

Report 99:06

**Guidelines for the
Risk Assessment of Contaminated Sites**

TA-1691/1999

REPORT 99:06

Norwegian Pollution Control Authority



P.O. Box: 8100 Dep, N-0032 OSLO, Norway

Office address: Strømsveien 96

Telephone: +47 22 57 34 00 Telefax: +47 22 67 67 06

Organisation no.: 970 935 657

Telegrams: "Forurensning"

www.sft.no

Executing institutions	SFT contact person	ISBN-number
Aquateam AS and NGI	Harald Solberg	82-7655-192-0

	SFT department Section for industry and contaminated sites	TA-number 1691/1999
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Project responsible	Year	No. of pages	Contract number - SFT
Eilen A. Vik and Gijsbert Breedveld	1999	107	992630

Publisher	Project financed by
SFT	SFT and NFR

Author (s) Eilen A. Vik, Gijsbert Breedveld, Terje Farestveit (Grøner AS), and others
Title – English and Norwegian Guidelines for the risk assessment of contaminated sites Veiledning om risikovurdering av forurenset grunn
Summary - sammendrag <p>A system has been developed for risk assessment of contaminated sites in relation to use of the land and recipient. Generic criteria related to sensitive land use have been calculated and the model for this is documented in the guidelines. The system involves a step by step approach where alternative acceptance criteria can be generated and also allows qualitative methods. The guidelines represent a further development and a supplement of the SFT-report 97:01 Management of contaminated land – Preliminary guidelines for executive procedures.</p> <p>Det er utviklet et system for hvordan risikoen ved en grunnforurensning bør vurderes i forhold til mulige konflikter med areal- og resipientbruk. Det er utarbeidet generelle normverdier for mest følsom arealbruk og dokumentasjon for hvordan disse er fremkommet, bl.a. beregningsmåten, fremgår. Systemet innebærer at vurderingene kan gjøres trinnvis, der alternative akseptkriterier kan beregnes og kvalitative vurderinger tillates. Veiledningen er utviklet som et supplement og videreutvikling av SFT-rapport 95:09 Håndtering av grunnforurensningssaker – en foreløpig saksbehandlingsveileder.</p>

4 emneord Grunnforurensning, risikovurdering, normverdier, akseptkriterier	4 subject words Contaminated sites, risk assessment, generic criteria for polluted soil, acceptance criteria
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Preface

The need for and the extent of remedial measures for contaminated sites are assessed based on the risk the contaminated site entails to humans and the environment. This guidance manual outlines how to carry out such a risk assessment. The guidance manual also presents the revised soil quality guidelines for most sensitive land use

It has been very important for SFT to obtain a working tool that will result in a more standardised rationale for decision-making in cases of contaminated sites. The SFT report 95:09, Management of contaminated land – Preliminary guidelines for executive procedures includes the elements in a contaminated land case, the most fundamental processes when assessing a contaminated site as well as remedial efforts. The report was missing, however, the rationale behind the preliminary soil quality guidelines for most sensitive land use as well as a working tool to undertake risk assessments.

An EU- collaboration project began in 1996 with the objective to obtain mutual recommendations on the use of risk assessments. The Norwegian work paralleled the EU-collaboration project. It was therefore possible to obtain expertise regarding the other countries systems as well as useful contacts. This has resulted in an updated Norwegian risk assessment working tool as well as ensured that contaminated sites in Norway are assessed based on an equitable approach as other countries comparable to Norway.

This guidance manual for Risk Assessment of Contaminated Sites is the result of a project commissioned by SFT with support from the Norwegian Research Council through their contaminated soil program (GRUF). The project is completed as a co-operation between Aquateam AS and the Norwegian Geotechnical Institute (NGI).

The project leader has been Eilen Arctander Vik, Aquateam.
Responsible for quality control of the project has been Gijsbert Breedveld, NGI.

The project's Steering Committee has been comprised of:

Knut Næss (chairman)	GRUF/Miljøringen
Per Antonsen	SFT

Responsible for quality control from the employer has been:

Harald Solberg	SFT
Terje Farestveit	Grøner AS

The project has also involved several resource persons having contributed via involvement in different working groups and in plenary meetings. These are:

Jan Alexander	Folkehelsa
Tor Norseth	Statens Arbeidsmiljøinstitutt
Sjur Andersen	Jordforsk
Toralf Kaland	SFT
Bjørn Bjørnstad	SFT
Kåre Helge Karstensen	SINTEF Kjemi
Hans Jørund Hansen	SFT
Marianne Langedal/Rolf Tore Ottesen	Trondheim kommune
Gunnar Brønstad	Noteby AS
Bernt Malme	PIL

The working groups have contributed to the guidance manual by publishing six sub-reports. All sub-reports are in Norwegian. Their English titles are the following:

- Sub-report 1 Human toxicology (Author: Mona Weideborg, Aquateam)
- Sub-report 2 Ecological risk assessment (Author: Siri Bakke, Aquateam)
- Sub-report 3 Transport and reaction mechanisms (Author: Allan Mogensen, Aquateam)
- Sub-report 4 Site-specific investigations and analyses (Author: Anne-Gunn Rike, NGI)
- Sub-report 5 Models and systems for risk assessment (Author: Hege Jonassen, NGI)
- Sub-report 6 Soil quality guidelines for most sensitive land use (Author: Mona Weideborg, Aquateam)

Furthermore, the following persons have prepared different additional tasks that are incorporated in the relevant sub-reports:

Freddy Engelstad	Jordforsk
Sjur Andersen	Jordforsk
Ingegjerd Rustad	SINTEF-kjemi
Lars Mouland	NTNU

This sub-reports have together with the final report from the EU-collaboration project CARA-CAS (Concerted Action on Risk Assessment for Contaminated Sites in the European Union) formed the basis for this guidance manual. The final report from the EU-project may be ordered (see the order form at the last page of this guidance manual). The final report consists of two documents:

- Risk Assessment for Contaminated Sites in Europe
 - Volume 1. Scientific Basis
 - Volume 2. Policy Frameworks

The guidance manual is divided into two documents; a) main report with appendices that contain more detailed information and b) a collection of samples that illustrate how the guidance manual can be used practically. Only the first document is translated to English.

These two documents are meant to facilitate those who work with contaminated sites, including the problem owner, consulting firms and governmental organisations to ensure standardised, cost effective decisions regarding remediation and acceptability to re-examine the rationale for decision-making. The guidance manual is prepared for a tiered approach to risk where Tier 1 is a simplified risk assessment and the measured contaminants are compared with soil quality guidelines. Tier 2 is an expanded risk assessment based on exposure calculations and Tier 3 is based on exposure measurements.

During the work to complete this guidance manual the need for further research and development has been indicated for several areas where knowledge is lacking and these are reported directly to the Norwegian Research Council.

Oslo, 12.05.99

Trond Syversen (authorised signatory)

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Section I: General description of the guidance manual

1. Introduction

1.1. Background for the guidance manual

In 1991 SFT published technical guidelines for environmental site investigations, which were in 1992 followed by a strategic plan for the clean-up of landfills, contaminated sites and contaminated sediments. The clean-up plan was based upon the results from a countrywide survey and registration effort of pollution from earlier discharges and waste disposal. The objective of this survey was to resolve the most serious contaminated soil problems within the year 2000.

In 1995 SFT published preliminary guidelines for executive procedures concerning the management for contaminated land (SFT report number 95:09, English version report number 97:01). The preliminary guidelines included soil quality guidelines for the maximum allowed levels for contaminated sites, and requirements for the contents, the extent as well as the quality of risk assessments for contaminated sites.

This document is a guidance manual for risk assessment of contaminated sites. The document presents the risk assessment section of 95:09 in more detail, revises the soil quality guidelines for most sensitive land use, and describes the background material upon which the criteria for contaminated sites are based. These new soil quality guidelines replace the values published in 1995.

Figure 1 illustrates, in chronological order, the respective elements of the decision-making model as published in 1995 (SFT 95:09, in English 97:01). The placement of this guidance manual in relation to SFT's executive procedures is highlighted in grey in Figure 1.

1.2. Important definitions

The most important definitions tied to risk assessment are the following:

Risk:

An expression for the danger that undesirable events represent for humans, the environment (ecosystem) or material values. Risk is expressed as the probability and the consequences of undesirable events.

Risk Analysis:

A systematic approach for describing and/or calculating risk. Risk analysis involves the identification of undesirable events, and the causes and consequences of these events.

Risk Assessment:

The comparison of the results from a risk analysis with the defined acceptance criteria for risk.

Undesirable event:

An event or condition that can cause human injury or environmental (ecosystem) or material damage.

Consequence:

The possible result of an undesirable event. The consequences may be expressed verbally or numerically to describe the extent of injury to humans, or environmental (ecosystem) or material damage.

Environmental Objective:

The defined ambition level for the desired condition of the environment. The expression can be used as a category for the condition/state of soil, water or air, or as a qualitative description of its condition/state that does not conflict with existing or future land use. Qualitative objectives are concretised when expressed as acceptance criteria.

Acceptance criteria:

Criteria based on regulations, standards, national and regional directives, experience and/or theoretical knowledge used as a basis for decisions about acceptable risk. Acceptance criteria may be expressed verbally or numerically.

1.3. Organisation of the guidance manual

The guidance manual is divided into 3 sections.

- Section I. General description (Chapters 1-2)
- Section II. Extended description (Chapters 3-9)
- Section III. Detailed information (Chapters 10-20)

Section I. General description (Chapters 1-2) describes the contents and organisation of the guidance manual for risk assessment of contaminated sites. The guidance manual for risk assessment is seen in light of the executive procedures published in 1995 on the management for contaminated land (95:09, in English 97:01). The system for risk assessment is descriptive as well as sets limits and uncertainty.

Section II. Extended description (Chapters 3-9) expands upon the elements in a risk analysis and risk assessment. This section describes how to obtain an acceptable data quality for the different tiers in a risk assessment, handle migration and transport, manage exposure of human beings and the environment (ecosystem), characterise risk as well as how to establish acceptance criteria.

Section III. Detailed information (Chapters 10-20) contains detailed equations and describes the background material that is utilised to determine the soil quality guidelines. This section includes a detailed description of the algorithms utilised to calculate migration/transport/exposure, health risk, environmental risk and the soil quality guidelines for most sensitive land use. This section also contains information for the selected chemical substances, definitions, and references as well as a check-list for the information needed when working with each tier of a risk assessment.

SFT has published another report that supplements this guidance manual. It is entitled *Risikovurdering av forurenset grunn, Eksempelsamling* (Risk Assessment of Contaminated Sites, Collection of Examples). This report illustrates how the guidance manual can be used practically through the use of examples. The report is in Norwegian.

1.4. Limits and uncertainty

Tolerance concentrations for receptors (amount of hazardous substance tolerated by the receptor without negative effects) are used as a starting point to determine the soil quality guidelines for most sensitive land use. The tolerance concentration is based on information

available for the different chemical substances. In some instances there is sparse information available on a chemical substance, and therefore a higher safety factor has been used to determine the tolerance concentration. It is possible to reduce the safety factor if more data is obtained during a specific case.

The soil quality guidelines are calculated based on the assumptions that humans and the ecosystem are exposed to one chemical substance at a time, that all of the exposure pathways act at the same time and that the exposure pathways for a chemical substance are additive (i.e. via ingestion, inhalation of vapour and dust, dermal contact, etc.) Additional assessments are needed for cases where there is simultaneous exposure to several chemical substances such that the different chemicals influence one another's mobility and bioavailability and lead to synergistic effects.

The calculations presented in this guidance manual do not cover periodic incidences such as snow melting and flooding. Such episodes must be assessed separately since they can lead to short-term high-exposure episodes. Furthermore, surface water run-off from contaminated surface soil or migration due to the ebb and flow of tidal waters are not included in the calculation of soil quality guidelines for most sensitive land use.

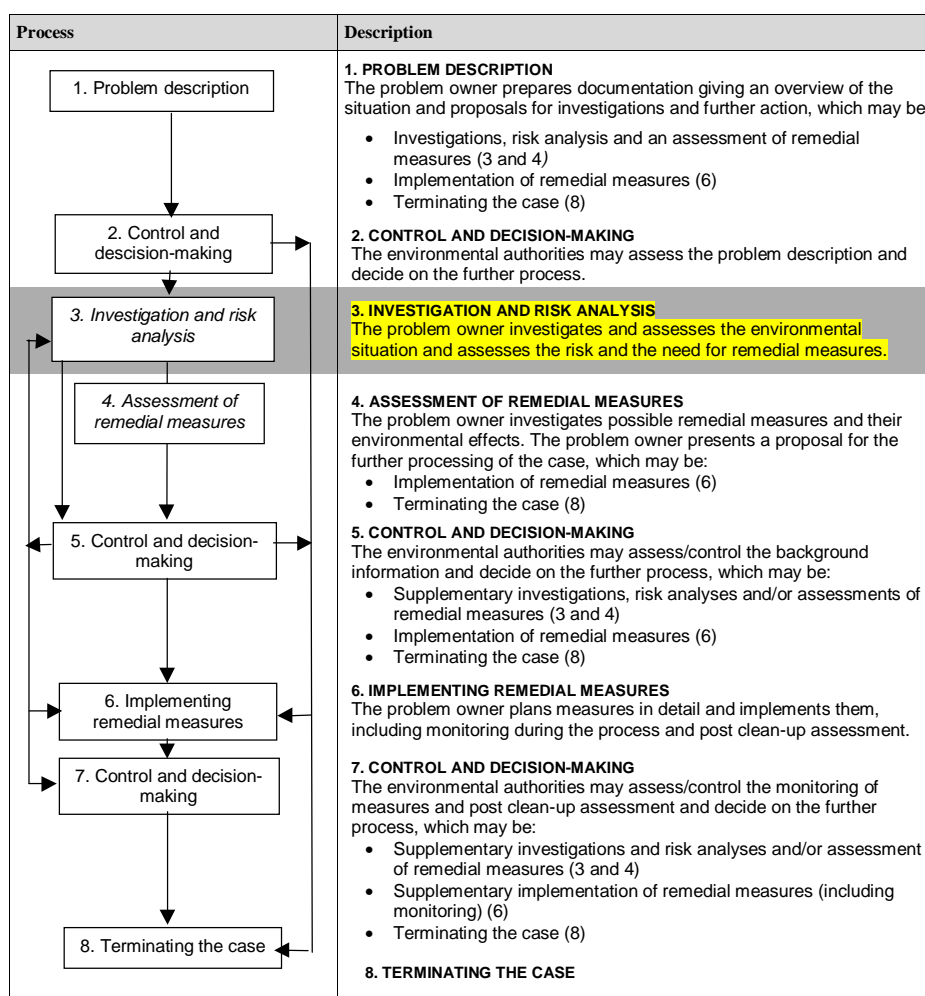


Figure 1. Risk assessments make use of several tiers in the decision-making process for cases of contaminated sites. The figure (which is taken from 95:09) illustrates all of the elements in the decision-making model where the placement of this guidance manual in relation to SFT's executive procedures is highlighted in grey.

