risicogestuurd saneren" (RIVM).
In conclusion it can be stated, that the attention for environmental impact of remediation is growing, but there is no general method that combines a thorough evaluation of risks, environmental impact and other criteria such as costs and social aspects. It appears to be difficult to implement the developed methods (like LCA) in the remediation practice.
International developments on LCA are discussed and coordinated in SETAC.

4.3 **Identification of relevant aspects for Environmental merit**

In this paragraph, the identification of environmental influences, and the selection of the aspects that are considered to be of most significance will be discussed.

As was defined in paragraph 2.1.2, environmental influences may be regarded as positive (i.e. improvement of soil and groundwater quality) and negative (i.e. emissions to water and air).

Environmental merit refers to the integrated score of environmental influences, where the negative environmental influences are subtracted from the positive influences.

$$\textbf{Environmental merit} = TEI_{i,\ \text{positive aspects}} - TEI_{i,\ \text{negative aspects}} \quad (6)$$

The positive aspects of environmental merit are considered to be one of the driving forces for remediation (next to risk reduction), where the negative aspects are the unwanted environmental influences that are needed to arrive at the remediation goal. Regarding the remediation as a black box, this can be expressed in terms of in- and outputs (see fig. 4.1):

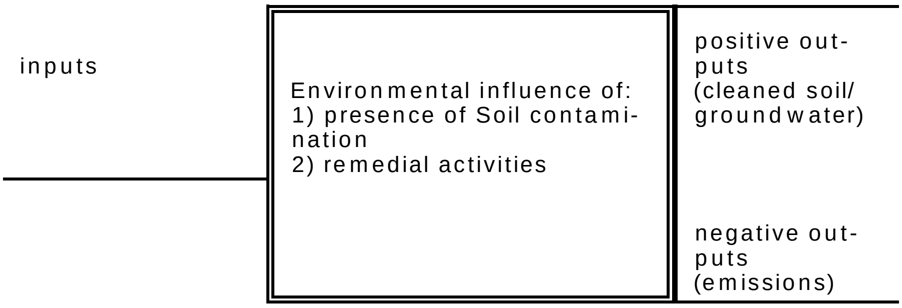

Fig. 4.1. Schematic presentation of Environmental influences.

The three perspectives of environmental influences will be discussed in the following sections.

4.3.1 *Benefits for the environment: positive outputs*

The first perspective to be operationalized is the assessment of the benefits of the remediation in terms of improvement of the soil and groundwater quality. As was already mentioned, this perspective is one of the driving forces for the remediation. Within this perspective, the benefits for the environment will be assessed. In remediation practice, two main types of alternatives are considered:

A. improving soil quality and groundwater quality by removing the contamination (by excavation and off site treatment or in situ);

B. preventing *future contamination* by containment measures.

Regarding the benefits for the environment, these two alternatives differ significantly in their contribution to improvement of the soil and groundwater quality. In both alternatives, the potential future contamination of soil and groundwater is prevented. However, in the first alternative, also the existing quality of contaminated soil and groundwater is improved.
The total benefits for the environment by remediation thus exist of two parts:

1. actual improvement of existing soil- and groundwater quality;
2. prevention of future soil- and groundwater contamination.

Both parts, for soil as well as for groundwater will be incorporated into environmental merit. Note that excavated soil that is not treated but disposed on a waste site doesn't contribute to the improvement of soil quality, and therefore will not be counted as positive output.

4.3.2 *Sacrifices for the environment: negative inputs*

To reach the goal of the remediation, a number of scarce commodities are used. All kinds of equipment and materials are needed to execute the remedial activities. In the scope of the REC-method, it is proposed to limit the assessment of the negative inputs mainly to ***primary inputs***, the resources that are used directly in the remedial activities. The so-called secondary and tertiary inputs, necessary to produce the equipments used are not included, except for the use of electricity. In several studies it was indicated that these inputs do not have significant impact on the total quantity of used commodities, and therefore do not have discriminating power.

To make an inventory of primary inputs in the remediation alternatives, these alternatives have to be described in detail. In Annexe A, an example of a schematic representation of the process of remediation is presented. For every step in the process, the inputs need to be defined, leading to the following list:

1. clean soil;
2. clean groundwater;
3. drinking water;
4. energy;
5. space;
6. chemicals (nutrients, conditioners, etc.);
7. materials used during remediation (piping, water treatment installation, sheet pile walls, etc.).

- *Clean soil*
  In some alternatives, the contaminated soil is replaced by clean soil from another source. This is considered to be a negative input of the remediation process.
- *Clean groundwater*
  During the groundwater remediation, an amount of clean groundwater is extracted to flush the contaminated zone.

- *Drinking water*
  In some alternatives, clean water is infiltrated in the soil. If drinking water is used for this purpose, this is considered to be a negative environmental input.
- *Energy*
  Energy that originates from fossil fuels is considered to be not renewable, and is evaluated a scarce commodity.
- *Space*
  Space is also considered to be scarce in the Netherlands. In this aspect, the use of space for installations and storage of final waste (including soil that is not treated) are counted. Besides this, the space that will be used ***additionally***, because of restrictions for use at the contaminated site will be taken into account.

From this list of inputs, these five inputs will be incorporated into the assessment of Environmental merit.

- *Chemicals*
  The chemicals that are used in the treatment process are considered to be no scarce commodities. There is no driving force to minimize the use of these chemicals, other than economic driving forces, so this will be reflected in the cost-criterium.
- *Materials*
  The materials that are used in the remediation are not 'consumed' during the remediation: after the remediation stops, the installation will be removed. The steel sheet pile walls will be available for further use, the plastic pipes can be recycled, and so on. So it is assumed, that the 'occupation' of materials during the remediation doesn't have significant impact on the environment.

The inputs 'chemicals' and 'materials' will not be included into the environmental merit criterium.

4.3.3 *Sacrifices for the environment: negative outputs*

The quality of the environment can be affected as a result of emissions of the remedial activities. In this paragraph, air, water and solid emissions are considered.

Air emissions

Air emissions as outputs of soil contamination and soil remediation are caused by two aspects:

1. the evaporation of the contamination;
2. the combustion of fuel:
   - directly, by the use of fuel for pumps, transports, etc.;
   - indirectly, by the production of electricity.

The first aspect, evaporation of the contamination is evaluated in the Risk reduction criterium, thereby relating the evaporation to specific objects. The contribution of evaporation of contamination to the total air emissions is negligible, and therefore considered not to be significant for the assessment of environmental merit.
The second aspect is considered to be relevant. The combustion of fuel can be related to different potential effects on the environment like climate change, stratospheric ozone depletion, photochemical smog formation, eutrophication and acidification. So the use of (non renewable) energy will serve as an approx for all the negative outputs of remediation, related to the fore mentioned environmental influences.

Water emissions
Water emissions as outputs of soil remediation are caused by the extraction of groundwater for dry excavation, groundwater remediation or containment. The extracted water that is infiltrated in the soil (after treatment) is considered to be no emission. The (nett) emission of water can be wasted into the sewer system or at the surface water.
Water emissions are regulated in quantity and quality. If the water is emitted to the sewer system, this water will be treated in the treatment system for the total water flow in the sewer system. It is assumed that the impact of the water emission to the sewer system on the efficiency of the water treatment system is negligible. So, emissions on the sewer system are considered to have no environmental influence.
If the water is emitted to the surface water, the surface water quality may be influenced. This depends on the quantity and quality (load) of the emission, and will be included as a negative output.

Solid emissions
Besides air and water emissions, remedial activities may lead to the production of solid waste (sludge, contaminated soil). Solid waste has no influence on the environmental quality as long as the solid waste is stored safely. The storage of waste has impact on the use of the scarce commodity 'space'. If solid waste is incinerated, the impact on the environment is evaluated on the basis of energy consumption and the emissions of energy consumption.
In the REC-method, the emission of solid waste is not evaluated as such, but is incorporated in the aspect 'space' or 'energy'.

Summary identification relevant aspects
In Environmental merit, the inputs and outputs that are selected can be divided into aspects affecting environmental quality and factors affecting the use of scarce commodities.

	scarce commodities	environmental quality
inputs	- clean soil - groundwater - drinking water - space - energy	not applicable
outputs	+ cleaned soil + cleaned groundwater	- air emissions - surface water emissions

4.4 Operationalization of selected aspects
In this paragraph the selected aspects will be operationalized: the procedure for quantification of the separate aspects will be discussed.

4.4.1 *Benefits for the environment: positive outputs*
For the quantification of the positive outputs for the environment, a distinction must be made between 1) the actual improvement of soil quality and 2) the prevention of potential soil contamination.

Actual improvement of soil and groundwater quality
For the assessment of the improvement of soil and groundwater quality, the existing contamination situation at the time of the REC-evaluation is compared with the final contamination situation at the end of the remediation (as a function of time necessary to achieve this).

The improvement of soil and groundwaterquality can be related to specific standards for these compartments. It must be discussed what standards are applicable for the operationalization of this aspect. In this phase, we use the existing Dutch soil- and groundwaterstandards as an example.

In this quantification, the total volume (m^3 soil and groundwater) contaminated above the S-values (clean soil standards) will be considered. However, a decrease in concentrations from I- to T-value is considered to be an improvement, and needs to be included into the environmental benefit. Therefore, the total volume will be combined with the level of contamination. Every m^3 soil contaminated above I-level must be counted 0 % improvement, every m^3 clean soil 100 % improvement. Assuming a linear relation between S- and I-value, every m^3 soil and groundwater can be counted for a specific percentage, related to the final concentration achieved in this m^3. (see fig. 4.2)

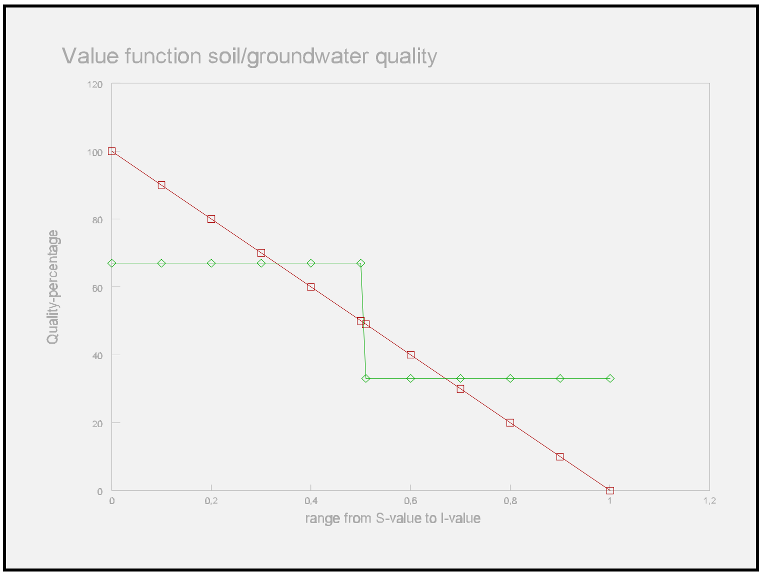

Fig. 4.2. Linear relation and step function between soil and groundwater quality and %-benefit.

For practical reasons (i.e. the availability of data from soil investigation), it is suggested to use a step function, that distinguishes four categories of soil and groundwater quality:

I.	< S-values: clean soil	100% benefit
II.	S-T-values:	67% benefit
III.	T-I-values:	33% benefit
IV.	> I-values: seriously contaminated	0% benefit

In the categorizing of a volume contaminated soil, the most important contamination determines the quality factor. So in case of a combination of contaminations, a certain volume is assigned to category II if all the contaminations are in category II or I.

In this way, the contamination situation is translated into ***lean Soil equivalents, Seq, and clean groundWater equivalents, Weq***.

clean Soil equivalents = Seq = $\Sigma\, Vsoil_{yj} \cdot \%_y$

clean groundWater equivalents = Weq = $\Sigma\, Vgrwater_{yj} \cdot \%_y$

in which:

V_{yj} is volume (m^3) with concentration y of substance j;
$\%_y$ is % benefit, related to quality categories I to IV.

The following example illustrates the quantification of the actual improvement of soil and groundwater quality.

Example
Contamination situation t = 0:
- 100 m^3 contaminated soil: 25 m^3 > I-value; 25 m^3 T-I; 50 m^3 S-T;
- 1000 m^3 contaminated groundwater: 250 m^3 > I-value; 250 m^3 T-I; 500 m^3 S-T.

Contamination situation t = end:
- 10 m^3 contaminated soil: 10 m^3 S-T; 90 m^3 clean soil;
- 200 m^3 contaminated groundwater: 10 m^3 T-I; 190 m^3 S-T; 800 m^3 clean groundwater.

First the total contamination at t = 0 is expressed in clean soil and groundwater equivalents:

soil: $25 \times 0 + 25 \times 0.33 + 50 \times 0.67 = 41.75$ Seq

groundwater: $250 \times 0 + 250 \times 0.33 + 500 \times 0.67 = 417.5$ Weq

Then the total contamination at t = end:

soil: $10 \times 0.67 + 90 \times 1 = 96.7$ Seq

groundwater: $10 \times 0.33 + 190 \times 0.67 + 800 \times 1 = 930.6$ Weq

The actual improvement thus is:

soil: 96.7 - 41.75 = 54.95 Seq

groundwater: 930.6 - 417.5 Seq. = 513.1 Weq

If the REC-method is applied in situations where one of the remedial options starts after a delay period, the additional soil and groundwater volume that will be contaminated during this delay period must be incorporated in the assessment of the actual improvement of soil quality.

The prevention of potential soil and groundwater contamination
Next to the assessment of the actual improvement of soil and groundwater quality as a result of remedial action it is necessary to evaluate another benefit of remediation or containment: further spread of contamination will be prevented, and thus potential environmental influence is prohibited. Although an ICC option doesn't improve the soil and groundwater quality, it sure has an environmental benefit: the future contamination of soil and groundwater is prevented.

The soil and groundwater contamination that may occur during the period that no measures are taken can be quantified in two ways:
1. a rough estimation is made of the groundwater velocity, the retardation of the contamination: this leads to an estimation of the contamination situation that exists at the end of the regarded time span;
2. in a worst-case approach, it is assumed that the total load is distributed over a soil volume, at a level of > S-value. This resembles the maximum Seq, Weq.

These two methods will be illustrated with the example given in the previous section.

Example
Contamination situation t = 0:
- 100 m^3 contaminated soil: 25 m^3 > I-value; 25 m^3 T-I; 50 m^3 S-T;
- 1000 m^3 contaminated groundwater: 250 m^3 > I-value; 250 m^3 T-I; 500 m^3 S-T.

Contamination situation t = end if no measures are taken:

I *based on rough estimation of spreading*

110 m^3 contaminated soil: 27 m^3 > I-value; 30 m^3 T-I; 53 m^3 S-T

1200 m^3 contaminated groundwater: 300 m^3 > I-value; 300 m^3 T-I; 600 m^3 S-T

II *based on distribution contamination on volume, > S-value*

500 m^3 contaminated soil S-T

37500 m^3 contaminated groundwater S-T

So the total prevention of future pollution can be calculated in Clean soil and groundwater equivalents:

I soil: (27-25) Å 1 + (30-25) Å 0.67 + (53-50) Å 0.33 = 6.35 Seq[2]

groundwater: (300-250) Å 1 + (300-250) Å 0.67 + (600-500) Å 0.33 = 116.5 Weq

II soil: (-25) Å 1 + (-25) Å 0.67 + (500-50) Å 0.33 = 106.8 Seq

groundwater: (-250) Å 1 + (-250) Å 0.67 + (37500-500) Å 0.33 = 11800 Weq

As can be concluded from this simple example, the difference in the two methods is very significant. The first method uses site specific information for the assessment of potential spreading, which is somewhat in contradiction with the definition of Environmental merit (being potential environmental influences, independent of the site of the influence).
However, the second method is not realistic and would overestimate the total benefit of the environmental influence of remediation. As a result of this, the contribution of the remediation (i.e. the actual clean up) would then be negligible. Therefore, it is suggested to apply the first method to quantify the environmental benefit of prevention of future contamination.

In spite of the fact that the prevention of future contamination is the same for all remedial alternatives, and as a result of this is not a discriminating factor, it is included in the calculation of Environmental merit. Reason for this is to take the benefit of containment measures into account, which will be reflected in a higher score on Environmental merit. This is especially important for the further development of REC towards a method to compare sites for priority setting.

Summary

For the quantification of the positive outputs for the environment, a distinction is made between 1) the actual improvement of soil quality and 2) the prevention of potential soil contamination.

1. The actual improvement is quantified by relating the volume of contaminated soil to a quality index. This procedure expresses the contamination situation in ***Clean soil and groundwater equivalents (Seq, Weq)***. This procedure can be applied before, during and after the remediation. The environmental benefits of the actual improvement of soil and groundwater quality can thus be quantified as function of time.
2. The prevention of potential soil and groundwater contamination expresses the environmental benefits of the contained situation by estimating the contamination situation that would occur if no measures were taken during the regarded time span. The increase in contaminated soil and groundwater is also expressed in clean soil and groundwater equivalents.

The total environmental benefit for soil and groundwater is the sum of the actual improvement and the prevention of potential contamination.

4.4.2 *Sacrifices for the environment: negative inputs*

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[2] Note that the percentage applied to calculate the potential benefit differs from the calculation of the actual improvement. Here the aim is to assess the seriousness of the contamination that will occur: every m^3 that will be contaminated above I-level must be counted 100 %, between T-I-level 67 % and so on.

- *Clean soil*

  The soil used to fill the excavation pit can also be characterized by two factors, volume and quality. The expression of Clean soil and groundwater equivalents is also applied here. If clean soil is applied, the total volume has to be counted to quantify the negative input 'clean soil'. If the soil that is used to fill the excavation pit contains concentrations above the S-level, the total volume is multiplied by the %, related to the soil quality.

- *Clean groundwater*

  It is assumed that all the water that will be extracted is replaced by clean groundwater: so the extraction uses clean groundwater for flushing. If water is infiltrated during the remediation, only the nett amount is considered to be used.

  $$V_{nett\ withdrawn} = V_{extraction} - V_{infiltration}$$

  Note that the effect of the extraction, i.e. lowering the groundwater table is not evaluated. If the extraction may lead to direct effects for the ecosystem of vegetation, this must be incorporated in the Risk reduction criterium, since it is site specific, and related to a specific object. This is not yet worked out in this phase.