2. Risk assessment, system description

2.1. Methodology

Risk expresses the probability that an undesirable event will occur and the consequence of what happens. In cases of contaminated sites, risk is analysed based on existing contamination and the possible future activities in the affected area. In the risk assessment scheme the results from the risk analysis are compared with the acceptance criteria.

When completing a risk assessment for a contaminated site, the probability that humans or the environment are exposed to undesirable, high concentrations is assessed. That is, if the exposure concentration is greater than a tolerable concentration. Determining the probability that animals, humans or the ecosystem may directly, or via migration, be exposed to high contaminant concentrations that can lead to unacceptable risk is a very important aspect in connection with contaminated sites. The following parameters must, therefore, be determined in a risk assessment investigation:

- all relevant exposure pathways.
- expected contaminant concentrations in all the different exposure pathways (load/dosage).
- which receptors (humans, animals, fish, shellfish, birds, plants, mushrooms, algae, bacteria, etc.) are most likely exposed to the contaminant and those whose protection is desired (environmental objective).
- which tolerance concentrations (acceptance criteria) exist for the relevant receptors.
- the probability that the contaminant may spread such that other receptors or additional exposure pathways must be considered.

Completion of a risk assessment scheme assumes that the environmental objectives as well as the affected area for a site are identified. The degree of protection for humans and the environment are defined in relation to existing or future land use or in relation to a more altruistic attitude of the site's environmental standard.

The risk assessment method is comprised of three tiers with increasing degree of complexity and detail. This tiered approach will ensure that simple cases can be completed relatively quickly with minimum resources while risk in more complex cases and potentially serious situations are completed with a greater use of resources. Information can be gradually expanded to reduce the uncertainty and subsequently improve the rationale for making a decision. Figure 2 illustrates the tiered approach. The degree of protection for humans and the ecosystem is the same for each tier; however, the degree of uncertainty for Tier 1 will be greater because fewer resources have been used to obtain the necessary information. Decisions must, therefore, be made with limited information (for example, in cases where a low level of the contaminant is expected or the problem is obvious). A larger safety factor must be used to avoid an underestimation of the risk (compensate for this larger uncertainty while maintaining the same degree of protection to humans and the environment). The uncertainties of the available information as well as the margins of safety are reduced in Tier 2 and 3 with an increase in the use of resources. There does not necessarily need to be large differences in the work format or the total amount of resources used between the different tiers. Additionally, it is possible to work within the same tier several times. The risk assessment for many contaminated sites will most likely be conducted at Tier 2 where the calculations may be repeated several times as the available information improves.

A tiered approach provides an overview and unified basis for the decision to assess the need for action or remediation. Figure 3 shows the risk assessment as a component in the rationale for the decision in contaminated site cases.

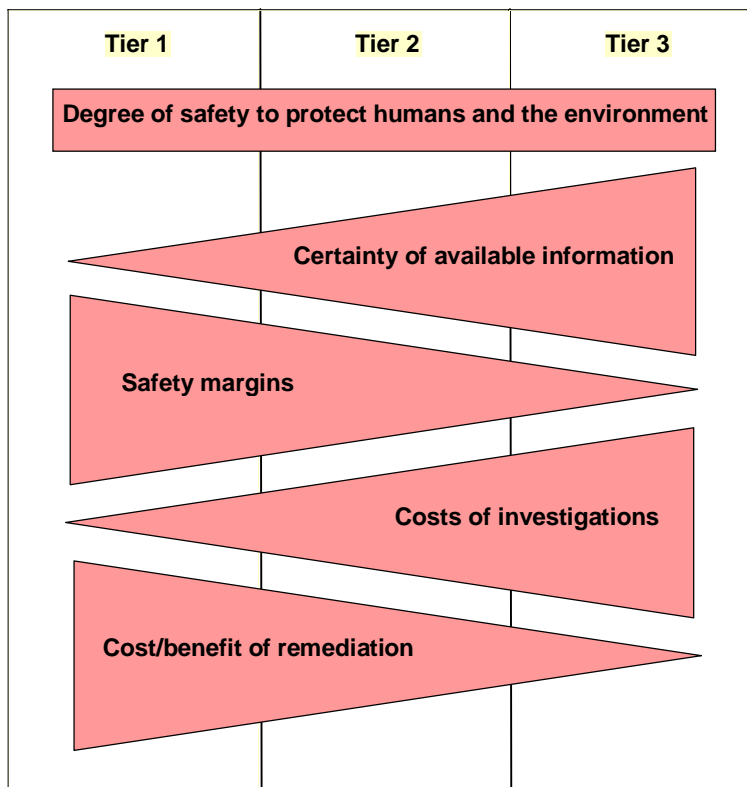


Figure 2. *This tiered approach for risk assessments makes it possible to provide the same degree of safety and protection to humans and the environment when determining the course of action, even when the available information is limited.*

The problem description is composed of the collection, review, assessment, and application of available information at the site. This includes the possible migration routes, the recipient, the land use as well as the local environmental objective. The following concerns will be addressed in the problem description:

- type, placement and extent of possible contaminant sources as well as the known properties of the suspected chemical substances.
- characterisation of potential migration routes (soil, water and air).
- assessment of the exposure potential based on the land use and characterisation of the recipient.
- identification of user conflicts and the local environmental objective.

The extent and need for an investigation of the site is assessed based on the results from the problem description. First the investigations will be directed at determining the type, composition and placement of possible contaminant sources. The problem description is described in more detail in SFT's executive procedures (1995, in English 1997). The first tier of the risk assessment may be completed based on the results from the problem description. Figure 4 illustrates the tiered structure of the risk assessment.

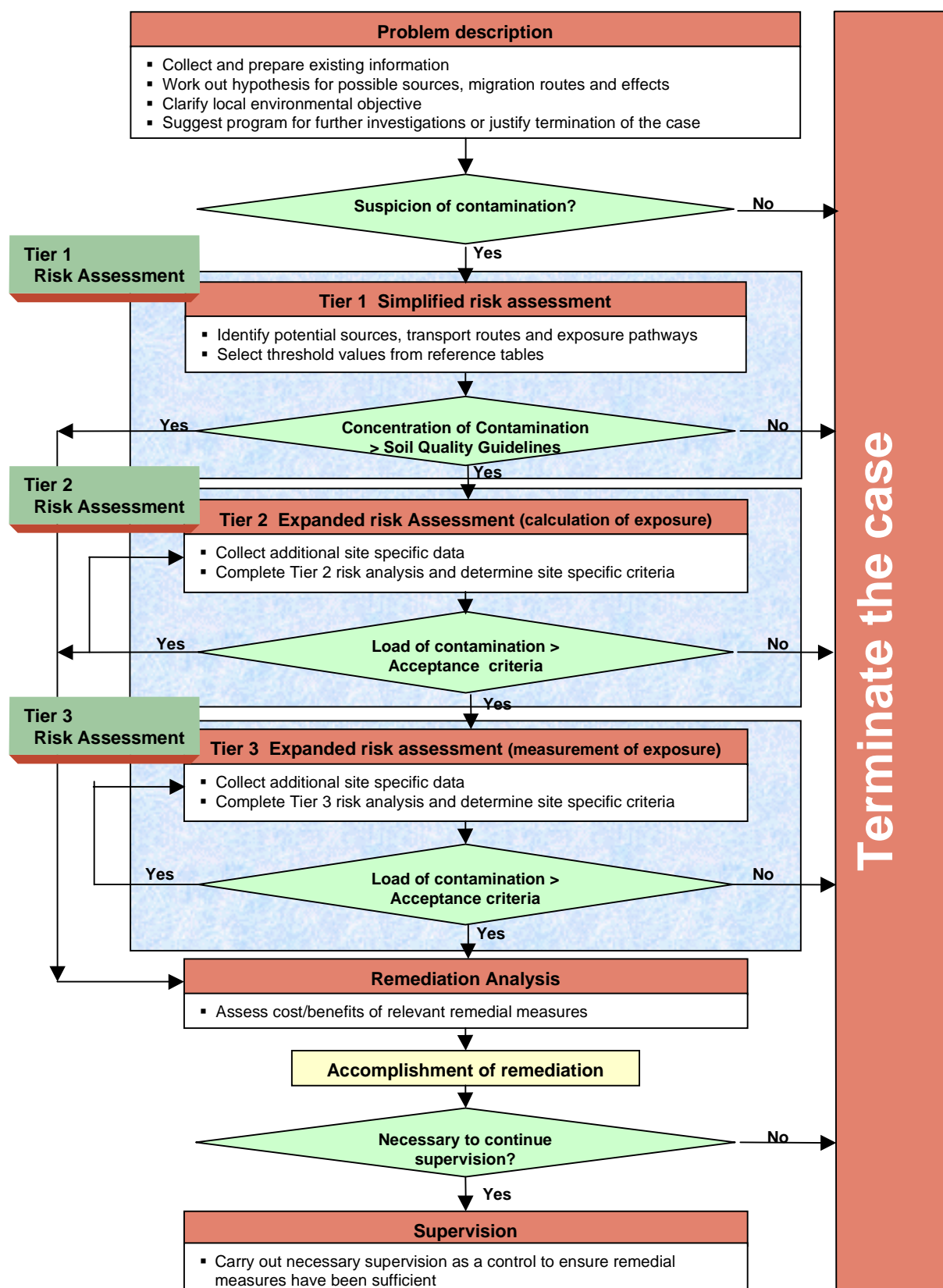


Figure 3. Description of the risk assessment as a component in the rationale for decision-making tied to contaminated sites.


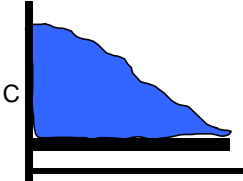
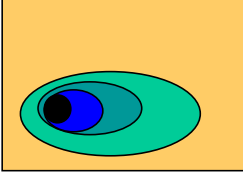
Tier number	Work tool in the guidance manual	Description of contents
1. Simplified risk assessment (soil quality guidelines for most sensitive land use)	 Reference tables.	<p>Objective: Assess if the soil quality guidelines, based on exposure at the source, are exceeded.</p> <p>Data requirement: Representative maximum concentrations at the source.</p>
2. Expanded risk assessment	 Distance from source (x) (empirical models, calculation algorithms, computerised working tools).	<p>Objective: Assess if the site specific acceptance criteria, based on the site specific exposure situation, are exceeded.</p> <p>Data requirement: Extent of the source, representative receptor concentrations and migration information. The soil quality guidelines are adjusted to the current land use. Site specific soil conditions (organic carbon, permeability, etc.) and related migration conditions are considered.</p>
3. Expanded risk assessment based on exposure measurements	 Verification of models and/or exposure measurements (not described in detail).	<p>Objective: Assess if the risk based acceptance criteria for health/environment are exceeded for the different exposure pathways.</p> <p>Data requirement: As in Tier 2, with the addition that effects, migration, exposure, etc. are measured at the location of the target receptors.</p>

Figure 4. Structure of the Norwegian risk assessment scheme for contaminated sites.

2.2. Tier 1: Simplified risk assessment (use of soil quality guidelines)

Soil quality guidelines for most sensitive land use form the basis of Tier 1. These are summarised in Table 1. A site specific investigation is conducted to determine the maximum concentrations of hazardous substances in the vicinity of the source. The results from the investigation are compared with the soil quality guidelines, which are based on the most sensitive land use. The soil quality guidelines are derived for a generic site comparing tolerable daily intake (human beings) and tolerable concentrations (terrestrial ecosystem) with exposure at the site through the defined exposure pathways as described in Chapter 6 (further expanded upon in Chapters 10, 11 and 12). In the future, soil quality guidelines may also be derived for other chemical substances than those included in this version of the guidance manual using the same set of calculations as given in Chapters 10, 11 and 12. The soil quality guidelines are calculated using a generic soil with 1 percent carbon, a pore water and air content of 0.2 (dm^3 water/air/ dm^3 soil), a permeability of 0.4 and a soil density of 1.7 kg/dm^3 .

To ensure the use of comparable input data quality in risk assessment of different sites, quality requirements to the investigation are described in Chapter 3. The highest measured contaminant concentration is utilised to compare the results from the investigation with the soil quality guidelines (see details in Chapter 2.5).

The following conclusions can be drawn depending on the results of the investigation:

- If none of the samples are greater than the soil quality guidelines, then the investigation may be terminated and there are no restrictions to the land use.
- If one or several of the samples are greater than the soil quality guidelines, then the high concentration values should be assessed as to whether they are due to the contaminant or due to local background levels. A Tier 2 risk assessment (Figure 3) may be conducted or remediation completed if the contents in one or several of the samples are not due to background levels.

2.3. Tier 2: Expanded Risk Assessment (calculation of exposure)

The expanded risk assessment is conducted for the current (or planned) land use for the site. The soil quality guidelines for most sensitive land use are determined by assuming that humans and the ecosystem are exposed via a set of defined exposure pathways. However, an expanded risk assessment only considers the exposure pathways that are relevant for the specific site. The tolerance concentrations for unacceptable effects are determined based on these exposure pathways. The calculations are shown in Chapters 10, 11 and 12. The information needed for the calculations is adapted for the local conditions with the composition of the source, the type of soil, and the relevant possibilities for exposure taken into account. Possible undesirable events are identified based on the available information (problem description, hypothesis).

2.3.1. Probability that an undesirable event will occur

A source and land use analysis, as well as a migration and transport analysis are useful tools to assess the probability that an undesirable event will take place.

The results from the risk analysis are compared with acceptance criteria which are based on identified environmental objectives for the site. The risk assessment will then be carried out (Figure 3).

Source and land use analysis will contain a description of the contaminated sources, select chemical substances and identify receptors that need to be protected. A source and land use analysis is required for present and any future planned land use. The probability that the site may be contaminated with other chemical substances than those that have been identified must also be assessed.

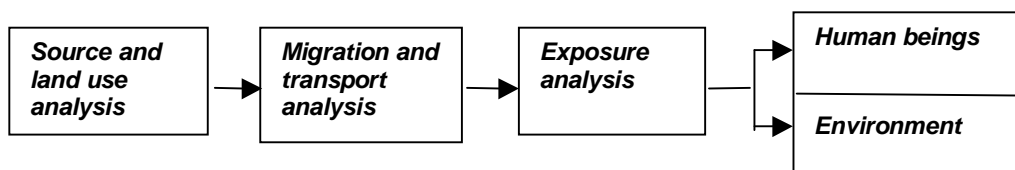


Figure 5. Assessments that will be carried out as part of a risk assessment, Tier 2 and 3.

Migration and transport analysis contain the modelling results and/or results of the measurements documenting the migration and transport of the contaminants in the unsaturated and saturated zone. Migration and transport analysis will be completed for all relevant environmentally hazardous chemical substances at the point of exposure for the receptors to be protected. The analyses are completed for existing and planned land use. The probability for additional routes of migration will also be assessed. This is especially important for conditions that are a result of periodic episodes.

Table 1. Soil quality guidelines for most sensitive land use.

Chemical substance	Background value in Norway ¹⁾	Soil quality value (mg/kg)
Arsenic	0.7-8.8	2
Lead	8.5-107.4	60
Cadmium	0.1-1.7	3
Mercury	0.05-0.20	1
Copper	6-27	100
Zinc	25-104	100
Chromium (total)	3-30 (total)	25
Nickel	3-19	50
Free Cyanide	m.d. ³⁾	1
Σ7 PCB	0.003-0.03	0.01
Pentachlorophenol	<0.005	0.005
Lindane	0.002-0.03	0.001
DDT	0.0003-0.02	0.04
Monochlorobenzene	m.d. ³⁾	0.5
1,2-dichlorobenzene	m.d. ³⁾	0.5
1,4-dichlorobenzene	m.d. ³⁾	0.5
1,2,4-trichlorobenzene	m.d. ³⁾	0.2
1,2,4,5-tetrachlorobenzene	m.d. ³⁾	0.3
Pentachlorobenzene	m.d. ³⁾	0.1
Hexachlorobenzene	0.0004-0.006	0.03
Dichloromethane	m.d. ³⁾	0.06
Trichloromethane	0.001	0.01
Trichloroethylene	0.001	0.01
Tetrachloroethylene	0.01	0.03
1,1,1-trichloroethane	0.001	0.1
Aromatic hydrocarbons		
Σ 16 PAH ²⁾	0.005-0.8	2
Benzo(a)pyrene	0.015-0.157	0.1
Naphthalene	m.d. ³⁾	0.8
Fluorene	m.d. ³⁾	0.6
Fluoranthene	m.d. ³⁾	0.1
Pyrene	m.d. ³⁾	0.1
Benzene	<0.1	0.005
Toluene	0.32	0.5
Ethylbenzene	<0.1	0.5
Xylene	<0.1	0.5
Aliphatic hydrocarbons ⁴⁾		
Aliphatics C5-C10	m.d. ³⁾	7
Aliphatics >C10-C12	m.d. ³⁾	30
Aliphatics >C12-C35	m.d. ³⁾	100
Additives to gasoline and oil products ⁴⁾		
MTBE (<i>tert</i> - Butyl Methyl Ether)	m.d. ³⁾	2
1,2-dichloroethane	m.d. ³⁾	0.003
1,2-dibromoethane	m.d. ³⁾	0.004
Tetraethyllead	m.d. ³⁾	0.001

1) Data reported from SFT's environmental hazardous substances (Beck and Jaques, 1993).
2) Calculated based on the most toxic PAH-compound, benzo(a)pyrene.
3) m.d. = missing data.
4) Composed based on available information grouped together by Naturvårdsverket and the Swedish Petroleum Institute (Naturvårdsverket, 1998).

2.3.2. Consequences of an undesirable event

The consequence that an event will in fact occur is assessed with, among other things, the help of an exposure analysis (Figure 5).

An exposure analysis determines the total exposure of the identified receptors using the defined exposure pathways. The receptors' exposure to the different chemical substances is determined for the planned land use. The assessments will be completed for acute and chronic exposure. If a hazard is identified for other exposure pathways than the most probable, the probability and consequences of these additional pathways will also be assessed in the exposure analysis.

2.3.3. Acceptance criteria

Acceptance criteria are derived from site specific environmental objectives. The environmental objectives report the ambition levels and the desired condition. Acceptance criteria describe how the environmental objectives will be documented. The environmental objective is, for example, the drinking water quality or concentrations that, to an acceptable degree of certainty, do not give an undesirable effect. Acceptance criteria, on the other hand, are the drinking water quality criteria and the concentrations that do not give a negative effect.

Acceptance criteria must be defined for each site and will take into account health/ecosystem related and migration related conditions.

2.3.4. Risk Assessment

Remediation must be carried out if the determined exposure is greater than the acceptance criteria. If there is a good chance that additional site specific information will lead to another conclusion, more information can be obtained and the Tier 2 risk assessment may be repeated. If there is a small chance that better information will lead to another conclusion, it is more natural to plan and perform remediation or define an acceptable change in land use (Figure 3).

2.4. Tier 3: Expanded risk assessment (measurement of exposure)

A Tier 3 risk assessment is to a large extent based on measured exposure, using the same risk analysis that is described for Tier 2. The data that should be utilised should as much as possible agree with field measurements and to a lesser degree be based on modelling, which is mostly used in a Tier 2 risk assessment. Tier 3 will therefore demand site specific investigations adapted to the local conditions.

The mobility, adsorption and degradation that are to be taken into account in the different media (soil, water or air) ought to be documented via field measurements or laboratory investigations. The concentration of the contaminants in the different exposure media (soil, water, air, recipient, target organisms and plants) should as much as possible be determined with measurements.

In addition, the consequences of the contaminant will as far as possible be documented using ecotoxicological tests, investigations of flora, fauna, animals and microbiological conditions at the site.

The results of the investigations are expected exposure concentrations based on measured values. The exposure concentrations for the different receptors are compared with the tolerance levels. Adjustments of tolerance concentrations due to documented bioavailability, etc., can be performed based on the site conditions.

2.5. Interpretation of the Results

The results from chemical analysis of soil samples are interpreted as follows:

- None of the samples have a contaminant level greater than the acceptance criteria. In this instance the investigation may be terminated and the site can be utilised of in accordance with the existing or planned land use. Future rezoning or changes to a more sensitive land use require a repetition of the risk assessment to determine that the change in land use will not lead to an unacceptable exposure due to the changed acceptance criteria.
- Contaminant level in one or more of the samples is greater than the acceptance criteria. It must be assessed whether the results that exceed the acceptance criteria are due to the contaminant or natural background levels. This is especially relevant for inorganic substances. In order to make this assessment the local natural background levels of the contaminants must be known or determined. If the contents in one or several of the samples is not due to the background levels there are three possible ways to proceed:
 1. Increase the certainty of the site specific data. Supplementary data can be procured by expanding the field investigations and a new risk analysis and the subsequent risk assessment be completed with the new information.
 2. Carry out remedial measures to reduce/eliminate the risk tied to the contaminant.
 3. Complete the risk assessment at the next tier.

The results of the risk assessment can be as follows:

- the calculated exposure level is less than the tolerable concentration (human health and the ecosystem) and there are no noticeable effects; the investigation may be terminated.
- the calculated exposure level is greater than the tolerable concentration (human health and the ecosystem), or there has been observed unacceptable effects to human beings or the environment; remedial measures to reduce or eliminate the risk or restriction of land use will be assessed.

Different criteria are used, depending on the number of available samples that have been analysed, to determine if the soil quality guidelines have been exceeded. The soil quality guidelines are regarded as not being exceeded if:

- the average of 3 analyses are less than the soil quality guideline and none of the analyses are greater than the soil quality guideline by more than 50%.
- the average of 4 to 10 analyses are less than the soil quality guideline and none of the analyses are greater than the soil quality guideline by more than 100%.
- the average of more than 10 analyses are less than the soil quality guideline and 90% are less than twice the soil quality guideline. The 90th percentile means that 10% of the highest values need not be taken into consideration; however, the highest value must be lower than twice the soil quality guideline.

Section II: Extended description

3. Data quality for site investigations

3.1. Background and assumptions

The determination of the contaminant concentrations and the general data collection must be completed as uniformly and as technically correct as possible. With a risk analysis it is important that not only the most probable events are assessed, but also the less-probable, yet genuinely possible.

The problem description does not often give an acceptable enough basis to complete a risk analysis with the desired quality and certainty. Therefore, additional site investigations must be completed to obtain better rationale for the decisions.

Both quantitative and qualitative information are utilised as effectively as possible to obtain optimal confidence in the data. The greater the uncertainty regarding the contaminant, the migration and the extent, the greater the need placed on the number of samples and the quality of sampling, analysis, etc.

3.2. Site investigations

Site investigations are divided into four steps:

- planning
- sampling
- analysis
- results processing

The uncertainty and sources of error for each activity ought to be controlled to ensure that the results from the site investigation is representative enough to be used for risk analysis. Quality control will ensure that the result has the desired quality. This is illustrated schematically in Figure 6.

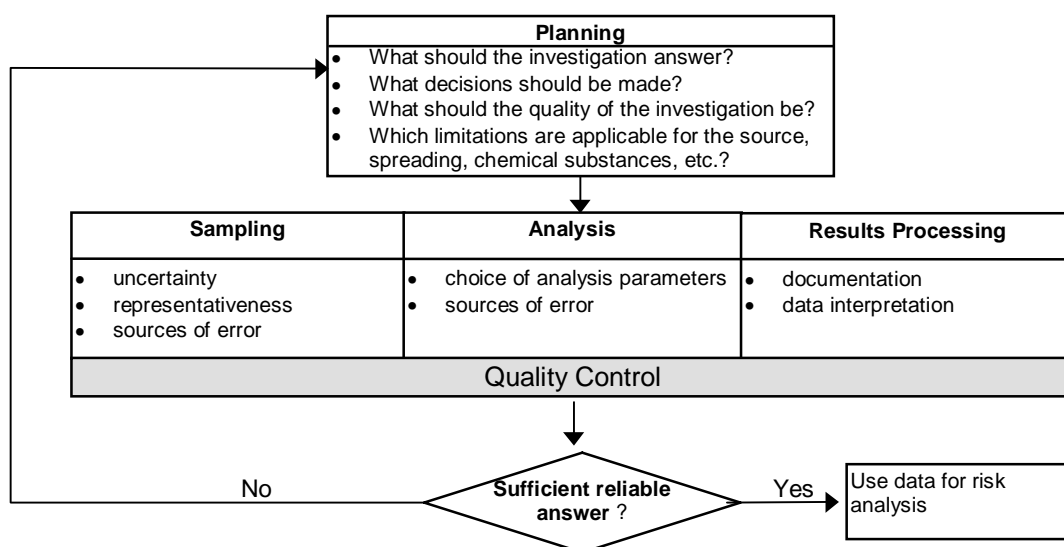


Figure 6. Schematic overview for the contents and quality control for site investigations for procurement of input data to risk analysis.

3.2.1. Planning

Central problems in planning site investigations include:

- what should the investigation answer?
- which sections are most appropriate to divide the investigation into?
- what decisions should be made based on the results from the investigation?
- what should the quality of the data be (limit of detection, uncertainty)?
- what is the consequence when inaccurate conclusions are drawn due to high uncertainty?
- what consequence does the selected data quality have for the chosen method?

Clarifying investigations are utilised to determine if the contaminant concentrations exceed the acceptance criteria, for example the soil quality guidelines for most sensitive land use. Normally a clarifying investigation does not give an answer on the extent and migration of the contaminant. It only determines if a contaminant is detected as given in the problem description.

After an extended investigation in the vicinity of the site has been completed, it is normally desired to describe the migration of the contaminant. This includes its degree of migration and if this varies with climatic conditions or is influenced by other natural or anthropogenic barriers or motivations. The closer the contaminant concentrations are to the acceptance criteria, the greater the demand for data quality. There will not be a need for several analyses if all of the values are clearly over or under the determined acceptance criteria. It is, therefore, appropriate to divide the site into:

- areas that are clearly not influenced or where low levels of contaminant are expected.
- sources with obvious high levels of contaminant.
- areas where there is uncertainty in the level of contaminant.

Within the site the distribution of concentrations are not often normally distributed, but log-normally distributed. In other words, there are a few samples that give relatively high and low values. One attempts with sufficient information to determine where the most and least contaminated sections are located, and still having a sufficient degree of certainty, to determine if the average concentration in the other sections lie under or over the defined acceptance criteria.

The planning encompasses the placement of sampling points (extent and depth), the assessment of parameters to be analysed, necessary detection limits, and the requirements for sampling and handling of the samples. It also addresses how to ensure that the analytical results are as comparable as possible.

3.2.2. Sampling

A sampling plan that ensures a technically justifiable number of samples, handling, transport and analysis, must be carried out before the sampling can begin.

The sampling will ensure that the samples and analytical results are representative for a defined area. In addition to identifying one or several sources, an assessment must be completed for possible migration routes, barriers, visual boundaries and geo (hydrogeo) logic conditions.

The number of samples that will lay the foundation for a risk analysis will vary depending on the current problem. Identifying the extent and direction of migration also normally requires a large number of samples. Few samples are normally needed to identify a known source, whereas many more samples are needed when mapping an area without localised sources.

Mixing of sampling can reduce the number of samples that need to be analysed and subsequently the cost tied to the investigation. Assumptions for mixing of samples include that:

- the contaminant is somewhat evenly divided or there is no suspicion of the contaminant.
- the analysis method manages to detect high concentrations even though pure and contaminated samples are mixed together.
- the individual samples that are mixed together can afterwards be analysed separately if a high concentration is discovered in the mixed sample (individual samples must be stored under acceptable storage conditions and the volume must be large enough).
- the investigation will clarify if excavated masses are contaminated. Mixing of several sample portions, for example a truck-load, can give a good description of the contaminant.

A mixed sample can represent the average level of the contaminant for a larger area if the area is diffusely contaminated. However, none of the samples can normally represent an area larger than 100 m² or a volume larger than 100 m³. Using a larger area or volume must eventually be justified. If potential conflicts are disclosed, it may be necessary to increase the number of samples. It will also be critical for the certainty in the rationale for the decision if the conflicts can be related to the surface soil only, given a smaller area (volume) or point.

It is most often economically favourable to undertake additional analyses to sort the masses in an optimal manner during remediation. There will also be other factors, for example the method of disposal, that will influence the choice and number of samples.

The number of samples that will lay the foundation for a risk analysis varies with the current problem. Some examples are as follows:

1. Diffuse and assumed homogenous contamination

A systematic investigation ought to be completed for the area if the contaminant is expected to be homogeneously distributed over the entire volume. The sampling points must be chosen such that they create a systematic pattern over the whole site.

The term “homogeneous” implies that the contaminant is of nearly the same order of magnitude over the entire area. Obvious gradients are not expected. Statistical methods can then be utilised to identify migration.

Such an approach requires a relatively high number of analyses, often 30 or more, for each parameter of the contaminant. The certainty that is obtained from many analyses influences the conclusions. Mixed samples taken in a statistical systematic manner can contribute to reduce the number of analyses.

Table 2 exemplifies the probability that one will not detect a circular shaped contaminant, for example a barrel, when sampling systematically in a rectangular or triangular grid. The table shows that if the contaminant constitutes only a small portion of the site, for example 10 percent. There is a 97 and 95 percent probability of not discovering the contaminant if the systematic sampling is conducted in a rectangular or triangular sampling pattern respectively.

If the only information that is available in a situation with diffuse contamination is the results from the analyses, then it is necessary to have relatively many samples in order to have good certainty in the conclusions that can be drawn. Normally this requires at least 30 samples. If the results within a portion of the area are normally distributed, one can quantify the uncertainty of the results, as well as the probability that the contaminated areas are overlooked.