- *Drinking water*

  If drinking water is used for the infiltration, this is considered to be the use of a scarce commodity. The total volume must be quantified.

- *Energy*

  Energy is used in two basic forms: electricity and combustion of fossil fuel (diesel). Since most of the electricity is produced from fossil fuel, both energy uses are considered to be equally scarce. The total energy use will be expressed in a normal unit for energy (MJ). The conversion factors for diesel and kWh are given:

  1 kg diesel (approx. 1.2 l) = 43 MJ

  1 kWh = 3.6 MJ

  Energy consumption, as negative input then can be measured in diesel consumption and kWh consumption.

- *Space*

  For the operationalization of the aspect space as scarce commodity, the ***surface*** occupied in a specific time period, as a result of the remediation must be quantified in m^2.

4.4.3 *Sacrifices for the environment: negative outputs*

Air emissions

The air emissions that are considered to be negative outputs of remediation are caused by the use of energy. The emissions related to the use of 1 litre diesel and 1 kwh will be compared, and a conversion factor for these two types of energy will be established. The total sacrifice for the environment, caused by the use of energy can be expressed in ***Air-emission equivalents***. This will be calculated with the following expression:

$$\text{Air-emission equivalents} = Aeq = \Sigma A_j/TA_j$$

in which:

A_j is total amount (load) of compound j;

TA_j is Target-value for compound j = air quality guideline values.

This expression gives insight in the amount of air that can be affected as a result of the air emissions. In Annexe B, the air emissions related to the use of energy are transformed to Air equivalents:

1 MJ electricity = 4.5 Aeq

1 MJ diesel = 6.7 Aeq

Water emissions

The quantification of water emissions resembles the method presented for Air emissions. The total sacrifice for the environment caused by emissions to the surface water will be expressed in ***Water-emission equivalents***.

$$\text{Water-emission equivalents} = Weq_{surf} = E\ W_j/TW_j$$

in which:

W_j is total amount (load) of compound j;

$TW_{j,\ surface}$ is Target-value for compound j for surface water.

The selection of a suitable Target-value is subject for discussion.
This expression gives insight in the amount of water that can be affected as a result of the water emissions.

4.4.4 *Summary of operationalization selected aspects*

In table 4.1 the content of paragraph 4.4 is summarized.

Table 4.1. Overview of selected aspects and the indicators and units for quantification.

perspective	selected aspect	indicator	unit
environmental benefits	1. improved soil quality 2. improved groundwater quality 3. prevented additional soil contamination 4. prevented additional groundwater contamination	1. volume, concentrations: soil 2. volume, concentrations: groundwater 3. estimated spread, volume, concentrations: soil 4. estimated spread, volume, concentrations: groundwater	Seq. (m^3) Weq. (m^3) Seq. (m^3) Weq. (m^3)
environmental sacrifices: use of scarce commodities	1. clean soil 2. clean groundwater 3. drinking water 4. energy 5. space	1. volume, concentrations: soil 2. nett volume: withdrawal - infiltration 3. volume 4. diesel and kwh-use 5. occupation of space/additional space needed for intended use	Seq. (m^3) m^3 m^3 J m^2
environmental sacrifices: environmental quality (emissions)	1. air 2. water	1. energy use (fossil fuels) 2. water emissions to surface water	Aeq. (m^3) Weq_{surf}. (m^3)

4.5 **Integration of the quantified aspects**

Now the selected aspects are quantified, the aspects need to be integrated, to arrive at a final score for Environmental merit. This integration will consist of the following three steps:

1. combining aspects that have the same unit: clustering the Seq. and Weq.;
2. standardizing the different scores, so that they can be added;
3. weighing of the different scores.

This last step will only be considered roughly, because for weighing additional research is needed. This can be done in phase 2 of the project.

4.5.1 *Combining soil and groundwater aspects*

The aspects that consider the same compartment will be combined. This means the scores on ***improved soil quality***, ***prevented additional soil contamination*** (both environmental benefits) and ***the use of clean soil*** (an environmental sacrifice) will be combined into one score. Since the environmental merit calculation is not-object oriented there is no need for weighing the aspect differently: all soil used is evaluated the same, independent of its location. The sum is expressed in the following formula:

$$Seq_{tot} = Seq_1 + Seq_2 - Seq_3$$

in which:

Seq_1 is improved soil quality (in Seq's);

Seq_2 is prevented additional soil contamination (in Seq's);

Seq_3 is used clean soil (Seq's).

The same procedure is followed for the aspects concerning groundwater: ***improved groundwater quality***, ***prevented additional groundwater contamination*** (both environmental benefits) and ***the use of clean groundwater*** (an environmental sacrifice).

$$Weq_{tot} = Weq_1 + Weq_2 - Weq_3$$

in which:

Weq_1 is improved groundwater quality (in Weq's);
Weq_2 is prevented additional groundwater contamination (in Weq's);
Weq_3 is used clean groundwater (Weq's).

4.5.2 *Standardization of the different (combined) aspects*

After this combining of aspects there remain seven quantified aspects:

1. total soil equivalents (Seq_{tot});
2. total groundwater equivalents (Weq_{tot});
3. drinking water (m^3);
4. energy (MJ);
5. space (m^2);
6. air equivalents (Aeq);
7. surface water equivalents ($Weq_{surface}$).

The first two combined scores on soil and groundwater are likely to be benefits for the environment, all the other scores are environmental sacrifices. Before integration of the seven aspects is possible, the scores on the separate (7) aspects must be standardized. In this way, the absolute scores are related to a scale that is derived from a general concept. If this general concept is applied on all the aspects, the standardized scores are comparable.

A general concept for standardization of different scores is defining a minimum and maximum value for a specific aspect. Comparing the actual score on a specific aspect with two extremes, positions the score in relation to the most desirable outcome and the less desirable outcome of the aspect.
The relation between the score on a specific aspect and its standardized value is assumed to be linear to the distance from both points. If for aspect Y the minimum score (Y = 0) -1000 and the maximum score (Y = 00) 6000, than for every score, Y can be derived from the linear relation (see fig. 4.3).

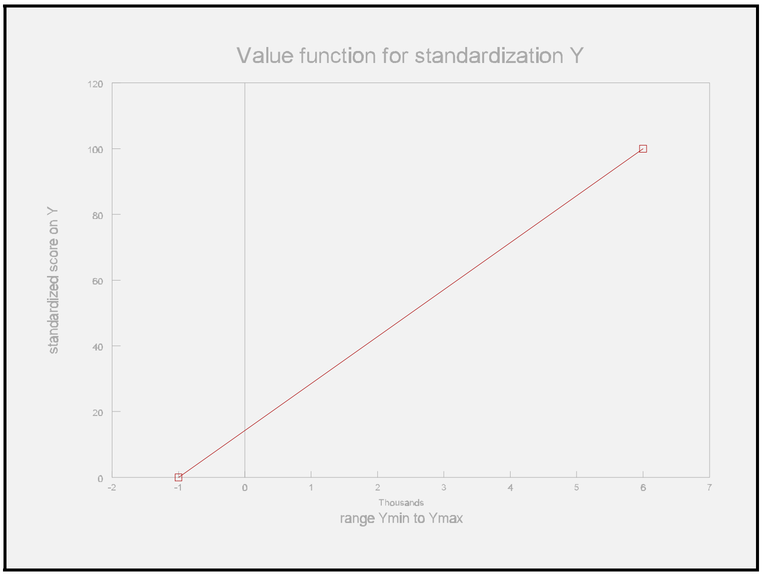

Fig. 4.3. Relation between 'minimum' and 'maximum' score for a specific aspect, and the normalized value for this aspect.

Now we have to define to the 'minimum' and 'maximum' score for all the seven quantified aspects. It is necessary to define a hypothetical minimum and maximum for the selected aspects. This will be derived according to a standard approach. For the determination of minimum and maximum values for the aspects, the most desirable and most undesirable situation for this contamination will be calculated by the standard approach, that is described in Annexe C. This leads to a minimum and maximum score for all the aspects. The minimum and maximum scores are related to a standardized score of 0 respectively 100.

4.5.3 *Weighing of the different aspects*

Before the final integration of the different aspects is possible a weighing can take place. Weighing of the different aspects can be done several ways, for example by: scientific research, policy priorities, expert guess or opinion research. At this moment there is no research available that covers the weighing of the selected aspects. Therefore in this phase of the development of the REC-method the different standardized scores are simply combined without weighing. Of course it is possible for the user to, within boundaries, add personal weighing.
This leads to the following formula:

$$\text{Environmental merit} = TEI_{i,\text{positive aspects}} - TEI_{i,\text{ negative aspects}}$$

$$= (W_s \times Y_1) + (W_w \times Y_2) - (W_d \times Y_3) - (W_e \times Y_4) - (W_{sp} \times Y_5) - (W_a \times Y_6) - (W_{surf} \times Y_7)$$

in which:

- W_s is weight factor, soil;
- W_w is weight factor, groundwater;
- W_d is weight factor, drinking water;
- W_e is weight factor, energy;
- W_{sp} is weight factor, space;
- W_a is weight factor, air emissions;
- W_{sur} is weight factor, emissions to surface water;
- Y_1 is standardized score, gained soil equivalents;
- Y_2 is standardized score, gained groundwater equivalents;
- Y_3 is standardized score, drinking water use;
- Y_4 is standardized score, energy use;
- Y_5 is standardized score, space occupation;
- Y_6 is standardized score, air emissions;
- Y_7 is standardized score, emissions to surface water.

4.6 Overview evaluated aspects Environmental merit

In this paragraph the discussions of this chapter are summarized. Table 4.2 gives an overview of the sequence of steps that are worked out.

Table 4.2. Overview of inventory, selection, operationalization, combination and integration of Environmental influences into Environmental merit.

inventory of relevant aspects	selection of aspects	operationalization of aspects	combination of aspects
1. gained soil volume with improved quality	1. gained soil volume with improved quality	1. Seq: volume combined with Q-level	1. Seq_{tot} = 1 + 3
2. gained groundwater volume with improved quality	2. gained groundwater volume with improved quality	2. Weq: volume combined with Q-level	2. Weq_{tot} = 2 + 4
3. use of clean soil	3. use of clean soil	3. Seq	
4. use of clean groundwater	4. use of clean groundwater	4. Weq (= volume)	
5. use of drinking water	5. use of drinking water	5. Volume	3. V_d
6. use of energy	6. use of energy	6. MJ	4. MJ
7. use of space	7. use of space	7. m^2	5. m^2
8. use of chemicals			
9. use of materials			
10. emissions to air of contaminants			
11. emissions to air of energy use			
12. emissions to sewer system	8. emissions to air of energy use	8. Aeq: energy type, standard emissions	6. Aeq
13. emissions to surface water	9. emissions to surface water	9. Weq_{sur}: load combined with standards	7. Weq_{sur}

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COSTS

5.1 Summary

In this chapter, a first description of the criterium Costs is presented. Costs refer to the expenses related to remedial activities as well as the changes in asset value that may be the result of increased possibilities in use of the property. Expenses cover as the direct as well as the indirect expenses (i.e. related to the remediation) and indirect expenses. A distinction will be made between foundation expenses at the beginning of the remedial activities, the replacement expenses and the continuous (operating) expenses.
To include the time value of money into the assessment of the total costs, it will be necessary to calculate the Nett Present Value of all future expenses.
The quantification of the change in asset value will be based on a combination of factors, such as the possibilities for use of the site, the current use, the market demand, prices, etc. This has not yet been worked out in phase 1.

5.2 Definition and context

In this paragraph, the definition and general expression of costs will be elaborated, as well as the existing practise for cost estimation in the Netherlands.

5.2.1 *Definition and general expression of Costs*

The building blocks for the Cost criterium are the **Financial expenses** directly or indirectly related to the remedial action. Besides this, **Changes in the value of assets** will be considered as costs. Both aspects will be expressed in monetary terms and need not to be normalized.
In chapter 2, Financial expenses and Change in value were expressed as:

Financial expenses: $F = (\text{cash flow})_i \, A \, t$ (7a)

Change in value: $V = (\text{asset increase/decrease})_i \, A \, t$ (7b)

in which:

F	is Financial expenses;
V	is change in Value;
cash flow	is amount of money paid for investments and operating costs;
asset increase or decrease	is change in value of asset by remediation;
i	is remediation alternative i;
t	is time.

Costs refers to the sum of expenses and changes in value, whereby, the change in the value of assets will (in most cases) be positive (i.e. a negative cost factor!).

Costs = $TF_{i(\text{positive sign})} + TV_{i(\text{negative sign})}$ (9)

The driving force for optimizing remediation alternatives is minimizing costs by minimizing the financial expenses and maximizing the increase of value of assets.

5.2.2 **Common practise on cost estimation**

Financial expenses

As was discussed in paragraph 2.3.1, it is common practise to compare the costs of remediation alternatives, based on the Nett Present Value. A simplified calculation method is described by the ministry of VROM. The nett interest rate that is applied in these calculations is set by the Minister of finance, once every year.
However, by calculating the Nett Present Value of financial expenses during the remediation period the following problems arise:

1. The party that has to pay for the remediation often prefers a cash flow that is more or less stabilized in time. Big fluctuations in expenses over the years result in a major impact on the profit and loss account of a company, and are therefore unfavourable.

2. By calculating with the interest rate set by the minister, the opportunity costs of money are evaluated from the opportunity to put the money in the bank. However, companies do evaluate investments on their internal rate of return: the opportunity costs of money are therefore significantly higher. If one calculates with a higher interest rate, alternatives that shift costs to the future (or spread these costs in time) are stronger favoured than by calculating with a lower interest rate.

3. The fixed interest rate is based on the interest that is expected to be realistic for short term investments (bank account) and a mean inflation rate, based on the general consumption pattern. However, the general inflation is not relevant, but the specific price developments of expenses for remediation (labour, capital goods). Since the calculated Nett Present Value is very sensitive for the selected interest rate, this aspect needs more consideration.

Changes in value of assets

Until now, the possibility of increased value of assets is not considered in the general cost estimation. In case of abandoning or hand over of a site, the total potential remediation costs are estimated (meaning the total, discounted financial expenses) and subtracted from the total value of the property. Based on this practise, one could conclude, that remediation doesn't lead to an increase in asset-value. However, it is accepted generally, that the value of the property is determined by the possible use of the site. This use is, among other things, determined by the soil quality and the restrictions related to remedial measures. Based on the evaluation of transactions of properties on contaminated sites, it is not clear until now what impact soil contamination has on the value of the assets or on the transaction speed.
Another aspect to be considered in the estimation of changes in asset vales is the interdependence between asset value and 'future remediation costs'. Part of the impact of soil contamination on the value of land is based on the assumption that remedial actions will be costly and necessary in the future. A devaluation of the property thus can be seen as a reservation for future expenses. If a significant reduction of remedial expenses will be achieved by new strategies like extensive remediation, than the impact on asset value is also expected to decrease. However, part of the 'psychological devaluation' is expected to remain relevant.
This aspect needs further elaboration in phase 2 of the REC-project.

5.3 **Identification of relevant aspects for Costs**

5.3.1 *Financial expenses*

The financial expenses related to a remediation can be divided in direct and indirect expenses. Direct expenses have to be made for the realisation of the remediation itself, and lead directly to the remediation goal. Indirect expenses are expenses that are prerequisite for remediation or the side effect of the remedial activities. The indirect expenses do not contribute directly to the remediation goal. An overview of direct and indirect expenses that can be discerned is given in table 5.1.

Table 5.1. Financial expenses of a remediation.

direct expenses	indirect expenses

- soil and sludge: costs for excavation, separation, temporary storage, transport, disposal, cleaning and re-use - roundwater: costs for withdrawal and cleaning - isolation measures: costs for installation - costs for management and environmental supervision of the remediation - costs for maintenance of remedial facilities - aftercare (for isolation option and temporary measures), including monitoring - replacement (for isolation and withdrawal facilities) - overhead costs	- investigation and planning costs - fees and costs of procedures and permits - costs of demolition and restoration - civil-technical costs - costs due to usage restrictions (capital and production losses) - compensation to third parties - protection costs - costs due to "nuisance and rigmarole"

5.3.2 *Change in value of the assets*

To evaluate the change in the value of the assets, the following aspects are considered to be relevant:

1. possibilities for soil use before, during and after the remediation (what scenario's are allowed: industry, residential area, agriculture, natural reserve, recreational area, etc.;
2. current use of site, and the immediate surroundings;
3. market demand for specific site use in the area;
4. current prices per m^2 for non-contaminated sites;
5. current prices per m^2 for contaminated sites (if available).

5.4 **Operationalization of selected aspects**

Financial expenses

The listed costs aspects are generally well quantifiable. However, some have an once-only character while others are recurrent. Furthermore, the moment of payment of the various aspects may vary widely. In order to be able to compare such sets of costs, it is necessary to recalculate them to a single investment (Nett Present Value) to be made at the start of the project.

In principle, three types of costs can be discerned:

1. foundation costs: single investments that are made at the start of the remediation;
2. continuous costs: recurrent costs for rent, maintenance, cleaning, etc;
3. replacement costs: costs for replacement of (large parts of) installations, at a later date.

These types of costs can be divided into one or more single investments at certain moments and continuous investments during certain periods.

Assuming an effective interest (interest on state obligations minus inflation rate and including an eventual risk surcharge for companies and for lower governments) of i %, the following formulas can be given:

single investments:

$$NPV = \frac{\text{investment}}{(1 + i)^n}$$

in which:

n is years between now and investment.

continuous investments (in case if infinite series of years):

$$NPV = \text{continuous yearly investment} \times 1/i$$

Besides this method for calculation of the nett present value, which is a first approximation, only applicable under the assumption of a fixed difference between interest and inflation, other methods for capitalization will be applied.

$$NPV = \frac{\text{investment} \times (1 + a)^n}{(1 + b)^n}$$

in which:

a is increase of specific prices;

b is interest rate (opportunity investment rate).

By applying this method in the REC-assessment, it is possible to investigate the sensitivity of the total Costs for assumptions on interest and price developments.