Table 2. The probability that one will not find a circular contaminated area when systematic sampling in a grid network is utilised.

Grid pattern	Diameter of the contaminated area in percent of the grid									
	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
Rectangular	0.97	0.88	0.72	0.50	0.21	0.06	0.0	0.0	0.0	0.0
Triangular	0.95	0.85	0.66	0.41	0.08	0.0	0.0	0.0	0.0	0.0

A mixed sample may reduce the number of analyses needed depending on the concentration gradients. There will often be a relationship between the different hazardous substances, such that a picture of the dimensions of the contaminant can be created when analysing a more limited number of parameters. Important qualitative information can be utilised to reduce the number of samples. It is also possible to limit the portions of the area without using statistical methods. However, then it is not possible to quantify the certainty in the basis for the decision, and a technical qualitative justification must be given as to why the decisions are taken with high enough certainty.

2. Contamination from point sources at an identified locality

When the contaminant is expected to be heterogeneously divided in relation to a point source at an identified locality, the potential contaminated area ought to be sampled in the first round to determine if a source is found and its possible extent. In order to accomplish a Tier 1 risk assessment, at least one sample per contaminated source is required. The problem description, based on a review of historical overview maps and results from earlier relevant mapping of the area, will very often identify certain or probable sources. Inspections and investigations of the site will also help ascertain probable migration routes that can occur along ditches in the ground or along roads, via draining pipes to end points, via a leakage point direct to the ground or groundwater, or the soil layers can entail that the migration occurs in natural zones/canals. Natural barriers such as a layer of clay or rock formations may also exist.

Special situations such as precipitation with a large amount of run-off, dominating run-off pathways, high groundwater levels, high/low tide, etc., can also be critical situations where the greatest amount of migration occurs. Based on such information it is possible to make a good argumentative hypothesis as to how the contaminant will spread. This is used as a basis for planning and carrying out the sampling or adjusting earlier established hypotheses.

3. Contamination from point sources at an unknown locality

When the localisation and migration of the contaminant is not known, the samples ought to be taken in a systematic pattern that covers the entire locality. The number of samples per unit area will still be decisive for proving the existence of the contaminant (Table 2).

The objective of the sampling will be to identify potential sources. Available information has indicated that different sources in fact exist. The exact location within the site is, however, unknown.

3.2.3. Analysis

The samples taken in the field ought to be analysed for the relevant parameters in relation to the expected contaminant (identified in the problem description). When it is unclear as to which chemical components ought to be analysed, priority compounds that are indicators for contamination from different activities have already been defined. In addition to the expected compounds, some samples ought to be analysed for a broad spectrum of priority compounds. Table 3 gives an overview over some usual analytical groups.

Table 3. Usual analytical parameters applied to contaminated sites.

Analytical parameter	Standard components
Physical characteristics	Water content, organic carbon and clay content
Heavy metals	8 elements: As, Cd, Cr, Cu, Hg, Ni, Pb, Zn
Aliphatic hydrocarbons	Total hydrocarbons, fractions $C_5 - C_{10} > C_{10} - C_{12}$ and $> C_{12} - C_{35}$
PAH ¹⁾	16 polycyclic aromatic hydrocarbons according to USEPA
PCB	7 congeners: 28, 52, 101, 118, 138, 150 and 180
BTEX ¹⁾	Benzene, toluene, ethylbenzene and xylene
VOCI	di-, tri- and tetraechloromethane, di- and trichloroethane, tri- and tetrachloro-ethylene

1) Aromatic hydrocarbons = PAH + BTEX

The extraction of the contaminant from soil samples during the analytical procedure, together with the problem with sampling and handling of samples, is one of the largest sources of error in handling the analyses. The analytical methods almost never determine the total content in the soil sample. Only the fraction that is possible to extract with the method applied can be determined. It is, therefore, important that the analytical method is given in order to interpret the data that is used in the risk analysis. In order for the results to be as comparable as possible, identical methods for extraction preferably ought to be applied.

Only laboratories accredited for the relevant parameters must be utilised. Information on the applied analytical method and the uncertainty in the analytical results must be included in the analytical report. Generally, one can expect that the uncertainty in the chemical analytical results are within 15 percent for heavy metals, while they can vary between 10 to 100 percent for organic compounds. In spite of the great uncertainty in the analytical results for organic compounds, the uncertainty in the representation of the samples taken in the field for most cases are much greater, and still difficult to quantify.

3.2.4. Results processing

The results from sampling in the field and the chemical analysis are collected to document the investigation and to interpret the data that has emerged. These results are compared with visual and smelling observations, geo (hydrogeo) logical conditions and historical data.

After the investigations are completed, the following ought to be assessed:

- is the expected contaminant described in the problem description demonstrated?
- is other contaminants than that expected shown, or is there a basis for analysis of additional parameters?
- are several contaminants found other than the one foreseen?
- what is the maximum concentration of the different compounds shown for each source?
- at what area and depth is the contaminant found, and for what sources?
- what are the probable dominating migration routes and will migration vary periodically as a result of external influences?

If the foundation of the data is sufficient, a Tier 1 risk analysis can be completed where the results are assessed in relation to soil quality guidelines.

3.2.5. Sufficient answer?

There are many factors that must be taken into consideration to answer the question regarding the results from the investigation being representative enough to be used as input data to the risk analysis, such that they can reveal possible undesirable events from the shown contamination. Examples of the factors that must be described are:

- all probable sources and migration routes.
- all probable exposure pathways.
- the work is completed according to the quality plan with no critical deviations registered during quality control.
- the demonstrated contamination situation is in agreement with the original basis for the investigation (for example, if an even distribution of contaminant was expected, point sources should not be revealed, otherwise the investigations should have been planned otherwise).
- the results are logical with consideration to the concentrations of the different contaminant, area division and other observations (for example visual observations, smells, etc.).
- the amount of data from the investigation is adequate to complete the desired tier in the risk analysis (maximum concentration at the source for a Tier 1, extent of the source and migration routes for a Tier 2).

4. Identification of possible undesirable events

4.1. General

Undesirable events from an existing contaminated site can be that the contaminant migrates continuously or episodically in undesirable amounts or concentrations. There can also be a danger of existing barriers eroding (weathering of asphalt coverings, removal of clay layer from excavating, etc.) such that migration increases and the contaminant becomes more available. The undesirable event can lead to the contaminant migration through soil or groundwater, and the front of the contaminant after a specified time reaching a protected recipient or a sensitive area. Additionally, other exposure pathways and/or receptors become relevant (it becomes relevant to utilise the soil, groundwater or surface water, the contaminated site is to be excavated, etc.) when land that has earlier been inaccessible (shut down industry) is to be used for a more sensitive land use.

It is not necessary to identify the undesirable events in a Tier 1 risk assessment. It is sufficient to compare results to the soil quality guidelines for most sensitive land use (unless land use includes dispersion routes that has been disregarded in the calculations of the soil quality guidelines). However, an assessment of the probability that future events can worsen the situation and the rationale for the decision is adequate enough for the current situation must be completed in the problem description.

If it is necessary to go further with the risk assessment (Tier 2 or 3), the first step is to identify possible undesirable events as a result of the contaminant at the site. Identification of the undesirable events begins with the information available from the problem description and the site investigations. Identifying the environmental objective is very important in this process.

It is often useful to define which timeline is most natural to work from and if the ambitions and environmental objective will change if another timeline is utilised.

Possible undesirable events that can arise from the sources of contaminant under consideration ought to be identified when planning site investigations. Both the hypotheses on migration and on possible undesirable events lay out the foundation for planning the investigations.

The problem description and the planning of the site investigations will normally focus on the most probable undesirable events and consequences. A risk analysis must also include the analysis of less probable events and the consequences if these should occur. Great risk can unfortunately occur if the probability for an undesirable event is small, but the consequences are large.

4.2. Events by and at the source

Processes that occur by and at the source can both increase and reduce the present risk. The contaminant can often exist in the soil over a long period of time before the investigations have been undertaken. Based on the field investigations, it is therefore possible to comment on the biological availability, the probability of exposure to human beings and terrestrial organisms, and the natural rates of biodegradation.

Biological degradation can both decrease and increase over time, depending on which products are produced during the biodegradation and the effectiveness of the degradation.

Barriers may also exist that currently limit the possibilities for migration of the contaminant. These barriers may sooner or later erode and increase the possibility for migration. This may

be due to human activities (excavating, building, pipe laying, etc.) or due to natural processes (erosion, flood, earthquake, extreme climatic conditions). Such events must be identified as well as the probability that these events will occur during the time perspective the risk analysis is supposed to cover.

4.3. Events due to migration and during transport

Migration from the source can be diffuse such that a more or less homogeneous concentration arises at some distance from the source. However, it is more likely that the migration is governed by outside influences such as the terrain surface, changes in permeability (in sanitary landfills for example), barriers such as rock formations, impermeable surface coverings, brick walls, and wharves, etc. The contaminated source can effectively be encapsulated for a short or long period of time, but these outside influences also affect the dominating direction of migration. Examples include concentrated streams of surface water run-off, ditches for water/wastewater or drainage systems.

All possible migration routes, including the less likely routes, must be identified. The probability of migration via these routes must be assessed within the relevant time perspective. Migration will often be an undesirable event in and of itself because the possibilities for supervision, control and removal of the unknown hazardous substances decreases.

4.4. Events due to exposure

Exposure must be assessed from the probability and the consequence. When both the source and the migration are assessed, an assessment of both the probability that an undesirable event could arise and the direct consequence of the exposure must be completed.

In a situation where there is small probability that an event can occur, but the consequence of such an event is very large, one focuses on assessing the certainty that the event will not arise. On the other hand, when there is a large probability that the event can occur, but the consequence is small, one will to a greater degree focus on the certainty surrounding the consequence assessments.

5. Probability that an undesirable event arises

5.1. General

The probability that the exposure will occur is not assessed when determining the soil quality guidelines for most sensitive land use. It is assumed that exposure will occur and the probability is set equal to 1. It is, therefore, not necessary to assess the probability in a Tier 1 risk assessment. The probability that an undesirable event arises will, however, be assessed in a Tier 2 or 3 risk assessment.

After the possible undesirable events are identified it is determined which event ought to be investigated in more detail. This is completed based on how great the probability that the event will arise and the consequence that the events occur. Undesirable events that are highly improbable with negligible consequences or that are covered by other events do not need to be followed up any further.

The events that result in exposure to or near the contaminant most often the most important to assess because these have the greatest consequences. Assessing the probability of unacceptably high concentrations over a short or longer time span and after migration or transport through other media can arise, are more complicated and require more effort.

5.2. Probability for migration

The calculations for migration will often be an important basis to determine the probability of exposure to human beings and the ecosystem. The models used to determine the most probable migration pathways are based on the most ideal conditions to include a homogeneous soil profile, chemical equilibrium between the phases (soil, air and water), homogeneous distribution of the contaminant, and stationary current/flow in the saturated zone. Under realistic conditions the soil profile is not homogeneous and the distribution between phases is not in chemical equilibrium. This is due to the natural dynamic migration processes. In addition, the climatic conditions in the Northern Countries, for example frost, freezing ground and snow melting in the spring, are of importance for fluctuating hydraulic conditions.

Due to the uncertainty of such processes, it is usual to utilise chemical information on the distribution between the different phases (vapour, water and solid mass). This is a critical parameter for calculating the most probable concentrations. The most important parameters for distribution in a soil system are site specific conditions such as: pH, redox/oxidation, soil porosity, water/air pore volume, clay and organic carbon content. Specific chemical substance information that is also important includes the solubility (S), water/soil partition coefficient or adsorption coefficient (K_d) and the vapour/liquid moisture coefficient and Henry's constant (H).

The components of the contaminant located at the source can exist in different forms for the migration processes:

- free-phase transport (for example, tar, oil and solvents).
- dissolved and thereafter transported in the water phase.
- transported in the vapour phase.
- erosion or transport of particulate material with water or in the air.

The components of the contaminant are exposed to several physical, chemical and biological processes under transport that can individually or together have critical meaning for the components' condition in soil. These processes include among others, dispersion, diffusion, complexation, biodegradation, chemical oxidation, photooxidation, ion exchange, etc.

The following phase migration and transport processes are central in relation to contaminated sites:

- phase distribution of the contaminant components between the vapour phase, pore water and soil).
- phase distribution of the contaminant between soil and plants.
- phase distribution of the contaminant between different media (water, soil, air) and receptors (fish/shellfish or terrestrial).
- transport of volatile hazardous substances to indoor air.
- transport of the contaminant from the contaminated site to groundwater.
- transport of contaminated groundwater to surface water (lake, river or fjord).

The transport of contaminated surface water from run-off in flood situations, low/high tidal effects, special climatic conditions as an extended drought or extreme precipitation, etc., can be decisive for the risk in relation to contaminated sites. These events must be assessed for each site and should not be generalised.

A contaminated site has, as shown in Figure 7, three central transport pathways that can lead to the exposure of human beings and the environment:

- volatile substances can migrate into the vapour phase and via diffusion reach the surface (indoor air).
- soluble substances can migrate into the pore water and thereafter be further transported to the groundwater, to drinking water and via groundwater to surface water and further to fish, or via pore water to plants.
- the contaminant can spread as particles via binding to soil and dust.

Additionally, indirect exposure can occur when human beings consume plants and fish.

Surface water run-off from contaminant in surface soils and transport due to tidal effects are not included in the migration considerations.

Most of these processes can be described mathematically based on laboratory experiments. In the meantime, it is difficult to predict each process' meaning to the environment, especially when all of the processes that must be considered occur at the same time. The mathematical description becomes even more complicated in that many of the hazardous substances have remained in the soil over a long period of time and subsequently, the mobility has changed. Furthermore, the chemical substances often exist mixed.

In addition to simple transport and reaction mechanisms in soil, water and vapour, the contaminant may also exist as an organic free-phase, bound to particles, or complexed to organic material dissolved in water.

These problems must be identified when planning the site investigations such that the following conditions can be determined:

- the probability that the undesirable events will arise as a result of direct exposure.
- the probability that undesirable migration exists in the free-phase.
- the probability that the undesirable events will arise as a result of exposure to or after migration/transport.
- the probability that the undesirable events will arise as a result of exposure after migration has reached a defined point (human beings, fish or other organisms).

It may also be evaluated, to the degree of information available, if the actual probability is large or small from the safety factors chosen for the different calculations. It is very important to control the certainty in the rationale for a decision after each step in the risk analysis process.

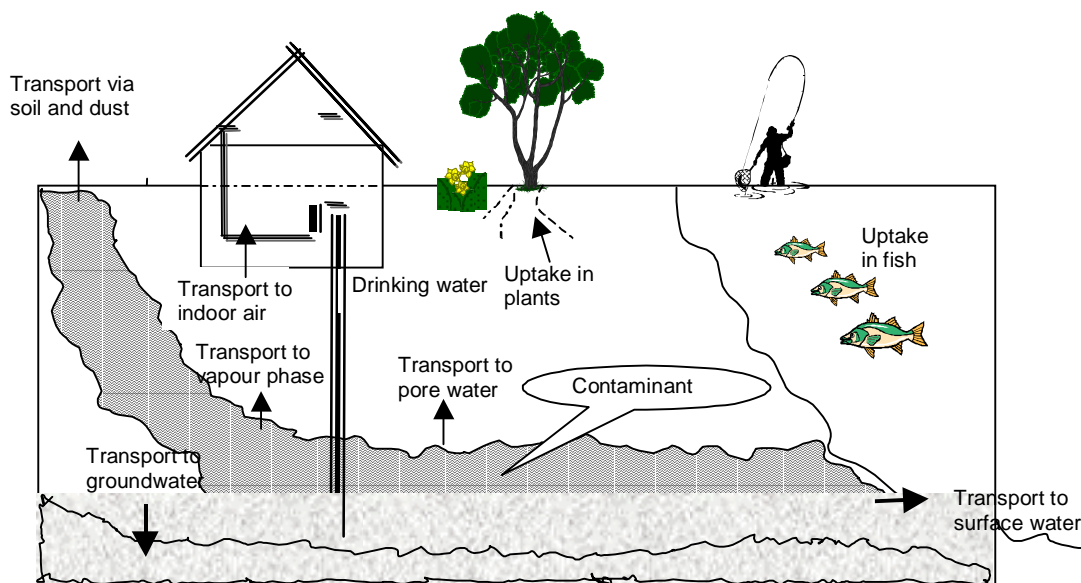


Figure 7. *Illustration of possible migration routes from a contaminated source to groundwater, the vapour phase, the free-phase, recipient, plants and fish. Surface water run-off from surface contaminated soil and migration due to tidal effects are not included in the model work tool.*

6. Consequence that an undesirable event occurs

6.1. General

The consequence assessment is the last element in a detailed risk analysis. An assessment is completed for the consequences that will or may occur from exposure to the expected concentrations.

6.2. Consequences for human beings

An exposure assessment and human toxicological assessment are included in the calculation of consequences for human beings. The most sensitive land use has been chosen in the preparation of the soil quality guidelines in the Norwegian guidance manual. This assumes that human beings are exposed to the contaminant via the following exposure pathways:

- ingestion of soil or dust.
- dermal contact to soil or dust.
- inhalation of dust.
- inhalation of soil vapour through indoor air from housing at the contaminated site.
- intake of drinking water from a groundwater well located at the contaminated site.
- consumption of vegetables and crops grown at the contaminated site.
- consumption of fish or shellfish from a nearby recipient contaminated by groundwater.

The following exposure pathways have not been included as they normally are shown to contribute less than 5% to the total exposure:

- dermal contact to drinking water (by showering).
- inhalation during showering.
- dermal contact during outdoor bathing.

There is uncertainty tied to the assessment of exposure via ingestion of meat and milk. These exposure pathways are not included in the establishment of soil quality guidelines for most sensitive land use.

The relevant exposure pathways mentioned above must be determined in a detailed risk assessment. Deviations in the duration of the exposure used in the risk assessment model must be determined. Chapter 11 describes the calculation method for each exposure pathway such that it is possible to concentrate on the relevant exposure pathways for each specific scenario. Additional relevant exposure pathways that are not already taken into account in the guidance manual must also be considered.

6.3. Consequences for the ecosystem

6.3.1. Soil/vapour phase

The consequence assessments used in Tier 1 and 2 uses measured concentrations from the contaminated masses to calculate the exposure to receptors. The concentrations are compared to the soil quality guidelines for soil. An approximation for additive toxicity may be utilised if several hazardous substances are detected. This assumes that there is an overview of all the hazardous substances that are present, that they are 100 percent bioavailable, that none of the substances have synergistic or antagonistic effects, nor that a substance func-

tions as a solvent for another substance therefore leading to increased mobility (bioavailability).

The soil quality guidelines for the ecosystem are determined from ecotoxicological laboratory studies using the pure chemical substances. These can have greater mobility and biological availability than hazardous substances that have been present in the soil for a long period of time. In order to take bioavailability, possible unknown chemical substances and possible synergistic effects into consideration, it is recommended as a minimum to complete toxicity tests of the contaminated soil mass or pore water as utilised in a Tier 3 risk assessment. The toxicity using a control soil (from an unpolluted site) is compared with the toxicity measured using the contaminated soil. Since the hazardous substance may accumulate in the organisms or plants it ought to be determined if these investigations ought not to be completed in a Tier 3 risk assessment.

6.3.2. Water

Measurements in the recipient or calculations of the expected concentrations in the recipient are completed when assessing migration to water. The consequences for organisms in water are assessed based on these concentrations and the water quality that will be used for drinking water, bathing water, fish and recreation, etc. The calculations that are described in Chapter 10 can be used in both Tier 1 and 2 risk analyses. Site specific conditions that are more unfavourable than those used as a basis in calculating the soil quality guidelines must also be taken into consideration. The concentrations in groundwater wells ought to also be measured. If the assessment reveals that there is a high probability that the contaminant will spread to groundwater or surface water, it also ought to be assessed if eventual undesirable events can be harmful to receptors, accumulate in the food web and thereafter be harmful, or come into conflict with the local environmental objectives (for example considering planned land use of the water resources). SFT's executive directives 97:03 and 97:04 outline the directives for classification of the environmental quality for freshwater and fjord/coastal waters respectively. The Social and Health Department's regulation on water supplies and drinking water, requires a minimum water quality for water supplies and drinking water. Chapter 14 contains the relevant data that may be used to determine acceptance criteria for aquatic organisms for those chemical substances not included in 97:03 or 97:04.

The effect may be measured directly if the contaminated groundwater or another recipient (water or sediment) are known. This is especially relevant in a Tier 3 risk assessment. The potential for accumulation in the food web ought to also be assessed in Tier 3. Time aspects must also be taken into consideration such that the most probable exposure is utilised.

7. Risk analysis

7.1. General

Risk is a function of probability and the consequence of an undesirable event. When assessing the probability and subsequent consequences of the possible different undesirable events, risk is made known. It is then possible to observe which combinations of probability and consequence represent the greatest risk. This is accomplished by establishing a picture of risk for the undesirable events as illustrated in Figure 8. This becomes the foundation for extended prioritising and risk assessing of the existing contaminant in relation to what is acceptable, Chapter 8.

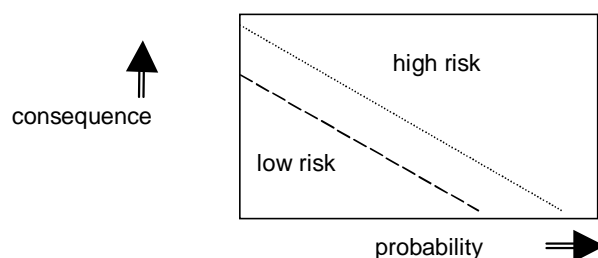


Figure 8. Risk is a function of probability and consequence.

Figure 8 illustrates the total risk based on an increase in probability along the X-axis and an increase in consequence along the Y-axis. The different levels are normally defined qualitatively, whereas the total risk is more technically assessed. A large amount of data is often required in order to place a number on the probability and its corresponding risk. This is very seldom possible in cases of contaminated sites.

7.2. Health risk analysis

7.2.1. Human toxicology

A risk analysis in relation to health includes a(n):

- systematic analysis of the probability that some of the chemical substances at the contaminated site could lead to exposure to human beings.
- determination of the expected concentrations that human beings can be exposed to for the relevant chemical substances, and if possible, the probability that these will occur.
- assessment of the dosage/response, in other words the consequence for the person that has been exposed.

The calculation of acceptable concentration is done either by starting with a chronic exposure or by an integrated lifetime exposure (exposure over an entire lifetime), depending on the chemical substance's characteristics. An integrated lifetime exposure is used for the genotoxic carcinogenic chemical substances. Chronic exposure is utilised for all the other chemical substances (non-genotoxic carcinogenic and non-carcinogenic). The methodology that is used is described in detail in Chapter 13.

Toxicological reference values for each chemical substance is used to determine the acceptable threshold concentration. A soil quality guideline expressed as the maximum tolerable daily intake (MTDI) is used as the acceptable threshold concentration in soil when human beings are exposed to contaminant via water or soil. A reference air concentration is utilised for inhalation. It is not possible to report a health-related concentration for genotoxic car-

cinogenic chemical substances with certainty. In such instances even low concentrations will increase the probability that a serious disease will arise. Extrapolation models are utilised (linear in the low concentration range) that determines the acceptable certainty based on lifetime exposure to a chemical substance. Such a model will overestimate the danger to cancer for several of the chemical substances, however it will not take synergistic effects into account. An acceptable cancer risk of 1 cancer case per 10^5 human beings is utilised.

7.2.2. Drinking water interests

In those instances where the local environmental objective exists in the form of a source of water (groundwater or surface water) that is planned as a future source for drinking water, the health authorities utilise criteria for quality of the drinking water source for surface water as well as the current drinking water criteria for groundwater. Calculations or samples must be taken to control whether the drinking water criteria could be exceeded in a given contaminant situation.

7.3. Ecological risk analysis

7.3.1. Terrestrial organisms

The protection of most of the soil living species naturally found in that habitat ensures that the soil functions are protected. However, it is a well known fact that soil, as opposed to other parts of the ecosystem, has to a large degree its own ability to self regulate as long as it already has a living community of microorganisms.

The choice of an acceptable type of test (growth, survival, reproduction) can be difficult as there is limited knowledge available for:

- the different chemical substances' affect on terrestrial organisms.
- the terrestrial organisms needed in order to maintain critical soil functions.
- the degree the earth's ecosystem can be disrupted before necessary functions for the different forms of land use are ruined.

Available information on the different relevant chemical substances' affect on terrestrial organisms is utilised to determine the soil quality guidelines for soil. The assumption has been that when such information is available for three trophic levels and there is enough information available on the tests and the quality of the tests, the toxic threshold value can be determined in the soil (mg/kg soil). The following type of data is preferred:

- microorganisms (nitrification test/respiration tests for organic chemical substances and heavy metals, and Microtox for heavy metals).
- plants (sprout tests, for example salad).
- animal organisms (worms in soil and/or *Collemboler* in soil/vapour phase).

When such data is not available, extrapolation between aquatic and terrestrial organisms is completed. In such an extrapolation the soil/water partition coefficient (K_d) is utilised. The K_d values that are utilised in the determination of the soil quality guidelines for most sensitive land use are given in Chapter 14. In a site specific risk analysis, this type of data ought to first be determined to represent the current situation.

The standards for soil quality are developed by determining the receptor's acceptable threshold dosage for the different chemical substances ($PNEC_{soil}$). This is determined by extrapolating the results of toxicity tests for a limited number of species. The protection of receptors in the three trophic levels mentioned above is desirable. Literature data is utilised, although in it has been necessary to extrapolate when the data is scarce. It has been nec-

essary to use safety factors depending on the quality of the data for all of the chemical substances for which soil quality guidelines are determined.

A special risk analysis must be conducted for especially sensitive sites or in areas where rare species exist. It is natural to assess the exposure for wild animals, birds and house pets using the same exposure pathways used to assess human exposure, water, soil, air and plants. Information on the amounts taken and the toxicological reference values for several of the species can be found in the literature.

A more conservative soil quality guideline is expected for those chemical substances that are based on aquatic data rather than if terrestrial data had been available. More current data from terrestrial tests ought to be utilised to adjust these values as quality assured information (GLP tests) becomes available.

Ecological data that is utilised for the determination of the soil quality guidelines comes from laboratory tests conducted with pure chemical substances. In addition, tests conducted for heavy metals often use a more soluble salt (chlorides or sulphates) than the compounds often found in soil. Chemical substances that have existed in the soil over a long period of time often behave differently and are often less bioavailable than those that have been utilised in the laboratory tests. Adsorption to the soil matrix, partial transformation/degradation, complexation, etc., changes the characteristics. Due to scarce information available it has not been possible to consider these processes when working out the soil quality guidelines. Therefore, toxicity testing of contaminated soil in the laboratory can give different results than those that have been calculated from laboratory tests using the pure chemical substances. Toxicity tests from field samples can be useful especially in a Tier 3 risk assessment when assessing a more realistic environmental risk in relation to terrestrial organisms.

7.3.2. Aquatic organisms

The environmental effect on nearby recipients, whether that be surface water or groundwater, is assessed in Tier 2 by comparing the calculated or measured concentration in groundwater or surface water with the established acceptance criteria based on the local environmental objective (Chapter 6.3.2). The calculations can, if local conditions are expected to be similar or more favourable than the models that are used as a basis for the soil quality guideline calculations, be undertaken as described in Chapter 12. The calculated concentration can then be compared to the local environmental objective or tolerance concentration, PNEC for aquatic organisms. Acute effects as seen in relation to probable maximum concentrations will most likely be assessed for water soluble chemical substances. Accumulation in the food web is a possibility and chronic effects must be assessed for persistent chemical substances that are not very soluble.

7.4. Risk analysis for material values

Contaminated sites can also affect economic interests. If residential or industrial buildings are to be developed at the site, it may be relevant to complete a risk analysis for the undesirable effects that includes material values. Examples of such material values include:

- the price effect on a lot value that results from the knowledge of the contaminant at the site.
- increased costs for development of a site.
- more direct effects such as corrosion.
- danger of explosion as a result of the collection of vapour in basements and sewer systems (for example methane from sanitary landfills).
- economic results of remedial measures that restrict the land use.

8. Environmental objectives and acceptance criteria

8.1. Environmental objectives

The environmental objective for an area is already determined in the problem description.

The risk must be assessed in relation to current and possible future user conflicts. This means that the danger that the contaminant may spread must be investigated and to what degree the concentration or the amount of the contaminant is in conflict with the local objectives. The local objectives will most often be clarified and discussed with the municipality, especially if a change in the land use is an option.

The environmental objective can be national, for example as shown in the publications from SFT for the classification criteria for surface water, or general environmental ambitions established by the environmental protection authorities (SFT, the Directorate for environmental administration, Environmental Department, regional commissioner). In addition, the municipalities and regions have direct and indirect requirements and objectives in the form of regulatory plans, municipality plans, plans for water and sewage, waterway plans, coastal zone plans, etc.

The following aspects must be considered:

- the planned land use (possible changes) for the site or nearby land.
- the planned exploitation of groundwater.
- the planned development of nearby recipients to improved quality.

In isolated cases, the risk assessment may dictate that migration of the contaminant may exist without resulting in noticeable negative effects, or immediate conflicts with the defined environmental objective. However, it may still be desirable to begin remedial measures against the migration of the contaminant if the investigated source is one of several contaminants to the same recipient. There is little desire for environmentally hazardous substances to spread in the environment even though the effect in isolated instances has little meaning.