For almost all the costs mentioned, default values per unit will be incorporated in the REC-assessment procedure. Default values are available for soil and water treatment, groundwater withdrawal, transport, etc. These default values are based on current market prices as are available at Tauw Milieu bv.

Changes in asset value

The operationalization of the changes in asset value will be worked out in phase 2 of the REC-project.

5.5 Integration of the quantified aspects

Since all the expenses (and later on the changes in asset value) will be expressed in monetary terms, the integration of the separate aspects is a simple adding of amounts of money (all expressed in Nett present values).

5.6 Overview of relevant aspects for Costs

Table 5.2. summarizes the inventory, selection, operationalization and integration of the relevant aspects for the Cost criterium.

Table 5.2. Overview of relevant aspects for the Cost criterium.

inventory relevant aspects	selection of relevant aspects	operationalization aspects	integration of aspects
1. financial expenses: • direct expenses • indirect expenses foundation expenses replacement expenses annual expenses (running costs) see table 5.1	1. see table 5.1	1. estimating expenses, based on current market prices; calculating Nett Present Value (2 methods); sensitivity analysis on inflation, interest rate, estimated expenses	1. adding all Nett Present Values
2. change in asset value	2. change in asset value	2. in phase 2	

HOOFDSTUK 6

ILLUSTRATING EXAMPLE

6.1 Summary

In this chapter an illustrating example is described. The example concerns a parcel with a house situated in a city area with a contamination from spilling around a former gas oil filling point of xylenes and benzene. The following four options are considered in the assessment:

Option I: Excavation and treatment of the contaminated soil and withdrawal and treatment of the contaminated groundwater.

Option II: Combination of soil air extraction treatment in the contaminated soil and above the contaminated groundwater.

Option III: Extensive (intrinsic) in situ bioremediation with intermitting soil vapour extraction and minimized groundwater withdrawal.

Option IV: Geohydrological containment of contamination combined with safety measures.

All these options start at t = 0 and the applicable time span is 30 years.

In the calculation of the risk reduction all exposed objects are defined (adults, workers, children and local ecosystem) with their exposure scenarios. For the different options the risk reduction is calculated. Their is a sensitivity check for the used time spane. In this situation the time span doesn't influence the final result much, because the risk is reduced for all options significantly after the start of the remediation.

In the calculation of environmental merit the identification of relevant aspects is done. Only the use of drinkwater has no relevance in all the options. The scores on the other aspect are calculated. For the standarization of the different aspects a default situation is used to calculate minimum and maximum scores for each aspect.

For the calculation of the costs a rough estimation is made. The annual cost are discounted with a nett intrest of 5 %. The results of the calculations are summarized in table 6.1.

Table 6.1. Summary R, E and C for remedial options.

Option	Risk reduction	Environmental merit	Costs
I.	16.81 (98.4 %)	- 96.6	262,500
II.	17.04 (99.8 %)	74.5	197,500
III.	16.89 (98.9 %)	164.5	157,000
IV.	12.80 (74.9 %)	- 5.7	329,000

6.2 Outline of the chapter

In order to be able to clarify the proposed methods for the elaboration and quantification of the REC-procedure, an example has been defined and worked out in this chapter. Paragraph 6.3 describes the location, for which four remedial options are generated. Based on this, the risk reduction (6.5), environmental merit (6.6), and cost (6.7) are quantified, after which a comparison of the alternatives can take place in step (6.8).

6.3 **Description of the location**

The location of the example concerns a parcel with a house (total area 250 m^2), situated in a city area. At the parcel, spilling around a former gas oil filling point has led to soil contamination. The contamination has spread via the groundwater but has not crossed the parcel boundaries yet. Therefore, risks for exposure to contaminants at this moment are limited to the parcel. The situation is sketched in figure 6.1. In table 6.2 some information on the contamination situation is presented.

Fig. 6.1. Sketches of the contamination situation.

Table 6.2. Contamination situation.

soil contamination	groundwater contamination
- surface 4 x 4 m (16 m^2) - traject 0-1.5 m-gl (slight contact with groundwater table) - average thickness 1.5 m - main contaminants: @ xylenes (avg. 40 mg/kg dm) @ benzene (avg. 15 mg/kg dm) - sandy soil with 2 % humus content	- groundwater table at 1.5 m-gl - surface 25 x 5 m (125 m^2) - average thickness 2.5 m - main contaminants: @ xylenes (avg. 5,000 :g/L) @ benzene (avg. 2,000 :g/L)

6.4 **Generation and elaboration of remedial options**

Previous to the elaboration of applicable remedial options, a quick estimate of the amount of risk-redu ction, environmental contribution and related costs of a number of possible remedial options is made. Based on this estimate, the following four remedial options have been selected as feasible:

Option I: Excavation and treatment of the contaminated soil and withdrawal and treatment of the contaminated groundwater.

Option II: Combination of soil air extraction/treatment both in the contaminated soil and above the contaminated groundwater, with compressed air injection below the contaminated groundwater.

Option III: Extensive (intrinsic) in situ bioremediation with intermitting soil vapour extraction and minimized groundwater withdrawal.

Option IV: Geohydrological containment of contamination combined with safety measures.

The four options are discussed in more detail in the following sections.

6.4.1 *Option I*

The remediation starts at t = 0.

The contaminated soil is excavated. The excavation takes place without lowering the groundwater table. The applied remediation threshold is the S-value. For technical reasons, a 1 : 1 talus is applied. The total excavated volume is 50 m^3, of which 24 m^3 is contaminated and 26 m^3 non-contaminated. The excavation of the contaminated soil will take 2 days and takes 4 workers. The contaminated soil is cleaned in a thermal treatment plant. This plant is situated at 50 km of the site. Clean soil is transported to the site over 25 km to fill the excavation pit.

The contaminated groundwater is withdrawn by means of a series of withdrawal wells. The applied remediation threshold is the S-value, the end concentrations in the groundwater will be approx. 1 :g/L. The required withdrawal discharge is 5 m^3/hour. The required withdrawal period is 1,5 years. The discharged water is treated by means of air stripping. The stripped aromatics are adsorbed on active carbon. The treated water will be discharged to the surface water.

6.4.2 *Option II*

The remediation starts at t = 0.

The contaminated soil is cleaned by means of soil gas vapour extraction. The applied remediation threshold is the S-value. The contaminated groundwater is cleaned by means of a combination of compressed air injection below the groundwater contamination and soil gas extraction in the unsaturated zone above it. The extracted soil gas is treated by means of active carbon. The required extraction period is 2 years. At this moment the remaining concentrations lie between S- and T-value (i.e. approximately 10 :g/L).

In order to avoid further spreading of contaminated groundwater, a groundwater catchment well is installed downstream of the contamination, extracting 3 m^3/h. The withdrawn groundwater is expected to be thus contaminated that it does not require treatment previous to discharge to the surface water.

6.4.3 *Option III*

The remediation starts at t = 0.

The contaminated soil is treated by means of extensive bioremediation: the intrinsic capacity for biodegradation is used and optimized by minimal stimulation. Soil vapour is extracted intermittently, for supplying oxygen, thereby lowering the volatilization. The applied remediation threshold is the S-value.

The groundwater is contained by minimal, intermitted extraction (1 day a week, 2 m^3/h). The withdrawn groundwater is expected to be thus contaminated that it does not require treatment previous to discharge into the sewer system. The extracted soil gas is treated by means of active carbon. The required extraction period is 10 years. At that moment the remaining concentrations lie between S- and T-value (i.e. approximately 10 :g/L).

6.4.4 *Option IV*

The site is not remediated. By temporary measures the actual exposure at the site is lowered to an acceptable level for people, i.e. the RIndex for the population is maintained equal to 1 for the total applicable time span.
The spreading of contaminated groundwater is prevented by a groundwater containment system, extracting 3 m^3/h continuously. The withdrawn water can be discharged into the sewer system.

6.5 **Risk reduction**

6.5.1 *Identification of threatened objects*

According to the described method in the main text, the first step is to identify the threatened objects, by following the decision schemes in paragraph 3.3:

1. There are humans in the system and there are relevant subpopulations (children). The exposure of adults and children will be assessed separately.
2. There are workers exposed to soil contamination and it is assumed that the exposure is not fully countered by protection. The exposure to workers will be quantified.
3. The ecosystem in the system is relevant, but cannot be specified. Therefore exposure to a standard ecosystem will be evaluated.

All options start at the same time (say t = 0). Therefore no objects outside the parcel are expected to be exposed in the future.

The applicable time span for this case is 30 years.

6.5.2 *Definition of exposure scenario*

For the threatened objects identified, a site specific exposure scenario is defined. In this case, the main focus is on inhalation of indoor air, which is the most important exposure route for volatile compounds. In table 6.3 the relevant data for exposure are summarized.

6.5.3 *Quantification of risk reduction*

Quantification for the reference situation R0

To calculate risk reduction for remedial alternatives, it is necessary to compare it with a reference situation. As reference situation, the existing situation has been chosen, assuming that it will remain the same during the standard time span of 30 years (see section 3.5).

People in the house

Based on the defined exposure scenario's and the contamination situation as listed in table 6.2, and applying the volatilization modules from the CSOIL model, the contamination leads to exceedence of TDI for children (1) and adults (2) with a factor of:

- children: xylenes 6.5 x TDI, benzene 6.7 x TDI (mainly via air);
- adults: xylenes 4 x TDI, benzene 4 x TDI (mainly via air).

Table 6.3. Relevant data for exposure.

Vulnerable objects	
- inhabitants of the house (2 adults, 2 children) - local ecosystem - workers: only during remedial works	
Possible exposure routes (for inhabitants of the house)	
- contact with contaminated soil	yes
- contact with contaminated air	yes (inner/outer air)
- contact with contaminated drinking water	yes (conduit permeation)
- contact with contaminated surface water	no (not present)
- contact with contaminated crops	no (not present)
- contact with contaminated meat/milk	no (not relevant)
- contact with contaminated fish	no (not relevant)
Definition of exposure scenario for exposed objects (focus on inhalation of air)	
Adult 1. worker time at work: 9 hours/working day: average 5.2 hours/day time at home: 15 hours/working day: average 17.4 hours/day (excl. 3 weeks holiday) bodyweight: 70 kg air intake: 0.83 m^3/h	
Adult 2. care-taker time at home: 22 hours/day: average 20.6 hours/day (excl. 3 weeks holiday outside) bodyweight: 70 kg air intake: 0.83 m^3/h	
Children 0-4 year time at home: 22 hours/day: average 20.6 hours/day (excl. 3 weeks holiday outside) bodyweight: 15 kg air intake: 0.32 m^3/h	
Children 5-6 year time at school: 5 hours/day: average 2.7 hours/day (excl. 8 weeks holiday, 3 weeks outside) time at home: 19 hours/day: average 19.9 hours/day (excl. 3 weeks holiday outside) bodyweight: 18 kg air intake: 0.32 m^3/h	

Ecosystem

Given the available HC_{50} for benzene at 15 mg/kg dm, and given the general form of the HC-curves (see fig. 6.2), it can be calculated from table D1 in Annexe D that, 76 % of the species is expected to be at risk.

Quantification of the exposure at t = 0 (based on risk determining component: benzene)

With the following quantification, it is assumed that the influence on the ecosystem is limited to the soil contamination. All the separate criteria for risk are weighted the same: $W_p = W_e = \ldots = W_w = 1$. The results of the quantification are listed in table 6.4.

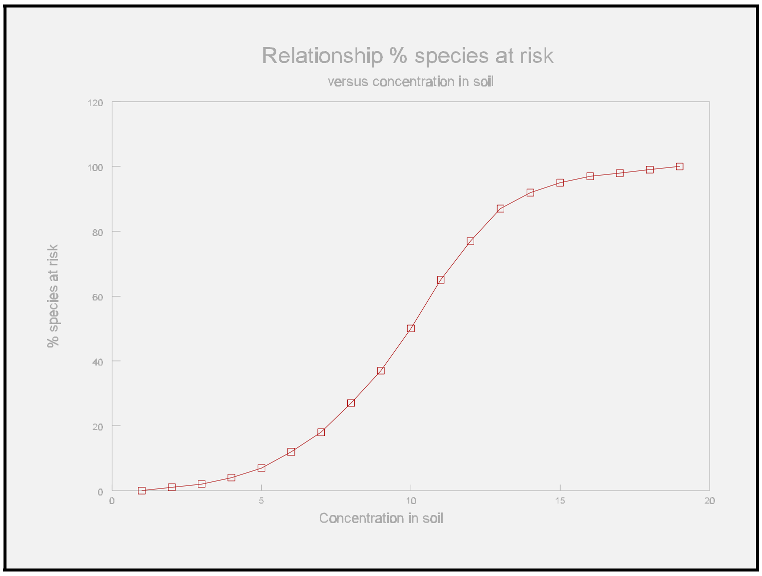

Fig. 6.2. Relationship % species at risk versus concentration in soil.

Table 6.4. Risk score of reference situation.

vulnerable object	RIndex[1]	n[2]	t[3]	score
humans: - children - adults - adults	 6.7 4 4	 2 2 2	 6/30 24/30 30/30	 2.68 6.40 8.00
ecosystem	76/50	141/500000	30/30	0.00
worker	n.a.[4]	-	-	-
total score				17.08

[1] RIndex is exposure/toxicological threshold;
[2] n is number of exposed vulnerable objects;
[3] t is time span of exposure divided by the standard time span of 30 years;
[4] n.a. not available.

Quantification for all remedial options (risks during execution of the remediation)

Option I

humans

The total exposure of the people in the house exists of the exposure during excavation (2 days) and the exposure during the groundwater remediation (1.5 year). The exposure during the excavation is assumed to be negligible given the short exposure time, compared to the groundwater remediation. Due to the expected form of the xylenes concentration curve in the groundwater (and thus in the soil gas) during the remedial works, the average concentration during the remediation is estimated at about 1/4 of the initial concentration (see fig. 6.3), hence 1200 :g of xylenes/L, and 500 :g of benzene/L.

workers

Given the contaminant concentrations encountered in the soil and assuming that the contaminant concentration in the excavation pit air will be about 10 % of the equilibrium concentration, pit air concentrations of 1300 mg/m^3 xylenes and 260 mg/m^3 benzene can be calculated. These concentrations exceed the MAC-value by about a factor 4 and 9 respectively. At these concentrations, personal protection equipment is required. It is assumed that this equipment provides 90 % protection. Thus for benzene exposure at 10 % of the outdoor concentration (or 10 % of the time exposure at outdoor level) occurs.

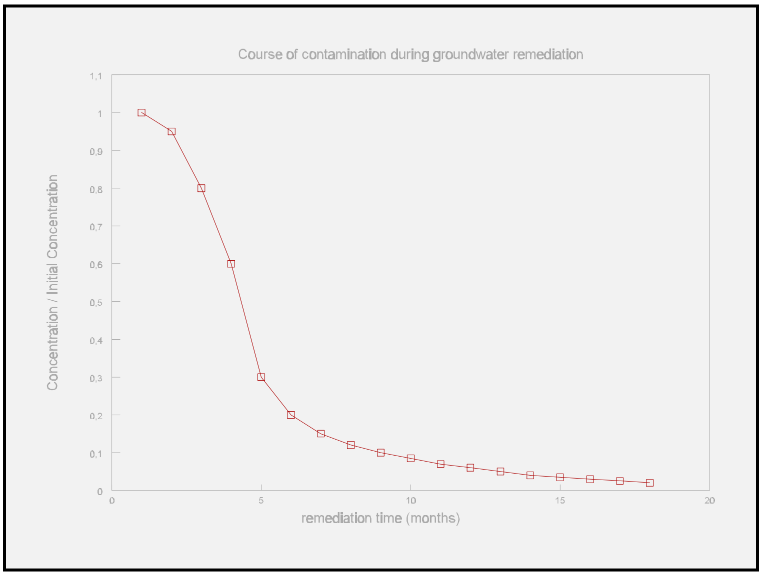

Fig. 6.3. Course of contamination during groundwater remediation.

ecosystem

The mean concentration during remediation of the groundwater is estimated at 1/4 of the initial concentration. At this concentration it is expected that 43 % of the species is protected. The surface area, affecting the ecosystem is decreased by excavation from 141 m^2 to 125 m^2. The excavation itself is assumed to be of no influence, because of the relatively small surface area affected. In table 6.5, the results of the calculations are summarized.

Table 6.5. Risk score during execution of remedial option I.

vulnerable object	RIndex[1]	n[2]	t[3]	score
humans: - children - adults	 1.7 1	 2 2	 1½/30 1½/30	 0.17 0.10
ecosystem	43/50	125/500000	1½/30	0.00
worker	0.9	4	0.0055/30	0.00
total score				0.27

Option II

humans

Since almost all exposure occurs as a result of inhalation of indoor air, it is expected that the actual evaporation of volatile compounds is prevented by the soil vapour extraction system. As a result of this, no exposure of people in the house takes place.

workers

In this option, the exposure of workers involved in the remediation to the contamination is assumed to be negligible.

ecosystem

Due to the expected form of the xylenes and benzene concentration curve in the soil, groundwater and soil vapour during the remedial works, the average concentration during the remediation is estimated at about 1/3 of the initial concentration.
For the ecosystem this is estimated to result in an average protection of the ecosystem of 50 % for benzene.

In table 6.6, the results of the calculations are summarized.

Table 6.5. Risk score during execution of remedial option II.

vulnerable object	RIndex[1]	n[2]	t[3]	score
humans: - children - adults	 0.002 0.001	 2 2	 2/30 2/30	 0.00 0.00
ecosystem	50/50	141/500000	2/30	0.00
worker	n.a.[4]	-	-	-
total score				0.001

Option III

humans

As for option II, the average concentration during the remediation is estimated at about 1/3 of the initial concentration. Almost all exposure occurs as a result of inhalation of indoor air. Due to the intermittent soil vapour extraction it is expected that actual evaporation of volatile compounds is possible for about 10 % of the existing concentration of 1200 :g/L for xylenes and 500 :g/L for benzene. This results in a RIndex for children of 0.17, and for adults 0.10 times the TDI.

workers

In this option, the exposure of workers involved in the remediation to the contamination is assumed to be negligible.

ecosystem

As for option II 50 % of the ecosystem is estimated to be at risk for benzene.