An environmental objective can also be to hold a recipient at an existing low contaminant level, even though moderate amounts of the contaminant will not give an immediate effect, such as a change in classification or similar. It can also be important to work towards improvement of a moderate or poor condition for a waterway by completing extreme remediation at a location that has relative little meaning to the classification condition, but can represent one of several efforts to carrying out a necessary group effort improvement in the long run.

The local environmental objective is the basis when establishing the operative goal (acceptance criteria). The environmental objectives contain the ambitions for a site and eventual recipients that may be affected. The environmental objective can, for example, specify that a source of surface water can function for the purposes of drinking water or obtain the quality of bathing water. Another environmental objective can be that the species diversity in an area will be restored or maintained. Acceptance criteria are formulated such that they may be abided based on the local environmental objectives. Acceptance criteria will be formulated such that the choice of solutions and effect of remedial measures may be evaluated.

The type of biological processes/receptors that ought to be protected in the different types of soil use are presented in Table 4. The table illustrates the primary and secondary organisms. The secondary organisms are those indirectly affected through ingestion of soil or plants with high levels of the contaminant.

Table 4. Biological processes and organisms that ought to be protected with different types of soil use.

Regulation objective	Soil use	Main objective ^{1, 2)}	Primary organisms	Secondary organisms
Building and renovation areas	Residential, sports, parks, hiking trails, vegetable gardens	Not to reduce production capacity	Microorganisms	Human beings and house pets
Protection of water and lake areas	Protection of special biotopes and defined ecosystem	No negative effect on organisms	Algae, shellfish and fish	Amphibians, birds and mammals
Nature and recreation	Protection of recreational land or reservations	No negative effect on existing species diversity	Terrestrial organisms	Human beings, animals and house pets
Farming	Grazing areas, forests and meadows	Maintain production, existing species diversity	Microorganisms in soil, plants and animals	Human beings, animals and house pets
Traffic and Industry	Covered areas (asphalt)	-	-	Human beings and animals
Mutual Areas	Playgrounds	No negative effect on existing species diversity	-	Human beings and house pets
Special areas	Restricted areas, varying availability	No negative effect on existing species diversity	-	Human beings
Hazardous areas	Unavailable	-	-	-

1) The ability for soil to regulate itself must also be maintained for each type of soil use except for hazardous areas.

2) Indicator organisms for three trophic levels (microorganisms, plants and lower animals) are used to document if objectives are reached where general ambitions are explicitly formulated.

8.2. Acceptance criteria

The acceptance criteria is the environmental objective in quantitative terms. The acceptance criteria are defined limit values (soil quality guidelines for soil, drinking water criteria, bathing water criteria, defined level of classification of surface water, occupational health limits for the indoor environment, threshold levels for smell, general health related criteria, etc.) based on the level of ambition/environmental objective for soil, water and air quality.

The acceptance criteria will, among other things, be based on the current applicable regulations, standards and guidelines with a starting point in the local environmental objective ambitions/goals. SFT has published soil quality guidelines for most sensitive land use as a helping tool (Table 1). These assume that all the exposure pathways for human beings have been considered and that both the soil and the ecosystem are protected. The soil quality guidelines have as a starting point that the site can be made used without any form for restrictions related to future land use. More details are described in Section III.

9. Risk assessment

The risk assessment will be based on:

- the conclusion from the risk analysis.
- the identified acceptance criteria.

An "intuitive" risk assessment is more or less completed as a part of the problem description since decisions are made as to whether or not further work is needed or the case may be terminated. This chapter refers to a more systematic risk assessment that, among other things, clarifies the need for remediation and risk assessment after such remedial measures have been accomplished.

A simple risk assessment consists of the comparison of contaminant concentrations from the site with the prevailing soil quality guidelines. The soil quality guidelines express the level of the contaminant that to a large degree of certainty ensures that the life and health of human beings and the ecosystem are not affected, independent of the land use.

A more detailed risk assessment (Tier 2 or Tier 3) should answer the need for, as well as the extent and the type of, remedial measures. The results from the risk analysis are then compared against acceptance criteria. The acceptance criteria are based on the planned land use, the environmental objective for the site (possibly supplemented with ambitions for the environmental quality) or other goals that have been brought forth in the process.

The risk assessment will result in one of the following conclusions:

- there is a need for additional investigations.
- there is a need for remedial measure, control or supervision.
- the case may be terminated with or without restrictions to the land use.

Need for additional investigations.

Additional investigations are undertaken when it is not possible to come to a certain enough conclusion based on the existing available information. For example, more samples may need to be taken, other contaminant sources may need to be assessed, samples may need to be taken during different seasons or during special climatic conditions, or the identified approach to the problem may need to be further researched. In some cases it may be easier and more reasonable to conduct remedial measures than to continue with extended investigations. This will influence the conclusion and must therefore be clearly presented.

Need for remedial measures and supervision.

If the risk assessment concludes that there is a need for further investigations or remediation, a plan of action is made to proceed with the additional investigations or to find the most cost effective remedial measures that can reduce the risk to an acceptable level. When it is expected that the natural processes reduce the risk of the contaminant in the long run, an acceptable remedial measure can consist of the control and supervision of the site condition. The time perspective for such an effort must be stated.

Termination of the case.

The case may be terminated if the risk assessment is satisfactorily completed and there is not a need for remediation or restrictions in land use. However, if it is concluded that the site is contaminated, but that remediation is not necessary because natural degradation of the contaminant is expected or little to no danger for migration under the existing conditions is expected, the case must be registered. The location of more detailed information on these conditions must also be documented.

Section III: Detailed information

10. Calculation algorithms for migration/transport

10.1. Phase distribution of contaminants

10.1.1. General

It is assumed that the contaminant is in equilibrium between the solid material in soil (soil), water in soil (pore water) and air in soil (vapour space) and there is not any free-phase of the contaminant. The phase distribution between soil and water and between water and air are the most important and must be determined.

10.1.2. Phase distribution between soil and water

All of the chemical substances have specific characteristics that have important meaning with respect to their existence in soil. The octanol-water partition coefficient (P_{ow}) is a key parameter for organic substances. Heavy metals' key parameter is the distribution coefficient between soil and water (K_d). It is known that these parameters will change over time due to ageing processes for those hazardous substances that have been in the soil for some time. More recent contamination will therefore behave differently than older contamination. However, it is assumed that utilising the specific characteristics for the hazardous substances as if it were recent contamination is an acceptable starting point for the risk assessment.

$$C_w = C_s \cdot \left[K_d + \frac{\theta_w + \theta_a \cdot H}{\rho_s} \right]^{-1} \quad (1)$$

where:

C_w	=	concentration of contaminant in pore water at the source (mg/l).
C_s	=	concentration of contaminant in soil (mg/kg).
K_d	=	soil/water partition coefficient (l/kg).
θ_w	=	soil water content (l water/l soil).
θ_a	=	air water content (l air/l soil).
H	=	Henry's constant.
ρ_s	=	soil's density (kg/l).

Heavy metals

The K_d value for inorganic substances (here: heavy metals) is dependent on the type of soil present. Therefore, this needs to be determined for the local conditions. The K_d values for the heavy metals used for a generic site are obtained from Naturvårdsverket (1996a). When Naturvårdsverket selected the K_d values for heavy metals they reviewed the US EPA values. The CSOIL and HESP programs were also reviewed. The data was compared with data from Swedish investigations (Statens Geotekniska Institut and IAEA). A special literature study was completed for mercury and cadmium. Conservative values were chosen by a group of Swedish chemists to be used throughout Sweden. Later review of results from leaching tests for lead, cadmium, mercury and copper have shown that the selected K_d values were conservative (Elert, 1999).

Organic substances

The K_d value for an organic substance is dependent on the soil's organic carbon content (f_{oc}) and the chemical substance's octanol-water partition coefficient (P_{ow}). The following algorithms are applicable:

$$K_d = K_{oc} \cdot f_{oc} \quad (2)$$

$$\log K_{oc} = 1.04 \cdot \log P_{ow} - 0.84 \quad (3)$$

where:

K_{oc}	=	organic carbon-water partition coefficient (l/kg).
f_{oc}	=	fraction organic carbon in soil.
P_{ow}	=	octanol-water partition coefficient.

10.1.3. Phase distribution between water and air

The concentration of volatile chemical substances in the vapour space is assumed to be in linear equilibrium with the concentration in the pore water dependent on the chemical substance's vapour/liquid distribution (Henry's constant).

$$C_a = H \cdot C_w \quad (4)$$

where:

C_a	=	concentration of contaminant in pore air at the source (mg/l).
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10.2. Dilution/transport of the different phases

10.2.1. General

Four main routes of transport for the contaminants are identified:

- transport of contaminants from the soil to indoor air.
- transport of contaminants from the soil to groundwater.
- transport of contaminants from the soil to surface waters (river/stream, lake, fjord).
- transport of contaminants from the soil to plants.

10.3. Transport of vapour from soil to indoor air

Empirical models are utilised to determine the concentration of indoor air.

$$C_{ia} = DF_{ia} \cdot C_a \quad (5)$$

where:

C_{ia}	=	concentration of contaminant in indoor air (mg/l).
DF_{ia}	=	dilution factor from pore air to indoor air.

The dilution factor DF_{ia} is determined using:

$$DF_{ia} = \frac{L \cdot A \cdot D}{V_{house} \cdot l} \cdot (Z \cdot L + A \cdot D)^{-1} \quad (6)$$

where:

L	=	intrusion rate of pore air (m^3/d).
A	=	area under the house (m^2).
D	=	diffusivity of air in soil (m^2/d).
V_{house}	=	inside volume of the house (m^3).
l	=	replacement rate for air in the house (d^{-1}).
Z	=	depth to the contaminant (m).

The diffusivity can be determined using:

$$D = D_0 \cdot \left[\frac{\theta_a^{\frac{10}{3}}}{\varepsilon^2} \right] \quad (7)$$

where:

$$\begin{aligned} D_0 &= \text{diffusivity in pure air (m}^2\text{/d).} \\ \varepsilon &= \text{soil's porosity.} \end{aligned}$$

10.3.1. Transport of contaminants from soil to groundwater

In order to determine the soil quality guidelines, a simple model is used that does not take degradation or dilution via lateral dispersion into consideration. When lateral dispersion is not considered, the width of the contaminant in relation to the direction of groundwater flow will not have an effect on the concentration in the water. The width of the contaminant is therefore, not included in the calculations below.

The concentration of contaminants in the groundwater can be determined by:

$$C_{gw} = DF_{gw} \cdot C_w \quad (8)$$

where:

$$\begin{aligned} C_{gw} &= \text{concentration of contaminant in groundwater (mg/l).} \\ DF_{gw} &= \text{dilution factor from pore water to groundwater.} \end{aligned}$$

The dilution factor DF_{gw} is determined by:

$$DF_{gw} = \frac{L_{gw} \cdot I}{k \cdot i \cdot d_{mix} + (L_{gw} + X) \cdot I} \quad (9)$$

where:

$$\begin{aligned} L_{gw} &= \text{length of contaminated site in direction of groundwater flow (m).} \\ I &= \text{infiltration rate (m/year).} \\ k &= \text{soil's hydraulic conductivity (m/year).} \\ i &= \text{hydraulic gradient (m/m).} \\ d_{mix} &= \text{thickness of mixing zone in aquifer (m).} \\ X &= \text{distance from the contaminated site to the well (m).} \end{aligned}$$

The thickness of the mixing zone in the aquifer can be determined by:

$$d_{mix} = \sqrt{0.0112 \cdot (L_{gw} + X)^2} + d_a \left[1 - \exp\left(-\frac{L_{gw} \cdot I}{k \cdot i \cdot d_a}\right) \right] \quad (10)$$

where:

$$d_a = \text{thickness of aquifer (m).}$$

10.3.2. Transport of contaminants from groundwater to surface water

The groundwater is assumed to be flowing into a lake, river or fjord with a given theoretical retention time. The concentration in the surface water can therefore be determined by:

$$C_{sw} = DF_{sw} \cdot C_{gw} \quad (11)$$

where:

$$\begin{aligned} C_{sw} &= \text{concentration of contaminant in surface water (mg/l).} \\ DF_{sw} &= \text{dilution factor from groundwater to surface water.} \end{aligned}$$

The dilution factor DF_{sw} is determined by:

$$DF_{sw} = \frac{Q_{di}}{Q_{sw}} = \frac{k \cdot i \cdot d_{mix} \cdot L_{sw}}{Q_{sw}} \quad (12)$$

where:

$$\begin{aligned} Q_{di} &= \text{discharge of groundwater from the contaminated area to surface water (m}^3\text{/year).} \\ Q_{sw} &= \text{water flow rate in surface water (m}^3\text{/year).} \\ L_{sw} &= \text{width of contaminated area perpendicular to the direction of groundwater flow (m).} \end{aligned}$$

The water flow rate in lakes can be calculated by:

$$Q_{sw} = V_{sw} \cdot k_t \quad (13)$$

where:

$$\begin{aligned} V_{sw} &= \text{volume of the lake (m}^3\text{).} \\ k_t &= \text{theoretical retention time in the lake (year}^{-1}\text{).} \end{aligned}$$

10.3.3. Transport of contaminants from soil to plants

The following calculation models are adapted for organic contaminants:

$$BCF_{stem} = (10^{(0.95 \cdot \log P_{ow} - 2.05)} + 0.82) \cdot 0.784 \cdot 10^{\frac{(-0.434 \cdot (\log P_{ow} - 1.78))^2}{2.44}} \quad (14)$$

where:

$$BCF_{stem} = \text{bioconcentration factor (plant uptake factor) in the stem portion of the plant (l/kg wet weight).}$$

and

$$BCF_{root} = 10^{(0.77 \cdot \log P_{ow} - 1.52)} + 0.82 \quad (15)$$

where:

$$BCF_{root} = \text{bioconcentration factor (plant uptake factor) in the root portion of the plant (l/kg wet weight).}$$

The total plant concentration factor K_{pl} , that describes the relationship between the concentration in the plant and the concentration in the soil (mg/kg plant) / (mg/kg soil), can be determined by:

$$K_{pl} = (BCF_{stem} \cdot f_{leaf} + BCF_{root} \cdot f_{root}) \cdot \left(\frac{\rho_s}{\theta_w + K_d \cdot \rho_s + H \cdot \theta_a} \right) \quad (16)$$

where:

$$\begin{aligned} f_{stem} &= \text{fraction of leaf/stem vegetables in total vegetable consumption.} \\ f_{root} &= \text{fraction of root vegetables in total vegetable consumption.} \end{aligned}$$

The relationship $f_{stem} + f_{root} = 1$ is applied. Normally is it assumed that the consumption of vegetables consists of 50% leaf/stem vegetables and 50% root vegetables.

11. Calculation protocol for health risk

11.1. General comments

Chronic exposure is not calculated for genotoxic chemical substances; however, integrated lifetime exposure is utilised for genotoxic carcinogenic chemical substances.