In table 6.7, the results of the calculations are summarized.

Table 6.7. Risk score during execution of remedial option III.

vulnerable object	RIndex[1]	n[2]	t[3]	score
humans:				
- children	0.17	2	6/30	0.07
- adults	0.10	2	4/30	0.03
- adults	0.10	2	10/30	0.07
ecosystem	50/50	141/500000	10/30	0.00
worker	n.a.[4]	-	-	-
total score				0.16

Option IV
Since the option is containment of the contamination, the site is not remediated. The time period 'during remediation' is (except for the installation of containment measures) negligible. The remaining risk after installation, thus during the actual contained situation is quantified in 'risk after remediation' in the following section.

Quantification of the exposure after the remediation

Option I
Due to the applied remediation thresholds the remaining risk after finishing remedial measures is expected to be very low. It is assumed that the remaining concentration of aromatic compounds will be approx. 1 :g/L. At this concentration the following risk levels can be quantified:

1 :g/L:
- children: (benzene) 0.002 TDI;
- adults: (benzene) 0.001 TDI;
- ecosystem: < 0.1 % species at risk.

The total time to evaluate after remediation is 30 - remediation time.

The calculation of the risk scores after execution of the remedial options I is summarized in table 6.8.

Table 6.8. Risk score after execution of remedial option I.

vulnerable object	RIndex[1]	n[2]	t[3]	score
humans:				
- children	0.002	2	4½/30	0.00
- adults	0.001	2	24/30	0.00
- adults	0.001	2	28½30	0.00
ecosystem	0/50	125/500000	28½/30	0.00
worker	n.a.[4]	-	-	-
total score				0.004

Option II

As for option I, due to the applied remediation thresholds the remaining risk after completing remedial measures is expected to be very low. It is assumed that the remaining concentration of aromatic compounds will be 10 :g/L. At this concentration the following risk levels can be quantified:

10 :g/L:
- children: (benzene) 0.018 TDI;
- adults: (benzene) 0.010 TDI;
- ecosystem: 0.1 % species at risk.

The calculation of the risk scores after execution of the remedial options II is summarized in table 6.9.

Table 6.9. Risk score after execution of remedial option II.

vulnerable object	RIndex[1]	n[2]	t[3]	score
humans:				
- children	0.018	2	4/30	0.00
- adults	0.01	2	24/30	0.02
- adults	0.01	2	28/30	0.02
ecosystem	0.1/50	141/500000	28/30	0.00
worker	n.a.[4]	-	-	0.00
total score				0.042

Option III

The third option is an alternative extended in time, of option II. Accordingly, remaining risk after remediation for humans and the ecosystem are similar to those. They differ however in its time span. For the population, now only adults are living at the site.

The calculation of the risk scores after execution of the remedial options III is summarized in table 6.10.

Table 6.10. Risk score after execution of remedial option III.

vulnerable object	RIndex[1]	n[2]	t[3]	score
humans:				
- adults	0.01	4	20/30	0.03
ecosystem	0.1/50	141/500000	20/30	0.00
total score				0.03

Option IV

humans

The RIndex for the population was reduced to 1 for ***lifetime exposure***, by temporary measures. Due to differences in lifetime exposure, the RIndex for children is 1.7 for 6 years, and for adults 0.93 for 64 years.

ecosystem

The exposure of the ecosystem is not altered, and similar to its risk score as calculated for the reference situation (R0).

The calculation of the risk scores after execution of the remedial options IV is summarized in table 6.11.

Table 6.11. Risk score after execution of remedial option IV.

vulnerable object	RIndex[1]	n[2]	t[3]	score
humans: - children - children - adults	 1.7 1 1	 2 2 2	 6/30 24/30 30/30	 0.67 1.60 2.00
ecosystem	76/50	141/500000	30/30	0.00
total score				4.27

6.5.4 *Total risk reduction*

Completing the risk reduction formula, the total risk reduction becomes:

Option I: 17.08 - 0.27 - 0.004 = 16.81 (98.40 %);
Option II: 17.08 - 0.001 - 0.042 = 17.04 (99.75 %);
Option III: 17.08 - 0.16 - 0.03 = 16.89 (98.91 %);
Option IV: 17.08 - 0 - 4.27 = 12.80 (74.94 %).

Influence of total time period

To find out if the outcome of the calculation of risk reduction is very sensitive for the chosen time period of 30 years, the calculations are executed for a time period of 10 resp. 70 years. The results of these calculations are shown in table 6.12.

From this example, it can be concluded that the time span regarded in the calculation of risk reduction doesn't influence the final result much; the most important impact can be expected on contributions to the total exposure that occur in a relatively short time period (such as the excavation and/or remediation time.

One's first impression on the results for the risk reduction could be, that the method is not discriminating between the four different alternatives. Only the Containment option (IV) does show a number significant deviating from the other options. The similarity of the three other options is mainly caused by its aspect of time: all three remedial options were started at t = 0. Besides, all three options in the example are rapidly decreasing actual exposure to an acceptable level. When a remediation is postponed, the risk reduction can easily become less pronounced. The method will be more discriminating in case options involve a larger number of remedial workers that work a longer period of time. It may be concluded that the similarly of the outcome for the example is in agreement with presuppositions, and that more variation in aspect of time and number of persons involved will give a larger discrimination between remedial alternatives.

Table 6.12. Overview of Risk reduction for different total time.

t = 30 years	TR_0	before remediation	during remediation	after remediation	Risk reduction	reduction (%)
optie I	17.08	0	0.27	0.00	16.81	98.40
optie II	17.08	0	0.00	0.04	17.04	99.75
optie III	17.08	0	0.16	0.027	16.89	98.91
optie IV	17.08	0	0	4.28	12.80	74.94
t = 10 years						
optie I	19.24	0	0.81	0.00	18.43	95.77
optie II	19.24	0	0.00	0.05	19.19	99.73
optie III	19.24	0	0.48	0	18.76	97.51
optie IV	19.24	0	0	4.84	14.40	74.84
t = 70 years						
option I	16.46	0	0.12	0.00	16.34	99.25
option II	16.46	0	0.00	0.00	16.46	100.00
option III	16.46	0	0.07	0.034	16.36	99.37
option IV	16.46	0	0	4.12	12.34	74.97

6.6 **Environmental merit**

For the determination of Environmental merit, the situation before, during and after the remediation has to be quantified. Since all the options start at t = 0, the environmental influences before remediation are 0. The environmental influences during remediation will be assessed in the following sections (6.6.1 to 6.6.3). The environmental influences after the remediation is executed, exist of the improved soil and groundwater quality and the prevented future contamination. This is taken into account in the operationalization (6.6.2). Environmental merit will be determined for the 4 options in 6.6.3.

6.6.1 *Identification of relevant aspects*

First, it is necessary to describe the remedial options in terms of environmental influences. Table 6.13 gives an overview for the four remedial options described in 6.4.

6.6.2 *Operationalization environmental influences*

Now the identified aspects will be operationalized, according to the described method in chapter 4.

Table 6.13. Overview identified environmental influences for remedial options.

identified environmental influences	Option I	Option II	Option III	Option IV
benefits for the environment: positive outputs:				
• improvement soil quality	yes	yes	yes	no
• improvement groundwater quality	yes	yes	yes	no
• prevention future soil and groundwater contamination	yes	yes	yes	yes
sacrifices for the environment: negative inputs:				
• clean soil	yes	no	no	no
• clean groundwater	yes	yes	yes	yes
• drinking water	no	no	no	no
• energy	yes	yes	yes	yes
• space	no	no	no	yes
sacrifices for the environment: negative outputs:				
• air emissions	yes	yes	yes	yes
• water emissions	yes	yes	no	no

Option I

Benefits for the environment

actual improvement

The soil quality is improved by excavation and replacement with clean soil. This has to be expressed in Soil quality equivalents.
In the initial situation, 24 m^3 soil is contaminated, from which 10 m^3 above I-level and 14 m^3 above T-level. In Seq this is $10 \cdot 1 + 14 \cdot 0.67 = 19.38$ Seq. The final situation contains no contaminated soil, so the actual improvement = 19.38 Seq.

The groundwater quality is improved by groundwater remediation. In the initial situation, 313 m^3 groundwater is contaminated, from which 100 m^3 above I-level, 150 above T-level and 63 m^3 above S-level. In Weq this is $100 \cdot 1 + 150 \cdot 0.67 + 63 \cdot 0.33 = 221$ Weq. In the final situation, all the contamination is removed, so the actual improvement = 221 Weq.

prevented future contamination

It is estimated that at the end of the regarded time span, the soil contamination is increased to 30 m^3 (12 m^3 > I, 18 m^3 T), and the groundwater contamination to 500 m^3 (150 m^3 > I, 200 m^3 > T, 150 m^3 > S).

The total prevented future contamination will be expressed in Seq en Weq:

soil: $(12-10) \cdot 1 + (18-14) \cdot 0.67 = 4.68$ Seq

groundwater: $(150-100) \cdot 1 + (200-150) \cdot 0.67 + (150-63) \cdot 0.33 = 112$ Weq

The total benefits for the environment in option 1 are thus:

soil: $19.38 + 4.68 = 24.1$ Seq

groundwater: $221 + 112 = 333$ Weq

Sacrifices for the environment: negative inputs

clean soil

In option I, 24 m^3 clean soil is used to fill the excavation pit. The input equals 24 Seq. However, it must be taken into account that the excavated soil will be treated, and therefore will again be available for use. If the quality of the treated soil equals the quality of the soil used to fill the excavation pit, the nett input of clean soil in the remediation is 0. The transportation and treatment of the soil will of course be considered at 'energy' and 'air quality'.
Since the soil is treated in a thermal treatment plant, it is assumed that the total volume (minus the organic matter content) will be available after treatment. Then only 0.5 m^3 additional soil will be used in this option: 0.5 Seq.

clean groundwater

In option I, 1 m^3/h will be withdrawn for 1,5 year. The total amount of groundwater equals 13.140 m^3, (= Weq).

energy

The energy consumption of the alternative exists of energy for excavation, transport of contaminated and clean soil, treatment of the soil, treatment of the groundwater and groundwater withdrawal.

excavation	85 ton	42 MJ/ton	3570 MJ
transport soil:			
- 100 km vv	43 ton	130 MJ/ton	5304 MJ
- 50 km vv	43 ton	65 MJ/ton	2652 MJ
treatment soil	43 ton	400 MJ/ton	16320 MJ
treatment water	4380 m^3	3.6 MJ/m^3	1577 MJ
withdrawn water	13140 m^3	0.08 MJ/m^3	1051 MJ
			))))))
			30500 MJ

Sacrifices for the environment: negative outputs

air quality

A distinction must be made between the use of electricity and diesel for energy consumption. It is assumed, that diesel is used for the excavation, transport and treatment of the soil, and electricity for the other items:

diesel: 28000 MJ Å 6.7 Aeq/MJ_{diesel} = 188000 Aeq

electricity: 2500 MJ Å 4.5 Aeq/$MJ_{electricity}$ = 11250 Aeq

Total sacrifice on air quality = 200000 Aeq.

water quality

It is assumed that the extracted water is treated until the demand of the license if met. The remaining concentration in the water is ten times above the Surface water quality guideline.
In Weq this leads to 13140 m^3 Å 10 = 131400 Weq.

Option II

Benefits for the environment

actual improvement

The soil quality is improved by intensive in situ remediation. This has to be expressed in Soil quality equivalents.
In the initial situation, 24 m^3 soil is contaminated, from which 10 m^3 above I-level and 14 m^3 above T-level. In Seq this is 10 Å 1 + 14 Å 0.67 = 19.38 Seq. The final situation contains remaining contaminated soil (10 m^3 < T-level = 3.33 Seq), so the actual improvement = 16.05 Seq.

The groundwater quality is improved by in situ remediation. In the initial situation, 313 m^3 groundwater is contaminated, from which 100 m^3 above I-level, 150 above T-level and 63 m^3 above S-level. In Weq this is 100 Å 1 + 150 Å 0.67 + 63 Å 0.33 = 221 Weq. In the final situation, the remaining contamination equals 100 m^3 < T-value (= 33 Weq), so the actual improvement = 188 Weq.

prevented future contamination

It is estimated that at the end of the regarded time span, the soil contamination is increased to 30 m^3 (12 m^3 > I, 18 m^3 > T), and the groundwater contamination to 500 m^3 (150 m^3 > I, 200 m^3 > T, 150 m^3 > S).

The total prevented future contamination will be expressed in Seq en Weq:

soil: (12-10) Å 1 + (18-14) Å 0.67 = 4.68 Seq

groundwater: (150-100) Å 1 + (200-150) Å 0.67 + (150-63) Å 0.33 = 112 Weq

The total benefits for the environment in option 2 are thus:

soil: 16.05 + 4.68 = 20.73 Seq

groundwater: 188 + 112 = 300 Weq

Sacrifices for the environment: negative inputs

clean groundwater

In option II, 0.6 m^3/h will be withdrawn for 2 year. The total amount of groundwater equals 10512 m^3, (= Weq).

energy

The energy consumption of the alternative exists of energy for groundwater withdrawal and soil vapour extraction.

withdrawal water: 10512 m^3 0.08 MJ/m^3 840 MJ
soil vapour extr: 2500 MJ

)))) 3340 MJ

Sacrifices for the environment: negative outputs

air quality

It is assumed, that electricity is used for the groundwater and soil vapour extraction.

electricity: 6705 MJ × 4.5 Aeq/$MJ_{electricity}$ = 15030 Aeq

water quality

It is assumed that the extracted water is discharged to surface water. The concentration in the water is 15 times above the Surface water quality guideline.
In Weq this leads to 10512 m^3 × 15 = 158000 Weq.

Option III

Benefits for the environment

actual improvement

The soil quality is improved by extensive in situ remediation. This has to be expressed in Soil quality equivalents.
The initial situation is 19.38 Seq. The final situation contains remaining contaminated soil (10 m^3 < T-level = 3.33 Seq), so the actual improvement = 16.05 Seq.

The groundwater quality is improved by in situ remediation. The initial situation = 221 Weq. In the final situation, the remaining contamination equals 100 m^3 < T-value (= 33 Weq), so the actual improvement = 188 Weq.

prevented future contamination

It is estimated that at the end of the regarded time span, the soil contamination is increased to 30 m^3 (12 m^3 > I, 18 m^3 > T), and the groundwater contamination to 500 m^3 (150 m^3 > I, 200 m^3 > T, 150 m^3 > S).

The total prevented future contamination will be expressed in Seq en Weq:

soil: (12-10) × 1 + (18-14) × 0.67 = 4.68 Seq

groundwater: (150-100) × 1 + (200-150) × 0.67 + (150-63) × 0.33 = 112 Weq

The total benefits for the environment in option 3 are thus:

soil: 16.05 + 4.68 = 20.73 Seq

groundwater: 188 + 112 = 300 Weq

(Note that the same benefits are achieved as in option II, but in a different time span).

Sacrifices for the environment: negative inputs

clean groundwater

In option III, 0.4 m^3/h will be withdrawn, 1 day a week, for a total time of 10 years. The total amount of groundwater equals 5000 m^3, (= Weq).

energy
The energy consumption of the alternative exists of energy for groundwater withdrawal and soil vapour extraction.

withdrawal water: 5000 m^3 0.08 MJ/m^3 400 MJ
soil vapour extr: 1200 MJ
))))))
1600 MJ

Sacrifices for the environment: negative outputs
air quality
It is assumed, that electricity is used for the groundwater and soil vapour extraction.

electricity: 1600 MJ Å 4.5 Aeq/$MJ_{electricity}$ = 7200 Aeq

water quality
It is assumed that the extracted water is discharged to the sewer system, so no surface water quality is affected.

Option IV

Benefits for the environment
actual improvement
The soil and groundwater quality is not improved by the containment measures.

prevented future contamination
It is estimated that at the end of the regarded time span, the soil contamination is increased to 30 m^3 (12 m^3 > I, 18 m^3 > T), and the groundwater contamination to 500 m^3 (150 m^3 > I, 200 m^3 > T, 150 m^3 > S).

The total prevented future contamination will be expressed in Seq en Weq:

soil: (12-10) Å 1 + (18-14) Å 0.67 = 4.68 Seq

groundwater: (150-100) Å 1 + (200-150) Å 0.67 + (150-63) Å 0.33 = 112 Weq

The total benefits for the environment in option IV are thus:

soil: 4.68 Seq

groundwater: 112 Weq

Sacrifices for the environment: negative inputs
clean groundwater
In option IV, 0.1 m^3/h will be withdrawn, for the total time of 30 years. The total amount of groundwater equals 26280 m^3, (= Weq).

energy
The energy consumption of the alternative exists of energy for groundwater withdrawal.

withdrawal water: 26280 m^3 0.08 MJ/m^3 2102 MJ

space

As a result of the containment measures, and the existing soil contamination, the intended use of the site cannot take place. Therefore, additional space needs to be developed to compensate the 150 m^2 surface that is contaminated.

Sacrifices for the environment: negative outputs

air quality

It is assumed, that electricity is used for the groundwater withdrawal.

$$\text{electricity: } 2102 \text{ MJ} \times 4.5 \text{ Aeq/MJ}_{electricity} = 9460 \text{ Aeq}$$

water quality

It is assumed that the extracted water is discharged to the sewer system, so no surface water quality is effected.

Table 6.14 summarizes the quantification of the identified aspects for option I to IV.

Table 6.14. Summary of quantification Environmental influences for option I to IV.

identified environmental influences	Option I	Option II	Option III	Option IV
benefits for the environment: positive outputs:				
• improvement soil quality + prevention soil contamination	24.1 Seq	20.7 Seq	20.7 Seq	4.68 Seq
• improvement groundwater quality + prevention groundwater contamination	333 Weq	300 Weq	300 Weq	112 Weq
sacrifices for the environment: negative inputs:				
• clean soil	0.5 Seq			
• clean groundwater	13,140 Weq	10,512 Weq	5,000 Weq	26,280 Weq
• energy	30,500 MJ	3,340	1,600 MJ	2,102 MJ
• space				125 m^2
sacrifices for the environment: negative outputs:				
• air emissions	200,000 Aeq	15,030 Aeq	7,200 Aeq	9,460 Aeq
• water emissions	131,400 Weq_{surf}	158,000 Weq_{surf}		

The data represented in table 6.14 are quantified for the total remediation period. The total Environmental merit is a function of time, in which the environmental merit fore, during and after the remediation are taken into account. However, in this case, all the options start at t = 0, therefore Environmental merit before remediation is 0. It is assumed that the environmental influences after remediation are negligible (no spreading of remaining concentrations) which results in a score on Environmental merit after remediation of 0. Therefore, it is possible to standardize the scores in table 6.14.

6.6.3 *Standardization of environmental influences*

The first step in the standardization of the environmental influences exists of the combination of the soil and groundwater aspects into an integrated score. Then the two extremes, least desirable and most desirable will be calculated for this situation (see Annexe C). The results of this calculation are presented in table 6.15.

Table 6.15. Result of calculation two extremes of identified aspects.

identified environmental influences	least desirable	most desirable	$Y = a + b \cdot X$
benefits for the environment: positive outputs:			
• improvement soil quality + prevention soil contamination + use of clean soil	-19.3 Seq	24.1 Seq	$Y1 = 44.5 + 2.3 \cdot Seq$
• improvement groundwater quality + prevention groundwater contamination + use of clean groundwater	-26,168 Weq	333 Weq	$Y2 = 98.7 + 3.8 \cdot 10^{-3} \cdot Weq$
sacrifices for the environment: negative inputs:			
• energy	33,580 MJ	0 MJ	$Y3 = 3.0 \cdot 10^{-3} \cdot MJ$
• space	250 m^2	0 m^2	$Y4 = 0.4 \cdot m^2$
sacrifices for the environment: negative outputs:			
• air emissions	202,300 Aeq	8 Aeq	$Y5 = 5.0 \cdot 10^{-4} \cdot Aeq$
• water emissions	262,800 Weq_{surf}	0 Weq_{surf}	$Y6 = 3.8 \cdot 10^{-4} \cdot Weq_{surf}$

Then the integrated scores will be standardized, using the relations in table 6.15.

Table 6.16. Standardized scores Environmental merit.

aspect	Option I		Option II		Option III		Option IV	
	quantity	standard score	quantity	standard score	quantity	standard score	quantity	standard score
Total Seq	23.6	98.8	20.7	92.1	20.7	92.1	4.68	55.3
Total Weq	-13,806	46.2	-10,212	59.9	-4,700	80.8	-26,168	0
Energy	30,658	92.0	3,340	10	1,600	4.8	2,102	6.3
Space	0	0	0	0	0	0	125	50
Aeq	200,000	100	15,030	7.5	7,200	3.6	9,460	4.7
$Weq_{surface}$	131,400	49.9	158,000	60.0	0	0	0	0
Total score		-96.9		74.5		164.5		-5.7

6.7 **Costs**

A rough cost estimation is made for the 4 alternatives (see table 6.17). The annual costs are discounted with a nett interest rate of 5 %.

6.8 **Comparison of options**

Finally, the options worked out for the remediation of the site can be compared on the criteria Risk reduction, Environmental merit and Costs. The results of the calculations are summarized in table 6.18.

Table 6.17. Rough estimation of costs of option I to IV.

Remedial option I (soil excavation/groundwater withdrawal 1½ year)	
Aspect	Costs
technical specification	15,000
soil excavation and treatment: - removal pump foundations/pump - soil excavation (50 m^3) - transport/treatment contaminated soil (25 m^3) - refilling with clean soil	 1,000 1,000 8,500 2,000
groundwater withdrawal and treatment: - emplacement groundwater withdrawal system - operation of groundwater withdrawal system - purification of contaminated groundwater - removal groundwater withdrawal and purification system	 25,000 115,000 85,000 10,000
Total remediation costs option I	262,500

Remedial ption II (compressed air injection/soil gas withdrawal 2 years)	
Aspect	Costs
technical specification	15,000
compressed air injection: - installation - operation	 3,000 60,000
soil vapour extraction: - installation - operation	 3,000 35,000
monitoring system (soil and groundwater): - installation and operation	 35,000
soil gas purification: - installation - operation	 7,500 5,000
groundwater withdrawal well: - installation - operation	 4,000 30,000
Total remediation costs option II	197,500

Remedial option III (extensive bioremediation with soil vapour extraction 10 years)	
Aspect	Costs
technical specification	10,000
soil vapour extraction: - installation - operation	 3,000 50,000
monitoring system (soil and groundwater): - installation and operation	 30,000
groundwater extraction well: - installation - operation	 4,000 60,000
Total remediation costs option III	157,000

Remedial option IV (containment 30 years)	
Aspect	Costs
technical specification	10,000
monitoring system (soil and groundwater): - installation and operation	 105,000
groundwater extraction well: - installation - operation	 4,000 210,000
Total remediation costs option IV	329,000

Table 6.18. Summary R, E, and C for remedial options.

Option	Risk reduction	Environmental merit	Costs
I	16.81 (98.4 %)	- 96.6	262,500
II	17.04 (99.8 %)	74.5	197,500
III	16.89 (98.9 %)	164.5	157,000
IV	12.80 (74.9 %)	- 5.7	329,000

FLOW CHARTS FOR APPLYING THE REC-METHOD

7.1 General description of flow charts

In this chapter, the application of the REC-method is described in three flow charts. In these flow charts, the activities that need to be executed to arrive at the R, E and C score are schematically described, and the necessary input documents and tools are defined. This gives a general overview of the activities: a more detailed break-down of all the detailed input data will be worked out during the application of the REC-method on real cases in phase 2.

Three symbols are used in the flow charts, that are explained in figure 7.1.

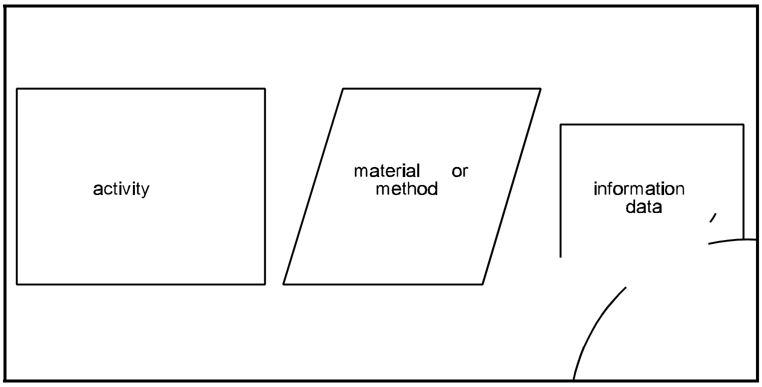

Fig. 7.1. Symbols used in flow charts REC-method.

In the following sections the flow charts of the three criteria will be presented and discussed.

7.2 Flow chart Risk reduction

Figure 7.2 represents the activities and inputs needed to arrive at an integrated score on Risk reduction.

The first activity is the selection of the type and number of relevant objects for the site. To do this, one needs information about the location (lay out of the site, the contamination situation in relation to the exposure media such as superficial soil concentrations, indoor air, etc.) and about the remedial alternatives. Based on the time span that must be regarded, the system area can be assessed.

The second activity exists of the calculation of Risk Indices for the selected objects. To do this, we need to define a representative exposure scenario and translate the existing contamination situation to exposure of humans and the ecosystem. Exposure models may be a usefull tool in this step, besides the measurements of direct contact media.

Based on the separate Risk Indices, an integrated score for the existing situation at t = 0 can be established in activity 3.

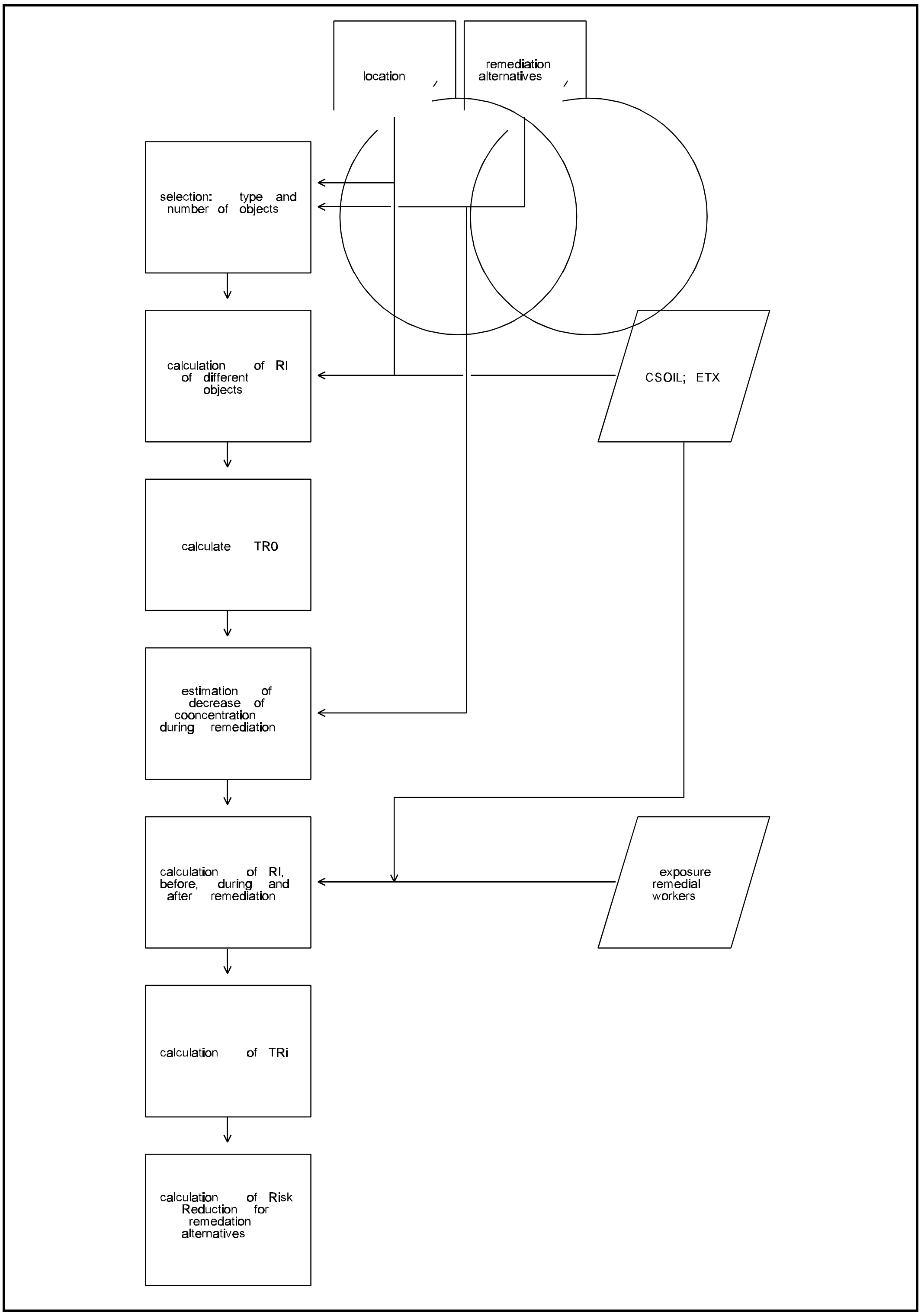

Fig. 7.2. Flow chart for the assessment of Risk reduction.

For the fourth and fifth activity, one needs information about the expected exposure of objects during and after the remediation. In case the exposure is totally intercepted (by means of isolation measures, complete soil vapour extraction, and so on) the Risk index for these alternatives will be 0. For all other alternatives, that result in a (slow) decrease of exposure, an estimation of the exposure during the decrease of the contamination must be made. Information about the number of remedial workers, their residence time on the site, and the effectivity of safety measures must be included in the calculation of Risk indices.

The total Risk index is calculated by adding up the separate indices in the sixth activity.

Finally, Risk reduction is calculated by subtracting the calculated total risk for a specific remediation alternative from the calculated Total risk based on exposure at t = 0.

7.3. Flow chart Environmental merit

In figure 7.3 the flow chart for the determination of Environmental merit is presented.

The first activity is the estimation of the concentration in soil and groundwater before remediation, during and after remediation and the expected spreading that would occur if no measures were taken. This activity is based on the information already available from the remedial investigation plan, and on rough estimates based on data from the location.

The second activity is to express the soil- and groundwaterquality improvement and the prevention of future contamination in clean Soil and groundWater equivalents, by means of comparing the actual concentrations with quality standards.

From the remedial investigation plan, a lot of data must be extracted to establish the Water use (Seq), Surface water emissions (Weq_{surf}), Clean soil use (Seq), space, Air emissions and energy use. For the last two, conversion factors will be necessary to arrive at the Air equivalents and MJ.

The third activity is to combine all the data on clean soil equivalents and clean groundwater equivalents into integrated scores.

The fourth activity is to define the minimum and maximum scores for the different aspects by defining the most desirable and most undesirable situation for the specific site.

In the fifth step, the actual score on a specific aspect can be related to the defined minimum and maximum.

Finally, the separate normalized scores are integrated by (weighed) addition.

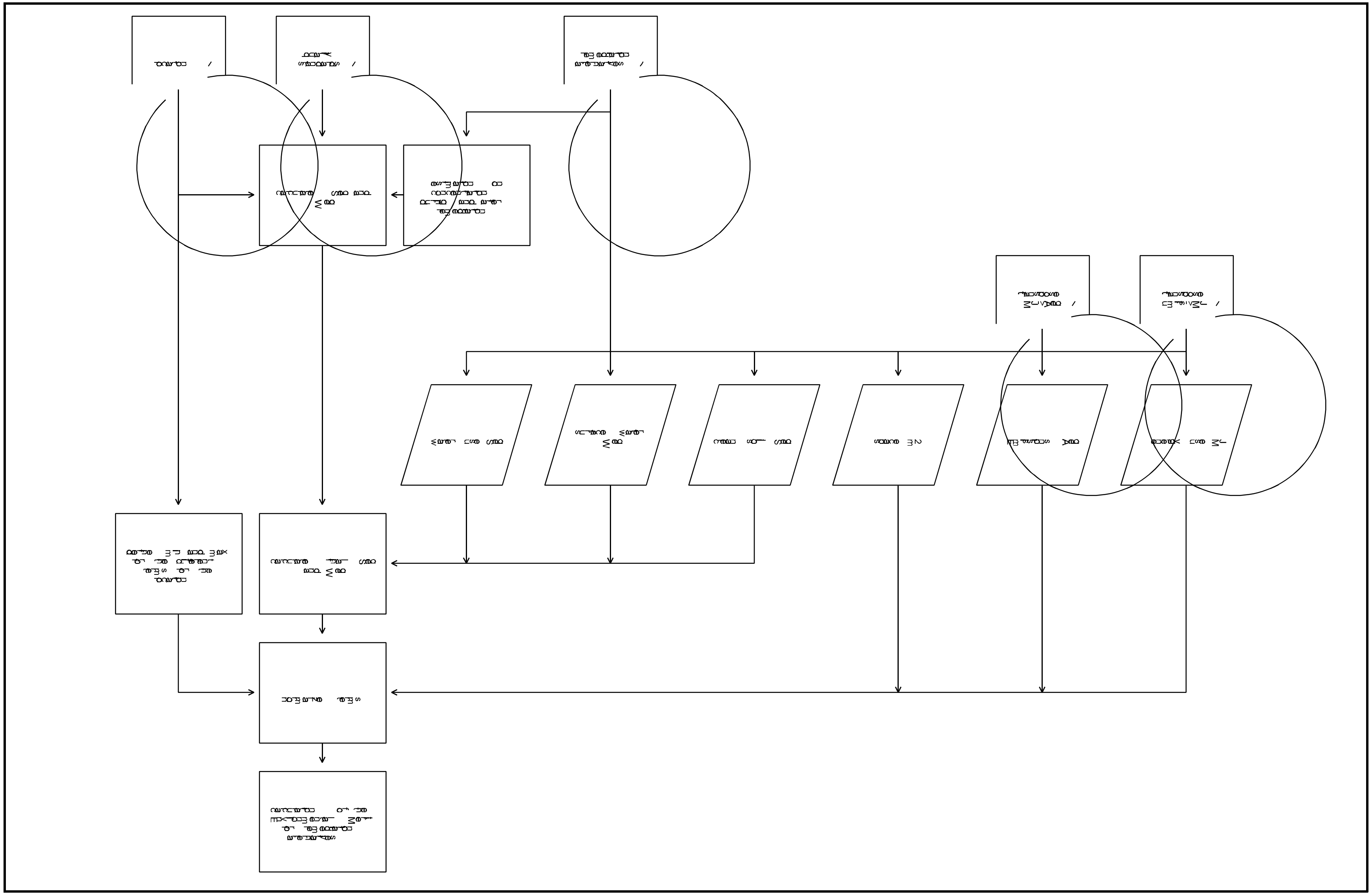

Fig. 7.3. Flow chart for the assessment of Environmental merit.

7.4 Flow chart Costs

In figure 7.4 the flow chart for the assessment of Costs is presented.
First, the expenses for the remediation will be quantified as a function of time, based on the information in the remedial investigation plan. Than the costs are all transformed into expenses for year 1 by applying the theory of discounting. The Nett Present Value will be determined according to a specific method, using selected interest and inflation numbers.
The Changes in asset value will be quantified (if possible) by valuation of the property and assets and comparing the value with similar, non contaminated sites. Historical and current transaction prices, and the impact on contamination on the transaction speed may be estimated. If possible, the total costs of the contamination, in terms of changes in value will be established and transformed by applying discounting.
Finally, the total Costs are calculated by adding the Nett Present Value of the expenses and the Nett present Value of the asset Value change.