Chronic exposure is based on the exposure of children (0-6 years) for most of the exposure pathways. Integrated lifetime exposure is based on an average exposure of a child (0-6 years) and the exposure of an adult (7-64 years). The body weight utilised for a child and an adult is 15 and 70 kg respectively.

The greatest uncertainty for all of the exposure pathways lies in the bioavailability of the different chemical substances that are exposed to human beings. The probability that a person will be exposed has not been taken into consideration. Bioavailability is 100% for the most sensitive land use.

11.2. Exposure pathways

11.2.1. Ingestion of soil and dust

Ingestion of soil or dust refers to direct intake of soil or dust when putting fingers or hands into the mouth. This intake is assumed to be greatest for small children. The reference soil concentration for consumption of soil, C_{is} (mg/kg), is calculated using the following equation:

$$C_{is} = \frac{TRV}{R_{is}} \cdot 10^6 \quad (17)$$

where:

- TRV = toxicological reference value (mg/(kg-d)). MTDI for non-genotoxic chemical substances and risk based daily intake for genotoxic carcinogenic chemical substances, TDI (tolerable daily intake).
- R_{is} = daily ingestion of soil per kg body weight (mg/(kg-d)), long-term ingestion of soil for non-genotoxic chemical substances and integrated lifetime ingestion of soil for genotoxic carcinogenic chemical substances.

Daily ingestion of soil per kg body weight is determined by:

$$R_{is} = \frac{DI_{is} \cdot f_{exp}}{KV} \quad (18)$$

where:

- DI_{is} = average daily ingestion of soil (mg/d).
- f_{exp} = fraction exposure time (d/year).
- KV = body weight (kg).

11.2.2. Dermal contact to soil and dust

Exposure via dermal contact refers to the contaminant attaching itself to the skin and being absorbed by the skin and taken up in the blood. There is a large variation from person to person when it comes to contact with soil. Dermal contact to soil and dust is assumed to occur both indoors (dust) and outdoors. The exposure calculations are based on the amount

of soil per skin surface area, the area of skin exposed, the time of exposure and the uptake of contaminants through the skin. The reference soil concentration for dermal contact to soil, C_{du} (mg/kg), is expressed by the following equation:

$$C_{du} = \frac{TRV}{f_{du} \cdot R_{du}} \cdot 10^6 \quad (19)$$

where:

- f_{du} = relative chemical specific absorption factor for dermal uptake. This is the relationship between absorption via the skin and absorption via digestion.
- R_{du} = daily dermal exposure per kg body weight (mg/(kg-d)), long-term dermal exposure for non-genotoxic chemical substances and integrated lifetime dermal exposure for genotoxic carcinogenic chemical substances.

Daily dermal exposure per kg body weight is determined by:

$$R_{du} = \frac{DI_{du} \cdot f_{exp}}{KV} \quad (20)$$

where:

- DI_{du} = average daily dermal exposure for soil (mg/d).

11.2.3. Inhalation of dust

Inhalation of dust refers to the inhalation of particles $< 10 \mu\text{m}$. Large particles attach themselves to the cilia in the airway and are transported away from the lungs and are swallowed. This exposure pathway is thought to have little meaning compared with oral ingestion of dust. For all contaminants, the contribution from inhalation of dust is found to be less than 1% of the total intake; however, the health danger of inhalation of chemical substances, especially toxic to the lungs, can be large. Important parameters for the exposure are the fraction of inhaled particles, the breathing rate and the time of exposure. The factors that describe inhalation are well known and acceptable calculation algorithms are easily found. If a toxicological based reference concentration for air is available, the following method for calculating the reference soil concentration for inhalation of dust, C_{id} (mg/kg), is utilised:

$$C_{id} = \frac{RfC}{f_{exp} \cdot C_{ad}} \cdot 10^6 \quad (21)$$

When such values are not found, the exposure is estimated using the following:

$$C_{id} = \frac{TRV}{R_{id}} \cdot 10^6 \quad (22)$$

where:

- RfC = toxicological reference concentration (mg/m³) for non-genotoxic chemical substances and risk based daily intake for genotoxic carcinogenic chemical substances.
- C_{ad} = average concentration of dust in inhaled air (mg/m³).
- R_{id} = daily inhalation of dust per kg body weight (mg/(kg-d)), long-term inhalation of dust for non-genotoxic chemical substances and integrated lifetime inhalation of dust for genotoxic carcinogenic chemical substances.

Daily inhalation of dust per kg body weight determined by:

$$R_{id} = \frac{C_{ad} \cdot PH \cdot LR \cdot f_{exp}}{KV} \quad (23)$$

where:

$$\begin{aligned} PH &= \text{breathing rate (m}^3/\text{d)}. \\ LR &= \text{lung retention (\%)}. \end{aligned}$$

11.2.4. Inhalation of soil vapour

Soil vapour refers to the volatile contaminants that are transported to the atmosphere or intrude into buildings. Important factors for this exposure pathway are the rate of transport from soil, dilution to indoor air, breathing rate and the exposure time. The exposure is calculated from the air concentration, the lung capacity and the exposure time. Problems in calculating the exposure are due to problems in calculating the concentration of the indoor and outdoor air. The factors that contribute to inhalation are well known and acceptable calculation algorithms are easily found. The lung ventilation utilised is the same as for rest or light work. Only vapour that comes into buildings is assessed. When a reference air concentration is available for a chemical substance, the following equation can be used to calculate the reference soil concentration for inhalation of soil vapour from pore air.

$$C_{iv} = \frac{RfC}{f_{exp} \cdot H} \cdot \left(K_d + \frac{\theta_w + \theta_a \cdot H}{\rho_s} \right) \cdot \frac{1}{DF_{ia}} \cdot 10^{-3} \quad (24)$$

When it is not possible to find such reference air concentrations, the calculation for C_{iv} is shown below:

$$C_{iv} = \frac{TRV}{R_{iv} \cdot H} \cdot \left(K_d + \frac{\theta_w + \theta_a \cdot H}{\rho_s} \right) \cdot \frac{1}{DF_{ia}} \quad (25)$$

where:

$$\begin{aligned} R_{iv} &= \text{daily inhalation of vapour per kg body weight} \\ &\text{((m}^3/(\text{kg}\cdot\text{d})) / (\text{g/m}^3)), \text{ long-term inhalation for non-genotoxic} \\ &\text{chemical substances and integrated lifetime inhalation for} \\ &\text{genotoxic carcinogenic chemical substances.} \\ DF_{ia} &= \text{dilution factor from pore air to indoor air calculated according to} \\ &\text{equation (6).} \end{aligned}$$

Daily inhalation of soil vapour per kg body weight is determined by:

$$R_{iv} = \frac{PH \cdot f_{exp}}{KV} \cdot 10^{-3} \quad (26)$$

11.2.5. Intake of drinking water

Important parameters for the exposure to drinking water are the concentration in the water and the intake of drinking water. When the concentration in groundwater that is utilised for drinking water can easily be measured, and it can be ascertained with a great amount of certainty that the measured concentration represents the actual concentration one can expect to find in the groundwater, measurements ought to be accomplished and this data ought to be utilised.

The exposure is calculated on the basis of WHO's values for daily intake of drinking water: 1 litre for children and 2 litres for adults. The TDI-values are utilised for the representative chemical substances. These are divided with the average daily intake of water in order to come to a possible exposure.

The reference soil concentration for the intake of drinking water (groundwater), C_{iw} (mg/kg) is calculated according to the following equation:

$$C_{iw} = \frac{TRV}{R_{iw}} \cdot \left(K_d + \frac{\theta_w + \theta_a \cdot H}{\rho_s} \right) \cdot \frac{1}{DF_{gw}} \quad (27)$$

where:

- R_{iw} = daily intake of drinking water per kg body weight (l/(kg(d))), long-term intake of drinking water for non-genotoxic chemical substances and integrated lifetime intake of drinking water for genotoxic carcinogenic chemical substances.
- DF_{gw} = dilution factor from pore water to groundwater calculated according to equation (9).

Daily intake of drinking water per kg body weight is determined by:

$$R_{iw} = \frac{DI_{iw} \cdot f_{exp}}{KV} \quad (28)$$

where:

- DI_{iw} = average daily intake of drinking water (l/d).

11.2.6. Consumption of vegetables grown at the contaminated site

The consumption of vegetables refers to the consumption of vegetables that are grown at the contaminated site. The intake for roots is included; however, the exposure from contaminated dust on the plants is not included in this assessment. Important parameters include the concentration in the edible parts of the plant, the consumption of vegetables and the fraction of the consumed vegetables that are grown at the site. The reference soil concentration for the consumption of vegetables, C_{ig} (mg/kg) is calculated using the following equation:

$$C_{ig} = \frac{TRV}{R_{ig} \cdot f_h \cdot K_{pl}} \quad (29)$$

where:

- R_{ig} = daily consumption of vegetables per kg body weight (kg/(kg-d)), long-term intake for non-genotoxic chemical substances and integrated lifetime intake for genotoxic carcinogenic chemical substances.
- f_h = fraction of consumption of vegetables grown at the contaminated site.
- K_{pl} = total plant concentration calculated according to equation (16).

Daily consumption of vegetables per kg body weight is determined by:

$$R_{ig} = \frac{DI_{ig} \cdot f_{exp}}{KV} \quad (30)$$

where:

- DI_{ig} = average daily consumption of vegetables (kg/d).

11.2.7. Consumption of fish and shellfish from nearby recipient

Using the risk assessment with regard to human health, the consumption of hazardous substances via fish and shellfish utilises the MTDI value as well as an assumed average consumption of fish and shellfish that is equal to 0.5 kg/week for children and 1 kg/week for adults. The calculation of the reference soil concentration for the consumption of fish and shellfish, C_{if} (mg/kg), is completed using the following calculation algorithm:

$$C_{if} = \frac{TRV}{R_{if} \cdot f_f \cdot C_f} \quad (31)$$

$$C_{if} = \frac{BCF_{fish} \cdot \rho_s \cdot DF_{sw} \cdot DF_{gw}}{\theta_w + K_d \cdot \rho_s + \theta_a \cdot H} \quad (32)$$

$$C_{if} = \frac{TRV}{R_{if} \cdot f_f \cdot BCF_{fish}} \cdot \frac{1}{DF_{gw} \cdot DF_{sw}} \cdot \left[K_d + \frac{\theta_w + \theta_a \cdot H}{\rho_s} \right] \quad (33)$$

where:

- R_{if} = daily consumption of fish and shellfish per kg body weight (kg/(kg·d)).
- f_f = fraction of consumption of fish and shellfish from nearby recipient.
- BCF_{fish} = bioconcentration factor for fish ((mg/kg fish) / (mg/l water)).

Daily consumption of vegetables per kg body weight is determined by:

$$R_{if} = \frac{DI_{if} \cdot f_{exp}}{KV} \quad (34)$$

where:

- DI_{if} = average daily consumption of fish and shellfish (kg/d).

The determination of BCF from a chemical substances' octanol/water partition coefficient is completed according to equation (35).

$$BCF_{fish} = P_{ow} \cdot I \quad (35)$$

where:

- I = lipid content of fish (%).

11.2.8. Determination of the total exposure

In calculating the total human exposure concentration, C_{he} (mg/kg), additive effects are assumed and the calculation of the total exposure concentration for most sensitive land use is completed utilising the following equation:

$$C_{he} = \frac{1}{\frac{1}{C_{is}} + \frac{1}{C_{du}} + \frac{1}{C_{id}} + \frac{1}{C_{iv}} + \frac{1}{C_{gw}} + \frac{1}{C_{ig}} + \frac{1}{C_{if}}} \quad (36)$$

where:

- C_{is} = reference soil concentration for ingestion of soil.
- C_{du} = reference soil concentration for dermal contact to soil.
- C_{id} = reference soil concentration for inhalation of dust.
- C_{iv} = reference soil concentration for inhalation of soil vapour.
- C_{iw} = reference soil concentration for intake of drinking water.
- C_{ig} = reference soil concentration for consumption of vegetables.
- C_{if} = reference soil concentration for consumption of fish/shellfish.

Such an equation does not take into consideration that chemical substances often act in different ways depending on if one is discussing the direct intake or, for example, the inhalation of dust.

12. Calculation protocol for ecological risk

12.1. Based on terrestrial data – organic substances

There are two methods that are utilised to extrapolate terrestrial data. The method that is selected depends on the amount and quality of the available data.

1. Safety factor (small data set)

With a small data set, the lowest available toxicity value and a safety factor of 1 – 1000, FAME = “Factorial application method”, is used. The safety factors for the terrestrial environment are derived using the same methods as used for corresponding aquatic data. The size of the safety factor depends upon the type of test, the number of trophic levels and the uncertainty tied to the determination of environmental effects based on laboratory data (Table 5).

If only one terrestrial test is available (worm or plant), the risk assessment will be completed based on this terrestrial test and based on the conversion from aquatic data (Chapter 12.3). The lower of these two PNEC values is then used further in the risk analyses.

Table 5. Safety factor for calculation of PNEC for the terrestrial environment.

Available information	Safety Factor
1) L(E)C ₅₀ value for acute hazardous substance tests (for example, plants, worms or microorganisms)*	1000
2) NOEC value for a chronic hazardous substance test (for example plants, in addition to 1)	100
3) NOEC value from chronic test from two trophic levels in addition to 1)	50
4) NOEC from chronic test for three organisms from two trophic levels in addition to 1)	10
5) Field data or data from the model ecosystem	Assessed on a case by case basis

* Three trophic levels

2. Statistical distribution (large data set)

When a large data set of terrestrial data is available, a statistical distribution method, DIBAEX (distribution based extrapolation method), is utilised to calculate the soil quality guidelines. This method is based on the following three assumptions:

1. The variation in the sensitivity of the different species (species specific NOEC values) follows a specific distribution function, for example a log-normal distribution.
2. The toxicity data that is utilised represents the sensitivity of the different species in the ecosystem. For statistical reasons it is advisable to base the extrapolation on experimental NOEC values for at least five species from similar taxonomic groups. If at least five NOEC values are not available, FAME is used instead.
3. The protection of a determined fraction of organisms protects both the function and the structure of the ecosystem.

Chapter 14 contains the data that is utilised for the substances that soil quality guidelines are calculated for. Terrestrial data is used to determine PNEC for those substances where PNEC is listed under terrestrial data.

12.2. Based on terrestrial data – inorganic substances

It is usual to complete toxicity tests using the dissolved salts for inorganic substances (heavy metals⁹). The test organisms are immediately exposed. Therefore, the NOEC values from these tests do not necessarily reflect the NOEC values that naturally exist in the environment. Furthermore, complexation of the metals to soil, different exposure pathways, the ability of the organisms to adapt to increased concentrations, contribute to the fact that the NOEC distribution can not simply be assumed to be due to variations in the sensitivity of the different species. The two extrapolation methods that are described above are therefore not utilised for metals. A direct evaluation of the lowest reported NOEC and EC_x values for the individual organisms is utilised. The fate, bioavailability and background concentration of the inorganic substances in the environment is also taken into consideration.