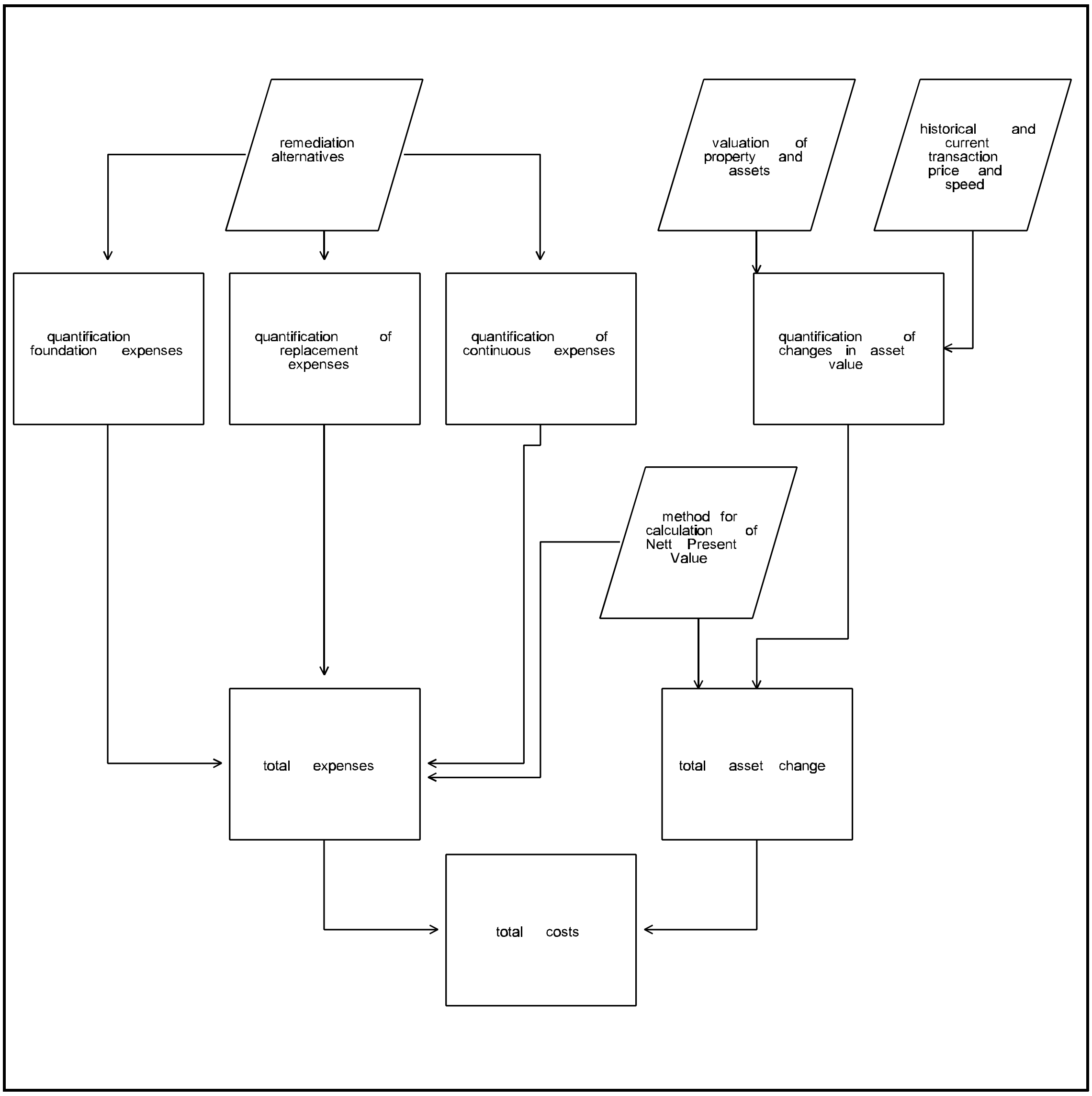

Fig. 7.4. Flow chart for the assessment of Costs.

ANNEXE A

EXAMPLE OF SCHEMATIC REPRESENTATION OF REMEDIATION PROCESS

ANNEXE B

CONVERSION OF DIESEL AND ELECTRICITY CONSUMPTION TO AIR EQUIVALENTS

For electricity in the Netherlands the following air emissions (a MJ) are identified by using simpro 3.0 (which is based on the LCA-method):

Dust = $1.2 \cdot 10^{-5}$ kg
SO_2 = $3.9 \cdot 10^{-4}$ kg
NO_x = $2.6 \cdot 10^{-4}$ kg
CO_2 = $1.6 \cdot 10^{-1}$ kg
C_xH_y = $6.3 \cdot 10^{-6}$ kg
HF = $3.2 \cdot 10^{-10}$ kg
F = $1.8 \cdot 10^{-6}$ kg
Hg = $7.0 \cdot 10^{-9}$ kg
Cd = $6.6 \cdot 10^{-8}$ kg
CO = $1.1 \cdot 10^{-5}$ kg

For diesel the following air emissions (a MJ) are identified by using simpro 3.0 (which is based on the LCA-method):

Dust = $9.4 \cdot 10^{-5}$ kg
SO_2 = $9.4 \cdot 10^{-5}$ kg
NO_x = $1.2 \cdot 10^{-3}$ kg
CO_2 = $7.6 \cdot 10^{-2}$ kg
C_xH_y = $2.3 \cdot 10^{-4}$ kg
Naphthalene = $3.8 \cdot 10^{-7}$ kg
Phenanthrene = $3.8 \cdot 10^{-8}$ kg
Chryseen = $2.5 \cdot 10^{-9}$ kg

It is difficult to relate the different air emissions to each other, because of the lack of target-values. There are emission-reduction targets in the Dutch policy, but they relate to the total amount of emission. Although there are no target-values, it is possible to relate the emission to maximum allowable emission per m^3. These values are available for the following substances:

SO_2 = 200 $mg/m^3{}_0$
NO_x = 200 $mg/m^3{}_0$
HF = 5.0 $mg/m^3{}_0$
F = 5.0 $mg/m^3{}_0$
Hg = 0.2 $mg/m^3{}_0$
Cd = 0.2 $mg/m^3{}_0$
Naphthalene = 50 $mg/m^3{}_0$

The values relate approximately to standard concentration in the air for the several substances as about 1 : 1000. Assuming that this relation can be applied on the other substances too, we can develop maximum allowable emissions per m^3 for the other substances. The actual concentrations for CO_2, CO and C_xH_y are respectively 360 ppm, 25 ppm and 2.2 ppm. For Phenanthrene and Chryseen the same target- value is used as for naphthalene.

This leads to the following intervention-values:

CO_2	. 700 g/m^3_0
CO	. 30 g/m^3_0
C_xH_y	. 1 g/m^3_0
Phenanthrene	. 50 mg/m^3_0
Chryseen	. 50 mg/m^3_0

Now it is possible to calculate the different standard Aeq's for electricity and diesel. For example the Aeq for CO_2 in diesel is 76/700 = 0.11. When all the scores are combined this leads to: 4.5 Aeq a MJ electricity and 6.7 Aeq a MJ diesel.

DEFAULT CALCULATION FOR STANDARDIZATION ENVIRONMENTAL INFLUENCES

In this annexe, a default situation for soil remediation is defined. This default situation is used to determine the difference between the desired and undesired situation. This is worked out for every aspect separately, to define the 'value function' for the standardization of the aspects. Underlying assumption in this approach is that it makes no difference what aspect is minimized or maximized. The over all aim is to minimize the negative aspects and maximize the positive aspects. The value-function is assumed to be linear. So the following remediation of the default situation is evaluated as equal:

I. Seq = 50 % maximum Seq. + Weq = 100% maximum Weq = 150

II. Seq = 100 % maximum Seq. + Weq = 50 % maximum Weq = 150

The default situation is used to derive the equations that express the standardization of the aspects.
For the illustration of the default situation the example of chapter 6 is used

Soil and groundwater

Most desirable scenario

Default situation: after remediation there is no contamination left and there is no clean soil or groundwater used.

The following calculation will be made:

In the initial situation, 24 m^3 soil is contaminated, from which 10 m^3 above I-level and 14 m^3 above T-level. In Seq this is 10 Å 1 + 14 Å 0.67 = 19.38 Seq. The final situation contains no contaminated soil, so the actual improvement = 19.38 Seq.

The groundwater quality is improved by groundwater remediation. In the initial situation, 313 m^3 groundwater is contaminated, from which 100 m^3 above I-level, 150 above T-level and 63 m^3 above S-level. In Weq this is 100 Å 1 + 150 Å 0.67 + 63 Å 0.33 = 221 Weq. In the final situation, all the contamination is removed, so the actual improvement = 221 Weq.

Prevented future contamination

It is estimated that at the end of the regarded time span, the soil contamination is increased to 30 m^3 (12 m^3 > I, 18 m^3 > T), and the groundwater contamination to 500 m^3 (150 m^3 > I, 200 m^3 > T, 150 m^3 > S).

The total prevented future contamination will be expressed in Seq en Weq:

soil: (12-10) Å 1 + (18-14) Å 0.67 = 4.68 Seq

groundwater: (150-100) Å 1 + (200-150) Å 0.67 + (150-63) Å 0.33 = 112 Weq

The total maximum benefits for the environment are thus:

soil: 19.38 + 4.68 = 24.1 Seq

groundwater: 221 + 112 = 333 Weq

Least desirable scenario

Default situation: the contaminated soil is only replaced by clean soil. Therefore to only benefit is the prevention of spreading (this is already calculated in the first scenario = 4.68 Seq). The sacrifices for this benefit are:

use of soil: 24 Å 1 = 24 Seq.

Thus the total score on soil in the worst-case scenario is:

soil: 4.68 - 24 = -19.3 Seq

Default situation: the use of groundwater the worst-case is that a lot of clean groundwater is withdrawn for containment, but without cleaning the contaminated groundwater. So the only benefit is the prevention of spreading (calculated in the first scenario). The maximum groundwater withdrawal is the withdrawal of geohydrological containment (0.1 m^3/h for a period of 30 years).

This leads to the following calculation:

groundwater withdrawal: 0.1 Å 24 Å 365 Å 30 = 26280 Weq.

Thus the total score on groundwater in the worst-case scenario is:

groundwater: 112 - 26280 = -26168 Weq.

Use of drinking water

Default situation: Sometimes the withdrawal of groundwater is compensated by infiltration. In a best-case scenario the use of drinking water is 0. The least desired scenario uses 90 % of the total amount of water withdrawn, in this case 23652 m^3.

Use of energy

Default situation: In the best-case scenario no energy is used for remedial action. A least desirable scenario for energy consumption is the following. For the calculation of energy use five elements are the most important in the calculation, they will be considered:

1. pumping of the groundwater;
2. treatment of the groundwater;
3. excavation of the soil;
4. transport of the soil;
5. treatment of the soil.

Least desirable scenario

Remedial action:

- groundwater pumped is the same amount is in the worst-case scenario of groundwater;
- all this water must be treated;
- all contaminated soil is excavated;
- all soil is treated in a thermal treatment plant off-site (distance 100 km from the site);
- all clean soil is transported to the site from a distance 100 km.

The normal energy consumption of the five elements above is the following:

m^3 water pumping a m ▪ 0.02 MJ (electricity)
m^3 cleaning of water ▪ 0.36 MJ (electricity)
ton soil excavated ▪ 42 MJ (diesel, 35 ton excavated per hour by a digging machine)
ton soil transport a km ▪ 1.3 MJ (diesel, considered a truck 1 km full and 1 km empty)
thermal treatment (ton) ▪ 60 MJ (electricity)

For the default-situation this leads to a total energy consumption of:

E: water withdrawal (head 4m) 2102 MJ
E: m^3 water treatment 8226 MJ
D: soil excavation 3754 MJ
D: soil transport 10608 MJ
D: soil treatment 16320 MJ
33584 MJ

Use of space

The minimum of space is 0, the maximum scenario is a total use of the space, which is 250m^2.

Emissions to the air

The best-case scenario has 0 Aeq. emission to the air. The worst-case scenario is the same as the worst-case scenario of energy-consumption. With conversion factors of annexe 2 this leads to:

12156 (Electricity) Å 4,5 46478

23256 (Diesel) Å 6.7 155818

Total 202300 Aeq.

Surface water emissions

Again the best-case scenario has 0 Weq. In the least desirable scenario all the extracted water is emitted to the surface water, containing concentrations that exceed the surface water standards with a factor 10. This results in 262800 Weq.
The results are summarized in table C1.

Table C1. Overview of standardization of selected and combined aspects.

aspect	least desirable	most desirable	$Y = a + b \cdot X$
benefits for the environment: positive outputs:			
• improvement soil quality + prevention soil contamination + use of clean soil	-19.3 Seq	24.1 Seq	$Y1 = 44.5 + 2.3 \cdot Seq$
• improvement groundwater quality + prevention groundwater contamination + use of clean groundwater	-22,516 Weq	333 Weq	$Y2 = 98.5 + 4.4 \cdot 10^{-3} \cdot Weq$
sacrifices for the environment: negative inputs:			
• drink water	20,500 m^3	0 m^3	$Y3 = 4.9 \cdot 10^{-3} \cdot m^3$
• energy	33,310 MJ	0 MJ	$Y4 = 3.0 \cdot 10^{-3} \cdot MJ$
• space	250 m^2	0 m^2	$Y5 = 0.4 \cdot m^2$
sacrifices for the environment: negative outputs			
• air emissions	201,100 Aeq	8 Aeq	$Y6 = 5.0 \cdot 10^{-4} \cdot Aeq$
• water emissions	262,800 Weq_{surf}	0 Weq_{surf}	$Y7 = 4.8 \cdot 10^{-4} \cdot Weq_{surf}$

ANNEXE D

NORMALIZED FUNCTION % SPECIES VERSUS CONCENTRATION

Normalized function to determine the percentage of species of an ecosystem at risk. One has to normalize the concentration in soil towards the HC_{50} of the compound, that has to be corrected for organic matter and clay.
The standardization is C = concentration in soil Â 100/HC_{50}. Table D1 will show the percentage at risk for C.

Table D1. Normalized function % species versus concentration.

C	% at risk	C	% at risk	C	% at risk	C	% at risk
1.0	0.1	10	6.7	100	50	1000	93
1.1	0.2	11	7.5	110	52	1097	94
1.2	0.2	12	8.4	120	55	1202	95
1.3	0.2	13	9.3	132	57	1318	95
1.4	0.3	15	10	145	60	1445	96
1.6	0.3	16	12	159	62	1585	96
1.7	0.4	17	13	174	64	1738	97
1.9	0.5	19	14	191	66	1906	97
2.1	0.6	21	15	209	68	2089	98
2.3	0.7	23	17	229	71	2291	98
2.5	0.8	25	18	251	73	2512	98
2.8	1.0	28	20	275	75	2754	99
3.0	1.1	30	22	302	76	3020	99
3.3	1.3	33	24	331	78	3311	99
3.6	1.5	36	26	363	80	3631	99
4.0	1.8	40	27	398	82	3981	99
4.4	2.1	44	30	437	83	4365	99
4.8	2.4	48	32	479	85	4786	99
5.2	2.7	53	34	525	86	5248	100
5.8	3.1	58	36	575	87	5754	100
6.3	3.6	63	38	631	89	6310	100
6.9	4.1	69	41	692	90	6918	100
7.6	4.6	76	43	759	91	7586	100
8.3	5.3	83	45	832	92	8318	100
9.1	5.9	91	48	912	93	9120	100
10	6.7	100	50	1000	93	10000	100

ANNEXE E

RISICOREDUCTIE, MILIEUVERDIENSTE, KOSTEN (RMK-METHODE): STAP 4 - WORKSHOP 21 JUNI 1996

E1 Inleiding

Deze bijlage bevat een verslag van de activiteiten in stap 4 van het NOBIS-project Risicoreductie, Milieuverdienste, Kosten (RMK, engelse afkorting REC). Deze bijlage vormt tezamen met het onderhavige rapport de afsluiting van fase 1 van het project.

Doel van de eerste fase van het RMK-project is het ontwikkelen van een methodiek voor het bepalen van Risicoreductie, Milieuverdienste en Kosten en het toetsen van deze eerste invulling op draagvlak voor het concept. Tevens moet aan het eind van fase 1 duidelijk zijn of en op welke wijze het project in fase 2 moet worden voortgezet.

In E2 zal het doel en de opzet van de workshop worden toegelicht. In E3 wordt een aantal generieke discussiepunten besproken, zoals die in de plenaire ochtendsessie zijn besproken. In E4 wordt verslag gedaan van de afzonderlijke sessies. E5 geeft een eerste opzet van de vervolgacties in fase 2.

E2 Doel en opzet van de workshop

Het doel van de workshop, die op 21 juni 1996 is gehouden in Hoog Brabant (Utrecht) van 10.00 tot 17.00 uur, is drieledig:

1. generale toetsing van het concept RMK;
2. inventarisatie van aspecten die nadere aandacht vergen;
3. selectie van aspecten die moeten worden uitgewerkt in fase 2.

De doelgroep van de workshop bestaat uit deskundigen die vanuit hun werkveld worden geacht een zinvolle bijdrage te kunnen leveren aan de discussie. De deelnemerslijst van de workshop is opgenomen in bijlage 1.

Ter voorbereiding aan de workshop is een uitgebreide vragenlijst aan de deelnemers toegestuurd, waarin voor de verschillende sessies de discussiepunten zijn aangegeven. Deze vragenlijst is opgenomen in bijlage 2.

Aan het begin van de workshop is het 'Mission Statement van de workshop' toegelicht:

De aanwezigen op de workshop vormen een 'klankbord' voor het consortium. Door discussie over de 'eerste uitwerking' van de RMK-methode wordt de gekozen 'richting getoetst' en wordt 'inspiratie' voor het vervolgtraject opgedaan. Door tijdige (en regelmatige) terugkoppeling met experts en gebruikers moet het draagvlak voor RMK worden vergroot.

Voor het consortium is het van belang om in een vroegtijdig stadium te toetsen of de ingeslagen richting de juiste is en welke verbeteringen kunnen worden aangebracht opdat het draagvlak wordt vergroot. Tevens moeten de knelpunten, zowel inhoudelijk als qua toepassing worden geïnventariseerd en geëvalueerd. In de evaluatie van de knelpunten moet worden vastgesteld of het knelpunt belangrijk is, of het kan worden opgelost, wie hierbij moet worden betrokken en op welke termijn dit moet plaatshebben.

Ter positionering van het RMK-project binnen NOBIS heeft de heer Deelen (VROM, bestuurslid NOBIS) een korte inleiding gehouden. Hierbij is de relatie gelegd tussen de missie van NOBIS (opheffen van stagnatie van maatschappelijke processen door significante kostenreductie van bodemsanering met behulp van extensieve grootschalige in situ sanering) en de positie van in situ sanering binnen de saneringsalternatieven. Bij het vergelijken van saneringsstrategieën worden varianten met verschillende doelen en tijdspanne met elkaar vergeleken. Wanneer alleen naar de gerealiseerde bodemkwaliteit als resultaat wordt gekeken, zal in situ sanering in de afweging ten opzicht van andere strategieën een onduidelijke plaats innemen. De oplossingsrichting voor dit knelpunt is de afweging van alternatieven meer integraal te benaderen, en varianten te beoordelen op de bijdrage aan risicoreductie, milieuverdienste en kostenreductie. NOBIS acht dit project voor het programma van groot belang, aangezien dit de acceptatie van in situ saneringen kan vergroten.

E3 Generieke discussiepunten

In de ochtendsessie wordt een viertal discussiepunten plenair besproken die betrekking hebben op het RMK-concept. Deze discussiepunten zijn:

1. toepassingen van de RMK-methode;
2. beperking van de methode tot R, M en K;
3. relatie tussen Milieuverdienste en Risicoreductie;
4. relatie R, M en K en de tijd.

In het onderstaande zal de discussie in het kort worden weergegeven.

E3.1 *Toepassingen RMK*

In het rapport wordt in figuur 1.1. een aantal niveaus onderscheiden waar de RMK-methode zou kunnen worden toegepast. De eerste fase, waarin RMK kan worden gebruikt, is het ontwerpstadium, het tweede de vergelijking van varianten voor een situatie, de derde toepassing betreft de evaluatie van lopende en afgeronde projecten en de laatste toepassing betreft het vergelijken van verschillende locaties met als doel het prioriteren van maatregelen.
Het detailniveau van de toepassing verschilt en vraagt om een ander detailniveau van input informatie. Bovendien stelt de toepassing gelijktijdig op verschillende locaties andere eisen aan de methode (externe referentie) dan wanneer de methode slechts op één locatie tegelijkertijd wordt toegepast (interne referentie).
In de discussie zijn de volgende aspecten naar voren gebracht:

- Als het concept goed wordt uitgewerkt, is het in principe voor alle toepassingen bruikbaar. Er mag geen verschil in de methode zitten voor de verschillende toepassingen (consistentie).

- Er bestaan twijfels ten aanzien van de inzetbaarheid van RMK als instrument voor prioriteitsstelling: voor prioriteitsstelling spelen andere dan R,M en K-criteria een doorslaggevende rol.

- De doelstellingen moeten verder worden geëxpliciteerd. Evaluatie van lopende saneringen kan voor twee doelen worden uitgevoerd: het toetsen van de kwaliteit van de RMK-methode (continue verbetering van het model door evaluatie van werkelijke risico's, milieufactoren, enz.) of voor het evalueren van de in situ technieken zelf (met als doel de uitvoering van in situ technieken te verbeteren).

- Het benodigde informatie niveau voor het uitvoeren van een RMK-beoordeling bepaalt in grote mate de kosten voor de toepassing.

- Er moet onderscheid worden gemaakt in '*RMK-denken*' en '*RMK-toepassing van de methode*'. Door kennis en toepassing van de RMK-methode ontstaat RMK-denken dat een belangrijke rol in de ontwerpfase kan spelen (b.v. ondersteund door een checklist van factoren die in sterke mate de scores op R, M en K bepalen).

- Een breed gedragen voorstel van de aanwezigen is om ook in fase 2 in eerste instantie de RMK-methode uit te ontwikkelen voor de toepassing 'vergelijking van saneringsvarianten', van waaruit de aanpassing naar de andere toepassingen moet worden gerealiseerd. Het is wel van belang deze andere toepassingen (ontwerpfase en evaluatie) steeds in beschouwing te nemen.

E3.2 *Beperking van de methode tot R, M en K*

Het NOBIS-project beoogt een methode te ontwikkelen die de besluitvorming met betrekking tot saneringsvarianten ondersteund. Hierbij is een subset van alle mogelijke relevante aspecten gekozen (R, M en K). Psycho-sociale en sociaal maatschappelijke factoren zijn niet in RMK opgenomen. Vraag aan de aanwezigen of dit acceptabel is.

- Het is van belang de gebruiksmogelijkheden van een locatie in RMK op te nemen. Dit is feitelijk reeds het geval binnen Risicoreductie (gebruiksspecifieke scenario's) en mogelijk binnen Kosten (waardeverandering van terreinen). Overigens is hierbij opgemerkt dat functionaliteit van varianten ook kan worden gezien als een randvoorwaarde (alle voorgestelde varianten moeten tenminste het gewenste gebruik mogelijk maken, RMK komt dan pas aan de beurt om tussen de overgebleven opties te selecteren).

- Veiligheid is tot op heden nog niet uitgewerkt en zou wellicht binnen risicoreductie moeten worden opgenomen.

- Psycho-sociale en sociaal maatschappelijke factoren worden door de aanwezigen als zeer belangrijke factoren in de besluitvorming onderkent. Men is echter ook van mening dat dit zich moeilijk laat objectiveren in een methode als RMK. Bovendien wordt RMK gezien als een *aanvulling* op het proces van afweging en selectie van saneringsoplossingen en niet als een vervanging. Incompleetheid is vrijwel per definitie het geval. Het wordt juist als de kracht van RMK gezien dat een duidelijke inperking van aspecten is gemaakt. De kracht van beslissingsondersteunende systemen ligt in de vrijheid die de gebruiker heeft (teveel vrijheidsbeperking leidt tot non-acceptatie). Besloten wordt om ook in het vervolg geen psycho-sociale factoren in RMK op te nemen.

- Restrisico's bij in situ saneringen zijn op voorhand moeilijk in te schatten en vormen vaak een belangrijk argument om van in situ af te zien. De vraag is of de huidige methode in voldoende mate tegenwicht aan deze argumenten geeft. Juist door het kwantificeren van 'residu-blootstelling' is restrisico gerelateerd aan het totale risico, waarmee getracht is restrisico's te beoordelen. Afstemming met het NOBIS-project 'restrisico's' is belangrijk en wordt gerealiseerd door de betrokkenheid van de kennisontwikkelaars bij beide projecten.

E3.3 *Relatie tussen Milieuverdienste en Risicoreductie*

Bij de definitie van de criteria Milieuverdienste en Risicoreductie is de oorzaak gevolg keten gebruikt en is een onderscheid gemaakt in schaalniveau waarop de criteria betrekking hebben.

- Ten aanzien van het begrip Risicoreductie wordt opgemerkt dat bij de invulling gekozen is voor het beoordelen van *blootsteling* en dat dit niet synoniem is aan risico. Voor stoffen waarvoor een 'geen-effect' niveau kan worden aangegeven, is blootstelling onder de TDI geen risico meer, maar nog wel blootstelling. Deze discussie wordt in de subsessie risicoreductie verder uitgewerkt.

- Door de invulling van het begrip Risicoreductie (afnemende risico's voor gebruikers van het terrein + risico's van saneringswerknemers) is het mogelijk dat de numerieke waarde van risicoreductie negatief wordt: als het risico voor het saneren groter is dan de afname van risico's voor gebruikers. Het begrip Risicoreductie is dan wellicht verwarrend.

- Bij de invulling van Milieuverdienste is gekozen voor vaststelling van potentiële beïnvloeding van de milieukwaliteit. Naar de mening van enkele aanwezigen is dit een achteruitgang ten opzichte van de ontwikkelingen in internationaal verband waar wordt getracht daadwerkelijke veranderingen in milieukwaliteit vast te stellen. Omwille van een heldere scheiding tussen Risicoreductie en Milieuverdienste is het noodzakelijk bij de invulling van Milieuverdienste niet de volledige doorvertaling naar effecten na te streven (behalve waar het om risico's voor geïdentificeerde objecten gaat). De filosofie van Milieverdienste is dat het ongeacht de plaats van handeling de mogelijke beïnvloeding van milieukwaliteit of gebruik van milieuruimte (schaarse goederen) meeneemt. In de onderlinge relatie van verschillende milieu-aspecten komen de uiteindelijke effecten weer in beeld voor de normalisatie.

E3.4 *Relatie R, M en K en de tijd*

In het rapport is toegelicht dat uitgaven die gespreid in de tijd plaatshebben door middel van disconteren naar een netto contante waarde worden omgerekend. Voor de in de tijd gespreide risico's en milieu-invloeden zou dit ook kunnen, als de filosofie achter disconteren (namelijk het verrekenen van opportunity kosten van geld en inflatie) ook voor risico's en milieu-invloeden gelden. In het rapport is voorgesteld R en M niet te disconteren.

- Er is een directe relatie tussen de totale tijdsduur die wordt beschouwd en disconteren. Als de beschouwde tijdsduur wordt beperkt, is dit impliciet een vorm van disconteren (door effecten na dit tijdstip niet meer mee te rekenen). Daarnaast kan binnen de gekozen tijdsduur nog discontering worden toegepast. Het is van belang om de gevoeligheid van de RMK-beoordeling voor de keuze van de saneringstermijn te toetsen.

- Als een korte termijn wordt geselecteerd, ligt de nadruk van de vergelijking van varianten op de wijze waarop dit wordt gerealiseerd (het saneringsproces), terwijl bij een langere tijdsduur het gerealiseerde eindresultaat zwaarder meetelt (een laag restrisico over een lange periode kan een aanzienlijke bijdrage aan R geven). Het is daarom van belang om de gebruiker van RMK inzicht te geven in de ontwikkeling van R, M en K in de tijd (grafisch) in plaats van alleen een geïntegreerde score.

- De RMK-methode moet de gebruiker de vrijheid geven de tijd in te stellen. Voor de defaultwaarde wordt de voorkeur gegeven aan een lange tijdsas (100 jaar). Hierover zal met verschillende marktpartijen aan de hand van cases moeten worden gediscussieerd.

- Er is opgemerkt dat het meetellen van risico's voor aanvang van de sanering eigenlijk niet juist is. Het is echter de verwachting van de ontwikkelaars dat er steeds vaker een afweging zal moeten worden gemaakt (op een bepaald moment) of uitstel van sanering *in vergelijking met direct beginnen* acceptabel is. Voor de toepassing als vergelijkingsinstrument is dit derhalve essentieel.

E4 Conclusies uit subsessies R, M en K

In deze paragraaf worden de belangrijkste conclusies ten aanzien van de discussie in de drie subsessies samengevat.

E4.1 *Risicoreductie*

In subsessie Risicoreductie is ingegaan op de vragen zoals geformuleerd in bijlage 2.

Aspecten die bij Risicoreductie moeten worden meegenomen

Algemeen werd opgemerkt dat objecten die vervangbaar zijn niet in het criterium risicoreductie zouden moeten worden opgenomen. Vervangbare objecten zijn in kosten uit te drukken. Met dit uitgangspunt zouden alleen de mens en het milieu op de locatie onder risicoreductie vallen.

Ten aanzien van de in tabel 3.3 opgenomen objecten werd het volgende opgemerkt:

Omwonenden: Relevant, moeten worden beschermd.

Werknemers: Niet relevant, Op enkele uitzonderingen na zijn er geen werknemers die blootstellingsrisico's ondervinden als gevolg van bodemverontreiniging. Werknemers kunnen echter wel in het model worden opgenomen.

Saneerders: Niet relevant gezien de veiligheidsmaatregelen. Voorgesteld wordt de risico's voor saneerders eenmaal goed in te schatten en aan de hand daarvan te bekijken of het in de tweede fase moet worden meegenomen.

Ecosysteem: De aansluiting die is gezocht bij de urgentiesystematiek wordt op pragmatische gronden juist gevonden. Omdat het merendeel van de bodemverontreinigingsgevallen in industrieel/stedelijk gebied liggen, vraagt men zich af of het criterium wel onderscheidend werkt. Als vee/vegetatie in economische schade zijn uit te drukken, moet dit bij de kosten worden meegenomen.

Infrastructuur/ overige objecten: Indien vervangbaar (in geld uit te drukken) niet meenemen.

Calamiteiten: Als op lokaal niveau een significante kans op schade kan optreden, moet dit worden geïdentificeerd. In de systematiek behoeft het niet als onderscheidend criterium te worden opgenomen. Het opnemen van calamiteiten in een voetnoot wordt voldoende geacht.

Achtergrondblootstelling/ combinatietoxiciteit: Beide criteria kunnen een rol spelen, er is echter een beleidsmatige principe uitspraak noodzakelijk over hoe met beide moet worden omgegaan. Achtergrond kan mogelijk een rol spelen bij de beslissing wel of niet saneren. Combinatietoxiciteit voor PAK en chloorfenolen moet worden meegenomen. Ten aanzien van risicoreductie kan mogelijk worden uitgegaan van het beoordelen van de door bodemverontreiniging toegevoegde blootstelling.

Berekenen van Risicoreductie

De weergegeven relatie R = RIndex Å n Å t is acceptabel, maar werd niet zozeer gezien als een relatie in termen van afhankelijke grootheden maar meer als functie. In de functie wordt het verloop van de risico's als functie van de tijd weergegeven.
Een belangrijke vraag voor de tweede fase is de tijdschaal. Met name het onderscheid tussen chronische en incidentele blootstelling is van belang. Als RIndex wordt gehanteerd voor de toetsing van blootstelling is de relatie mogelijk niet bruikbaar voor weergave van risico.
Aangegeven werd dat duidelijk het verschil tussen blootstellingsreductie en risicoreductie moest worden aangegeven. Door toxicologen kan mogelijk de relatie tussen beide worden uitgezocht.
De discussie over kwantificeren van de blootstelling spitste zich toe op het modelleren van het pad, met name in de toekomst. Op dit punt kan de systematiek mogelijk worden uitgebreid. Ten aanzien van risico's als gevolg van verspreiding werd aangegeven dat dit mogelijk een onderdeel was voor milieuverdienste.
Het gebruik van subgroepen in relatie tot blootstelling werd acceptabeler geacht.
Het aansluiten bij geaccepteerde normen werd als positief ervaren. Ten aanzien van humane risico's werd aangegeven dat onder het MTR geen nadelige effecten worden verwacht en dus niet kan worden gesproken over risicoreductie; beter is de term blootstellingsreductie. Ten aanzien van de MAC-waarde wordt aangegeven dat in analogie met de arbo-wetgeving beter kan worden uitgegaan van 0,2 Å MAC.
Ten aanzien van ecosystemen werd aangegeven dat de voorgestelde benadering als best bruikbaar kon worden gehanteerd. Voor een betere beoordeling van ecologische risico's zou een uitgebreide studie naar het effect op bodemecosystemen moeten worden uitgevoerd. Dit valt echter buiten het kader van het RMK-project.

Integreren van objecten

Met het voorstel om alle objecten in eerste instantie gelijkwaardig te beoordelen werd ingestemd. De onderlinge weging is een maatschappelijke keuze. De mogelijkheid zou moeten worden geboden om af te wijken van defaultwaarde 1 voor de weging van objecten.
Ten aanzien van ecologische risico's werd aangegeven dat een weegfactor al is verdisconteerd in de gehanteerde methodiek die immers gebiedstype afhankelijk is.

Praktische toepasbaarheid

Aangegeven was dat de systematiek zo simpel mogelijk moest zijn. Als voorbeeld werd de systematiek van Utrecht aangehaald.
Het model lijkt het algemene gevoel goed weer te geven.
Uiteindelijk moest het RMK-model een transparant model worden waarin objectieve zaken worden vastgelegd en subjectieve zaken door middel van een weegfactor aan de gebruikers worden gelaten.

E4.2 *Milieuverdienste*

In subsessie Milieuverdienste is ingegaan op de vragen zoals geformuleerd in bijlage 2.
Algemeen werd opgemerkt dat het begrip milieuverdienste communicatief verwarrend is: er vallen namelijk zowel baten als lasten onder dit begrip in de huidige methodiek. Wellicht is iets van 'milieubalans' beter.
De naamgeving van 'voorkomen van toekomstige verontreiniging' (prevention of future contamination) is ongelukkig: standstill wordt duidelijker gevonden.

Aspecten die bij Milieuverdienste moeten worden meegenomen

In verband met internationale ontwikkelingen in het kader van de LCA-methodiek wordt benadrukt dat aansluiting hierbij zinvol is. Hierbij is het niet noodzakelijk om het concept van de LCA over te nemen, maar kan het nuttig gebruik worden vergroot. Voorgesteld wordt om bij het uitwerken van een case ook de beschikbare tools (LCA) op deze case los te laten en de meerwaarde van een dergelijke instrument te beoordelen.

Bij de geïdentificeerde factoren die relevant worden geacht voor de bepaling van milieuverdienste werd aan de opbrengstzijde toegevoegd: het vrijkomen van nuttige producten. Het gelijk waarderen van schone (aanvul)grond en thermisch gereinigde grond werd onjuist geacht: waardeverschillen moeten tot uitdrukking komen door schone grond als gebruik te rekenen en gereinigde grond als een nuttig product (met lagere milieuwaarde).

Er bestaat consensus over de geselecteerde aspecten. Er is echter behoefte aan de onderbouwing van de selectie: het gebruik van materialen en chemicaliën zou in sommige gevallen relevant kunnen zijn, alsmede tweede orde processen (de productie van actief kool). Als dit door middel van geringe inspanning kan worden onderbouwd (zonder dat het wordt opgenomen in RMK), vormt dit een versterking van de basis van Milieuverdienste. Door Iwaco en Tauw uitgevoerde onderzoeken naar LCA-analyses bij bodemsanering kunnen hiervoor een basis bieden.

De aanname dat lozing op het riool niet leidt tot beïnvloeding van milieukwaliteit is te ruw: een berekening met een gemiddeld reinigingsrendement van de RWZI zou beter zijn.

Stank en geluid kunnen wellicht worden meegenomen in Risicoreductie (gekoppeld aan objecten) daar waar het als gezondheidsbepalende factor wordt geïdentificeerd.

Integratie van aspecten

In de subdiscussie is geen tijd besteed aan de discussie over de integratie van de geïdentificeerde milieu-aspecten. Suggesties die hiervoor gedaan zijn, betreffen de relatie van milieu-aspecten aan de doelstellingen voor de aspecten of achterliggende milieuthema's. Tevens is aangegeven dat voor het vaststellen van het onderling belang van factoren het vaststellen van waarderingsfuncties door gesprekken met experts te voeren een bruikbare methode is. Het is vooral belangrijk om een aantal uiteenlopende cases uit te werken en op basis hiervan de gesprekken te voeren.

Praktische bruikbaarheid

Ten aanzien van de praktische bruikbaarheid van de RMK-methode wordt opgemerkt dat het geheel niet veel complexer kan worden dan het op dit moment is. Aanvullingen en wijzigingen mogen niet resulteren in een complexere uitvoering van de methode.

E4.3 *Kosten*

In de subsessie kosten is ingegaan op de vragen zoals geformuleerd in bijlage 2.

Aspecten die bij Kosten moeten worden meegenomen

Er is uitgebreid gediscussieerd over de vraag in hoeverre waardeverandering moet en kan worden meegenomen in de RMK-methode. De waarde van een terrein is afhankelijk van de ligging, de gebruikswaarde, de fiscale waarde, de boekwaarde, en dergelijke. Kosten als gevolg van waardeverandering zouden moeten worden gerelateerd aan toekomstig gebruik en met inachtneming van de planningshorizon van de probleembezitter. Dit is nauwelijks kwantificeerbaar. Conclusie is dat er wel kosten zijn, dat dit een enorm effect kan hebben, maar dat dit erg specifiek is en erg afhankelijk van de perceptie van de waarde. Dit is een brug te ver voor de RMK-methode.

Kwantificering van het criterium Kosten

Bij de tijdwaarde van geld moet onderscheid worden gemaakt in vermogensinvesteringen, variabele of lopende kosten en de wijze van disconteren (technologisch of monetair). Zoals het nu in de RMK-methode is uitgewerkt, wordt voor alle financiële uitgaven (aanvangsinvesteringen, herinvesteringen, lopende kosten) een monetaire discontering toegepast. Het is denkbaar dat vanuit een ander perspectief dit disconteren anders of niet moet plaatshebben. Als saneringskosten worden gezien als 'operating costs' vormt dit mogelijk geen onderdeel van de 'investeringsbeslissing bodemsanering' (deze kosten worden dan geheel niet meegenomen?). Kapitalisatie is afhankelijk van de specifieke situatie en moet in de methode met de nodige vrijheid worden ingevoerd.

Het verdelen van kosten over verschillende kostendragers wordt binnen de subsessie als niet zinvol geacht. In de afweging van varianten gaat het om de totale kosten en niet om de wijze van financiering. Hierbij wordt opgemerkt dat als RMK wordt gebruikt om de communicatie tussen partijen over de keuze van een saneringsvariant te bevorderen, inzicht in de kosten per partij wel van belang worden geacht.

De onzekerheden in kosten kunnen verschillende oorzaken hebben:
- het niet systematisch evalueren van werkelijke kosten ten opzichte van geraamde kosten;
- onzekerheden ten aanzien van verontreinigingssituatie en bodemopbouw;
- onzekerheden ten aanzien van de performance van een technologie;
- onzekerheden ten aanzien van de prijsontwikkeling van saneringskosten;
- onzekerheden ten aanzien van ontwikkelingen op de kapitaalmarkt (rente, inflatie).

De algemene mening is dat er onvoldoende financiële expertise in het consortium aanwezig is. Voorstel voor fase 2 is om door experts van bijvoorbeeld Berenschot Osborne, Brink Groep of KPMG naar het kostencriterium te laten kijken.

E5 **Vervolgacties voor fase 2**

Op basis van de discussies die op de workshop zijn gevoerd, is de volgende richting voor het vervolg van het RMK-project aan te geven.

De methode 'RMK'

Ten aanzien van het proces van totstandkoming van de RMK-methode is er een grote mate van consensus met alle betrokkenen. Het is van groot belang de balans te bewaren tussen enerzijds de *toepasbaarheid* van de methode, rekening houdend met de beschikbare gegevens, tijd en middelen en anderzijds de *degelijkheid* van de methode: gelijkwaardige aandacht voor R, M en K, onderbouwde keuzen en een doordachte invulling en integratie.

Het is dan ook de algemene mening dat het uitwerken van voorbeeldprojecten en de op basis van deze resultaten verdere discussie de beste methode is voor de verdere ontwikkeling van de voorliggende eerste invulling van de methode.
Voordat echter aan deze toetsprojecten kan worden begonnen, is het van belang een aantal inhoudelijke aspecten nader uit te werken.

Voor het toepasbaar maken van het criterium Milieuverdienste is het noodzakelijk om een nadere discussie te voeren over de integratie van aspecten. In discussie met een beperkte groep specialisten kan een eerste invulling van de onderlinge weging van aspecten worden uitgewerkt. Aan de hand van de cases kan een en ander verder worden ingevuld.
Voor een case kan een LCA-berekening worden uitgevoerd om de selectie van aspecten te onderbouwen (uitsluiting chemicaliën, materialen, tweede orde processen).

Voor het verder uitwerken van het criterium Kosten kan expertise buiten het consortium worden gezocht.

Na deze 'aanscherping van de voorliggende methode' wordt een aantal case-projecten geselecteerd, waarvoor een RMK-beoordeling wordt uitgevoerd. Naast partijen in het consortium is het wellicht zinvol één of meer externe partijen een RMK-beoordeling te laten uitvoeren.

Deze case-projecten hebben tot doel de gebruikersvriendelijkheid van de methode te toetsen, alsmede de bruikbaarheid van de uitkomsten voor het proces van onderhandeling over de selectie van saneringsvarianten. Het is van groot belang verschillende partijen van belanghebbenden in dit proces te betrekken.

Uit deze case-projecten komen conclusies en aanbevelingen ten aanzien van:
- verdere uitwerking van onderdelen die onvoldoende blijken te zijn uitgewerkt;
- eliminatie van aspecten die niet relevant blijken;
- aanbevelingen voor het verhogen van de communicatieve waarde van RMK.

Communicatietraject

Gedurende de looptijd van fase 2 is een voortdurende communicatie met betrokken partijen van belang. Naast terugkoppeling tussen consortium en begeleidingscommissie is verbreding naar andere marktpartijen van belang. Dit stelt hoge eisen aan de uitwerking van het projectplan van fase 2. Niet alleen neemt de complexiteit aan activiteiten toe, tevens zal het aantal betrokkenen toenemen.

Op basis van de evaluatie van de ervaringen in fase 1 van het project is het van groot belang de discussie met betrekking tot de inhoudelijke invulling van de verschillende activiteiten, en de hiermee samenhangende verdeling van taken en verantwoordelijkheden voorafgaande aan deze activiteiten, vast te leggen. Fase 2 zal dan ook moeten beginnen met een degelijke definitiestudie voor fase 2 (fase 2A). Product van fase 2A is een activiteitenplan en een herziene projectorganisatie.

BIJLAGE 1

DEELNEMERSLIJST WORKSHOP RMK-PROJECT

Vrijdag 21 juni 10.00-17.00 uur

Hoog Brabant (Hoog Catharijne) Utrecht.

Naam	Instantie
Dhr. ir. G. Beuming	Shell International Oil Products
Dhr. ir. C. Buijs	Gemeentelijk Havenbedrijf Rotterdam
Mw. drs. L. Schelwald-van der Kley	Gemeentelijk Havenbedrijf Rotterdam
Dhr. dr. R. Janssen	VU-IVM
Dhr. drs. A. Weenk	TNO-MEP
Dhr. ir. M. Nijboer	Tauw Milieu
Mw. ir. A. Nijhof	Tauw Milieu
Dhr. ir. R. van den Berg	RIVM
Dhr. dr.ir. C. Versluijs	RIVM
Dhr. drs. N. de Wit	VROM
Dhr. ir. P. van Mullekom	Provincie Utrecht
Dhr. ir. J. Kamerman	Provincie Gelderland
Dhr. ir. J. Verhulst	BMRO/AKZO
Dhr. drs. J. Kuyper	NAM
Dhr. drs. A. Deelen	VROM
Dhr. dr. L.G. de Klerk	Provincie Zuid Holland
Dhr. ing. J. Verheul	CUR/NOBIS
Mw. ir. E. Soczo	RIVM
Dhr. ing. H. van Veen	TNO-MEP
Dhr. dr. H. Leenaers	TNO-MEP
Dhr. dr. W. Veerkamp	Shell
Mw. M. Scholtens	RU Groningen
Dhr. drs. W. van Vossen	Iwaco Den Bosch
Dhr. drs. P. Dijkmeester	Iwaco Rotterdam
Dhr. ir. P. de Bruijn	DHV
Dhr. ir. J. Koolenbrander	Tauw Milieu
Dhr. drs. J. Okx	Tauw Milieu
Dhr. dr. J. de Wit	Tauw Milieu
Dhr. ing. A. Bonneur	Tauw Milieu

BIJLAGE 2

OPZET WORKSHOP RMK: 21 JUNI 1996

Doel van de workshop:
1. generale toetsing van het concept RMK;
2. inventarisatie van aspecten die nadere aandacht vergen;
3. selectie van aspecten die moeten worden uitgewerkt in fase 2.

Ochtend programma:
10.00-10.15 Welkom en introductie Consortium
10.15-11.00 Toelichting op de eerste uitwerking van RMK
11.00-12.30 Discussie over kenmerken van RMK

Vragen voor de ochtend sessie:
Welke toepassingen van RMK zijn van belang? (zie fig. 1.1)
Welke toepassingen zijn realistisch?
Is de beperking van de methode tot R, M en K acceptabel in relatie tot de gewenste toepassingen? (zie 1.4)
Is de scheiding tussen Milieuverdienste en Risicoreductie helder c.q. gewenst? (zie 2.2)
Is het gekozen schaalniveau voor de invulling van R en M gewenst? (zie fig. 2.2)
Is de wijze waarop de tijd wordt opgenomen in RMK in overeenstemming met de gewenste wijze van beoordelen? (zie 2.3)
Is het acceptabel dat risico's en milieuverdienste niet worden verdisconteerd? (zie 2.3.2 en 2.3.3)
Is het gewenst dat binnen de drie criteria de afzonderlijke aspecten worden geïntegreerd tot een score? (zie 2.4)
Is het acceptabel dat er geen integratie tussen de drie criteria R, M en K plaatsheeft?
Is het acceptabel dat er 'randvoorwaarden' worden toegepast, die buiten de afweging worden gehouden? (zie begin hoofdstuk 2)
Wat is het gewenste eindproduct van fase 2?

12.30-13.30 Lunch

Middagprogramma:
13.30-16.00 Subsessies: Risicoreductie, Milieuverdienste, Kosten
16.00-17.00 Terugkoppeling resultaten subsessies en formuleren doelstelling en aanpak fase 2

In het algemeen wordt in de subsessies de volgorde gehanteerd zoals is weergegeven in de bijgevoegde figuur. De vragen kunnen fungeren als een leidraad voor de discussie.

Risicoreductie

1. Wat moet in risicoreductie worden meegenomen? (zie 3.3)

aspect/object	relevant	belangrijk voor fase 2	uitvoerbaar/operationaliseerbaar	hoe/door wie
objecten: 1. omwonenden werknemers 2. saneringswerkers 3. ecosysteem 4. infrastructuur 5. overige objecten: @ vee @ vegetatie 6.				
calamiteiten				
achtergrondblootstelling				
combinatietoxiciteit				
overige aspecten:				

2. Hoe berekenen we risicoreductie?
   Is de relatie R = RIndex Å n Å t duidelijk en acceptabel? (zie 3.4.1)
   Kan RIndex worden gedefinieerd als blootstelling/toetsingsnorm? (zie 3.4.2)
   Is n een maat voor de blootgestelde individuen of soortensamenstelling? (zie 3.4.2)
   Kunnen kortdurende en langdurige blootstelling worden gesommeerd aan de hand van tijdsfracties? (zie 3.5)
   Kan de blootstelling van objecten aan bodemverontreiniging worden gekwantificeerd?
   Is de keuze voor het afzonderlijk beoordelen van subgroepen (kinderen, volwassenen) gewenst? (3.4.2)
   Is het gebruik van TDI, MAC en HC_{50} gewenst c.q. acceptabel? (zie 3.4.3)
   Kan de blootstelling van het ecosysteem worden benaderd door beoordeling van concentratie niveaus in de bovengrond? (zie 3.4.2)

3. Hoe integreren we risicoreductie voor de geïdentificeerde objecten?
   Is het Maximaal Toelaatbaar Risico-Niveau een maatschappelijke keuze?
   Is $MTR_{humaan} = MTR_{eco}$?
   Is het aantal blootgestelde objecten (n) equivalent met het genormaliseerde oppervlak voor het ecosysteem? (zie 3.4.2)
   Kan het totale risico worden bepaald door sommatie van de onderdelen? (zie 3.5)
   Is er behoefte aan weegfactoren die het belang van de afzonderlijke onderdelen kan beïnvloeden? (zie 3.5)

4. Is de voorgestelde werkwijze (na aanpassingen en verdere uitwerking) praktisch toepasbaar?

Milieuverdienste
Concept
Is Milieuverdienste een ***verschil*** tussen positieve en negatieve aspecten voor het milieu? (zie 4.3)
Moeten bij de negatieve aspecten van milieuverdienste zowel aspecten worden meegenomen die gerelateerd zijn aan 'schaarste van goederen' als aspecten die gerelateerd zijn aan potentiële milieukwaliteitsbeïnvloeding? (zie 4.2.1)
Is de tijd voor milieuverdienste relevant, of kan worden volstaan met een verschilmeting tussen begin en eindsituatie? (zie 2.1.2)

1. Welke aspecten moeten in milieuverdienste worden meegenomen? (zie 4.3)

aspect	relevant	belangrijk voor fase 2	uitvoer baar/operationaliseerbaar	hoe/door wie
positieve aspecten: 1. verbeterde grond- en grondwaterkwaliteit 2. preventie van verontreiniging grond en grondwater 3. .... *negatieve aspecten*: gebruik schaarse goederen: 4. schone grond 5. schoon grondwater 6. drinkwater 7. energie 8. ruimte 9. chemicaliën 10. materialen .... *beïnvloeding milieukwaliteit*: 11. luchtemissies verontreiniging 12. luchtemissies energie 13. wateremissies oppervlaktewater 14. wateremissies riolering				
overige aspecten:				

2. Hoe berekenen we milieuverdienste?
   Is de relatie $TEI_{positief}$ - $TE_{negatief}$ duidelijk en acceptabel? (zie 2.1.2 en 4.3)
   Sluit het concept aan bij wat onder een milieubalans van activiteiten verondersteld wordt?
   Moet in de vaststelling van $TEI_{positief}$ rekening worden gehouden met de verbeterde grond- en grondwaterkwaliteit en de preventie van toekomstige verspreiding? (zie 4.4.1)
   Moet er gewerkt worden met kwaliteitsindices om de relatieve verbetering te beoordelen? (zie 4.4.1)
   Kunnen de negatieve aspecten die gerelateerd zijn aan het gebruik van schaarse goederen worden gecombineerd met de negatieve aspecten die gerelateerd zijn met emissies? (zie 4.4.2 en 4.4.3)
   Heeft er een ongerechtvaardigde dubbeltelling plaats door energieverbruik en emissies als gevolg van energieverbruik op te nemen? (zie 4.4.3)
   Kunnen emissies worden omgezet in lucht- en waterequivalenten met behulp van kwaliteitsdoelstellingen? (zie 4.4.3)

3. Hoe integreren we de verschillende aspecten binnen milieuverdienste?
   Is de voorgestelde wijze van standaardisatie tussen minimum en maximum gewenst c.q. acceptabel? (zie 4.5.2)

- Is het gebruik van een locatiespecifieke standaardisatie een probleem voor de toepassing van RMK als relatief instrument voor de vergelijking van gegenereerde varianten? (zie 4.5.2)
- Is het mogelijk door middel van expertpanels te komen tot een onderlinge weging van de geselecteerde criteria (1 m^3 schone grond is y A m^3 grondwater waard)?
- Worden er andere uitkomsten verwacht als de onderlinge weging van milieu-invloeden wordt aangepast, of leidt dit tot dezelfde voorkeursvolgorde?
- Op welke wijze kan een onafhankelijke meetlat worden ontwikkeld waarop een absolute vergelijking van milieu-invloeden mogelijk is?
- In hoeverre is het voor een onafhankelijke meetlat nodig om naar effecten te kijken, en wat is dan het onderscheid met risicoreductie?

4. Is de voorgestelde werkwijze, na aanpassing en verdere uitwerking toepasbaar in de praktijk?

Kosten

Moet onder het criterium kosten zowel de uitgaven (direct en indirect) voor de sanering als de verandering in waarde van terreinen en bezittingen worden meegenomen? (zie 5.2.1)
Moet de tijdwaarde van geld (disconteren) worden meegenomen? (zie 2.3.1)
Moeten alle kostenposten dezelfde kostendrager hebben (ofwel moeten kosten voor de 'opdrachtgever' en kosten voor derden (b.v. de kosten van bevoegd gezag) worden gescheiden?

1. Welke aspecten moeten in kosten worden meegenomen? (zie 5.3)

aspect	relevant	belangrijk voor fase 2	uitvoer baar/operationaliseerbaar	hoe/door wie
uitgaven: **direct** 1. stichtingsinvesteringen 2. vervangingsinvesteringen 3. jaarlijkse kosten voor in stand houden, onderhoud systemen 4. jaarlijkse kosten voor monitoring .... **indirect** 1. eenmalige uitgaven voor sloop, planvorming, vergunningen, compensatie voor derden. 2. kosten voor begeleiding vanuit de opdrachtgever/bevoegd gezag				
waardeverandering: - kosten voor vertraging transactiesnelheid - waardeverandering in relatie tot gebruiksmogelijkheden				

2. Hoe berekenen we kosten?
   Welke kapitalisatiemethode moet worden gebruikt voor het disconteren van toekomstige kosten? (zie 5.4)
   Welke rente- en inflatiepercentages moeten worden gehanteerd? Is dit afhankelijk van de kostendrager?
   Met welke onzekerheden moeten rekening worden gehouden in de kostenraming en op welke wijze? (zie 5.4)