12.3. Conversion from aquatic data – organic substances

In the instances where terrestrial data is not available, an extrapolation method based on aquatic data is utilised. This method is based on equilibrium between water and soil as well as on the following two assumptions.

1. The bioavailability and therefore the toxicity of the contaminants to the organisms in the soil are only determined using the concentration in the pore water.
2. The effect on the terrestrial organisms due to the chemical substances adsorbed to soil particles is not taken into consideration.

PNEC_{soil} is calculated based on PNEC_{water} and the distribution coefficient between soil and water (K_d):

$$\text{PNEC}_{\text{soil}} = \text{PNEC}_{\text{water}} \cdot K_d \quad (37)$$

Experimental values for K_d are preferred, especially if these can be applied for site specific conditions. Such K_d values are however seldom available. K_d can be estimated based on the K_{oc} value (organic carbon-water distribution coefficient) and the fraction of organic carbon in the soil (f_{oc}), see equation (2). The reported K_d value can be utilised if f_{oc} is known. This value is adjusted using the same equation and relationship to f_{oc} as for the model soil. When K_{oc} data is not available, P_{ow} (octanol-water distribution coefficient) data can be used. K_{oc} is calculated according to equation (3). This extrapolation method is suitable for hydrophobic substances. For soluble (disassociated) substances, the fraction of the dissolved substance must be known. This fraction depends on the substance's disassociation constant (pK_a) and the soil's pH- value. The adjusted K_d is calculated according to equation (38).

$$K_{d, \text{adjusted}} = K_d / (1 + 10^{(\text{pH} - \text{pK}_a)}) \quad (38)$$

When PNEC terrestrial is calculated from aquatic data, the data is listed under aquatic data for each individual substance in Chapter 14.

13. Calculation of soil quality guidelines for most sensitive land use

13.1. Migration and transport

13.1.1. Phase distribution

In the calculation of the soil quality guidelines, the equations in Chapter 10.1.2 and 10.1.3 are used to determine the phase distribution between soil, vapour and pore water. A model soil is utilised to calculate the soil quality guidelines. The characteristics of the soil are shown below in Table 6.

Table 6. Characteristics of model soil utilised for calculating the soil quality guidelines for most sensitive land use.

Symbol	Parameter	Value	Units
θ_w	soil water content	0.2	l water/l soil
θ_a	air water content	0.2	l air/l soil
ρ_s	soil's density	1.7	kg/l
f_{oc}	fraction organic carbon in soil	0.01	-

13.1.2. Migration/transport

From soil to indoor air

The equations in Chapter 10.2.2 are used to determine the soil quality guidelines for the concentration of the contaminant in indoor air. It is suggested to utilise a set of standard parameters to calculate the dilution factor to indoor air (Table 7).

The depth to the contaminant and the soil's porosity are key parameters that determined the soil's water contents and therefore influence the dilution factor to indoor air. A contaminant that is 0.2 m underneath the surface will have a $DF_{ia} = 1:1300$ for sand ($\varepsilon = 0.35$, $\theta_w = 0.11$, $\theta_a = 0.23$) and will have a $DF_{ia} = 1:22000$ for clay ($\varepsilon = 0.45$, $\theta_w = 0.39$; $\theta_a = 0.05$). $DF_{ia} = 1:2000$ is used as the dilution factor to indoor air for the determination of the soil quality guidelines.

Table 7. Parameters utilised to calculate dilution factor to indoor air for the determination of soil quality guidelines for most sensitive land use.

Symbol	Parameter	Value	Units
L	intrusion rate of pore air	2.4	m^3/d
A	area under the house	100	m^2
V_{house}	inside volume of the house	240	m^3
I	replacement rate of air in the house	12	d^{-1}
Z	depth to the contaminant	0.5	m
D_o	diffusivity to pure air	0.7	m^2/d
ε	soil's porosity	0.4	-

From soil to groundwater

The concentration in the groundwater is determined according to the equations in Chapter 10.2.3. The distance to the groundwater well is equal to zero meters, in other words the groundwater well is located at the source. Data used in calculating the soil quality guidelines correspond with the values given in Table 8. A value of $DF_{gw} = 1:10$ is used as the dilution factor to groundwater for the calculation of the soil quality guidelines.

Table 8. Parameters utilised to calculate dilution factor of pore water to groundwater for the determination of soil quality guidelines for most sensitive land use.

Symbol	Parameter	Value	Units
L_{gw}	length of the contaminated site in direction of groundwater flow	50	m
I	infiltration rate	0.075	m/year
k	soil's hydraulic conductivity	10^{-5}	m/s
i	hydraulic gradient	0.02	m/m
d_{mix}	thickness of mixing zone in aquifer	5.87	m
d_a	thickness of aquifer	10	m
X	distance from the contaminated site to the well	0	m

From groundwater to surface water

The concentration in the surface water is calculated according to the equations in Chapter 10.2.4. The data in Table 9 is utilised. A value of $DF_{sw} = 1:1840$ is used as the dilution factor from groundwater to surface water in the calculation of the soil quality guidelines.

Table 9. Parameters utilised to calculate dilution of groundwater to surface water for the determination of soil quality guidelines for most sensitive land use.

Symbol	Parameter	Value	Units
Q_{sw}	water flow rate in surface water	500,000	$m^3/year$
L_{sw}	width of contaminated area perpendicular to the direction of the groundwater flow	7.34	m
Q_{di}	calculated discharge of groundwater from the contaminated area to surface water	272	$m^3/year$

13.2. Exposure

13.2.1. Health

A body weight of 15 kg, age 0-6 years, and a total exposure time of 6 years are used to calculate the exposure for children. A body weight equal to 70 kg, age 7-64 years, and a total exposure time of 57 years are used to calculate the exposure to an adult.

The standard values given in the chapter are rounded values. See Tables 21 and 22 to obtain the "default values" that are used to calculate the soil quality guidelines.

Ingestion of soil and dust

The equations in Chapter 11.2.1 are utilised to determine the exposure via direct ingestion of soil and dust. The data in Table 10 is used to determine R_{is} for most sensitive land use. The ingestion per day as well as the exposure time may be reduced for a less sensitive land use. This also applies if the contact to soil is covered with snow during the colder seasons, for example park areas and sports arenas, etc. can utilise 50 mg/d exposure, 5 days a week for 6 months of summer. The average daily soil intake is multiplied with the fraction of exposure time f_{exp} . A value of 10 mg/(kg·d) is utilised (Table 10) to calculate the soil quality guidelines for most sensitive land use for long-term exposure. A value of 1.5 mg/(kg·d) is utilised for the integrated lifetime ingestion of soil. The exposure to children and adults are calculated separately and then the most sensitive of the two is chosen.

Table 10. Parameters utilised to calculate exposure via ingestion of soil for the determination of soil quality guidelines for most sensitive land use.

Symbol	Parameter	Value		Units
		Child	Adult	
DI _{is}	average daily intake of soil	150	50	mg/d
f _{exp}	fraction exposure time	365	365	d/year
R _{is}	calculated long-term intake of soil per kg body weight	10	0.7	mg/(kg-d)
R _{is}	calculated integrated lifetime intake of soil per kg body weight	1.6		mg/(kg-d)

Dermal contact to soil and dust

The equations in Chapter 11.2.2 are utilised to determine the exposure via dermal contact to soil and dust. The data in Table 11 is used to determine R_{du} for most sensitive land use. The time of exposure can be adjusted for less sensitive land use, for example park areas and sporting arenas, etc. Values of 27 and 15 d/year exposure time can then be used for children and adults respectively, instead of 80 and 45 as described in Table 11. This gives 7 mg/(kg-d) for long-term dermal contact to children and 1 mg/(kg-d) integrated lifetime dermal contact compared with the values given in Table 11.

Table 11. Parameters utilised to calculate exposure via dermal exposure for the determination of soil quality guidelines for most sensitive land use.

Symbol	Parameter	Value		Units
		Child	Adult	
	exposure to soil	5100	5100	mg/(m ² -d)
	exposed skin area	0.28	0.17	m ²
DI _{du}	average daily dermal exposure for soil	1400	900	mg/d
f _{exp}	fraction exposure time	80	45	d/year
R _{du}	calculated long-term dermal exposure per kg body weight	21	1.5	mg/(kg-d)
R _{du}	calculated integrated lifetime hudeksponering per kg body weight	3.4		mg/(kg-d)

Inhalation of dust

The equations in Chapter 11.2.3 are utilised to determine the exposure via inhalation of dust. Table 12 presents an overview of the parameters used to calculate exposure when there is not data available for reference air concentration. The time of exposure can be adjusted for less sensitive land use, for example when 5 days per week for only 6 months is used for park areas and sporting arenas, etc. (122 days/year leads to a long-term exposure of 0.0005 mg/(kg-d) to children and an integrated lifetime exposure of 0.003 mg/(kg-d)).

Table 12. Parameters utilised to calculate exposure via inhalation of dust for the determination of soil quality guidelines for most sensitive land use, when there is not available data for reference air concentration.

Symbol	Parameter	Value		Units
		Child	Adult	
C _{ad}	concentration of dust in inhaled air	0.041	0.041	mg/m ³
PH	breathing rate	7.6	20	m ³ /d
LR	lung retention	75	75	%
f _{exp}	fraction exposure time	365	365	d/year
R _{id}	calculated long-term inhalation of dust per kg body weight	0.016	0.009	mg/(kg-d)
R _{id}	calculated integrated lifetime inhalation of dust per kg body weight	0.01		mg/(kg-d)

Inhalation of vapour

The equations in Chapter 11.2.4 are utilised to determine the exposure via inhalation of vapour. Table 13 shows an overview of the parameters used to calculate exposure for most sensitive land use. The time of exposure can be adjusted for less sensitive land use, for example when 5 days per week for only 6 months (122 days/year) is used for park areas and sporting arenas. This leads to a long-term exposure of 170 mg/(kg-d) to children and an integrated lifetime exposure of 100 mg/(kg-d). A value of $DF_{ia} = 1:2000$ is utilised as the dilution factor from pore vapour to indoor air to calculate the soil quality guidelines for most sensitive land use.

Table 13. Parameters utilised to calculate exposure via inhalation of soil vapour for the determination of soil quality guidelines for most sensitive land use, when there is not available data for reference air concentration .

Symbol	Parameter	Value		Units
		Child	Adult	
PH	breathing rate	7.6	20	m ³ /d
f _{exp}	fraction exposure time	365	365	d/year
R _{iv}	calculated long-term inhalation of vapour per kg body weight	507	286	(mg/(kg-d)) / (g/m ³)
R _{iv}	calculated integrated lifetime inhalation of vapour per kg body weight	307		(mg/(kg-d)) / (g/m ³)

Intake of drinking water

The equations in Chapter 11.2.5 are utilised to determine the exposure via intake of drinking water. The dilution factor is equal to 1:10. Table 14 shows an overview of the parameters used to calculate exposure for most sensitive land use. Exposure to drinking water assumes that the drinking water is from groundwater. If the drinking water comes from a nearby surface water source, the concentration is calculated according to the methods described for consumption of fish and shellfish and the dilution factor is calculated as described in Chapter 10. This exposure pathway may be omitted for less sensitive land use where groundwater is not used.

Table 14. Parameters utilised to calculate exposure via intake of drinking water for the determination of soil quality guidelines for most sensitive land use.

Symbol	Parameter	Value		Units
		Child	Adult	
DI _{iw}	average daily intake of drinking water	1	2	l/d
f _{exp}	fraction exposure time	365	365	d/year
R _{iw}	calculated long-term intake of drinking water per kg body weight	0.067	0.028	l/(kg-d)
R _{iw}	calculated integrated lifetime intake of drinking water per kg body weight	0.032		l/(kg-d)

Consumption of vegetables grown at the site

The equations in Chapter 11.2.6 are utilised to determine the exposure via consumption of vegetables. It is assumed that the vegetables are comprised of 50% root vegetables and 50% stem/leaf vegetables. Table 15 illustrates the parameters used to calculate exposure for most sensitive land use. This exposure pathway may be omitted for less sensitive land use (for example park areas and sporting arenas) since growing vegetables does not normally occur at such areas.

Table 15. Parameters utilised to calculate exposure via the consumption of vegetables for the determination of soil quality guidelines for most sensitive land use.

Symbol	Parameter	Value		Units
		Child	Adult	
f_h	fraction of consumption of vegetables grown at the contaminated area	0.3	0.3	-
f_{blad}	fraction of leaf/stem vegetables in total consumption of vegetable	0.5	0.5	-
f_{Root}	fraction of root vegetables in total g consumption of vegetable	0.5	0.5	-
DI_{ig}	average daily consumption of vegetables	0.15	0.29	kg/d
f_{exp}	fraction exposure time	365	365	d/year
R_{ig}	calculated long-term consumption of vegetables per kg body weight	0.01	0.004	kg/(kg·d)
R_{ig}	calculated integrated lifetime consumption of vegetables per kg body weight	0.005		kg/(kg·d)

Consumption of fish and shellfish from nearby recipient

The equations in Chapter 11.2.7 are utilised to determine the exposure via consumption of fish and shellfish from a nearby recipient. Table 16 illustrates the parameters used to calculate exposure for most sensitive land use. The fraction of fish/shellfish intake may be reduced for a less sensitive land use.

Table 16. Parameters utilised to calculate exposure via consumption of fish and shellfish for the determination of soil quality guidelines for most sensitive land use.

Symbol	Parameter	Value		Units
		Child	Adult	
DI_{if}	average daily consumption of fish and shellfish	0.07	0.14	kg/d
f_{exp}	fraction exposure time	365	365	d/year
f_f	fraction of consumption of fish and shellfish from nearby recipient	1	1	-
l	lipid content of fish	10	10	%
R_{if}	calculated long-term consumption of fish and shellfish per kg body weight	0.005	0.002	kg/(kg·d)
R_{if}	calculated integrated lifetime consumption of fish and shellfish per kg body weight	0.002		kg/(kg·d)

Total exposure

The equations in Chapter 11.2.8 are utilised to determine the total exposure for most sensitive land use. All of the above mentioned exposure pathways are utilised to derive the soil quality guidelines for soil. Only those exposure pathways that are relevant for the specific site are included in a site specific risk assessment.

14. Background data for selected substances

14.1. Inorganic hazardous chemical substances

Available terrestrial toxicity data is utilised to determine the soil quality guidelines for most sensitive land use for all of the inorganic hazardous chemical substances/heavy metals.

14.1.1. Arsenic

Parameter	Data	Reference
Ecotoxicology		
<u>Terrestrial toxicity</u>		
Microorganisms NOEC	50 - 374 (mg/kg)	Scott-Fordsmand, and Pedersen (1993)
Plants NOEC	2 - 80 (mg/kg)	
Safety Factor	10	
PNEC	0.2 (mg/kg)	
<u>Accumulation</u>		
BCF Fish	200	Beck and Jaques (1993)
BCF Stem	0.015	Naturvårdsverket (1996a)
BCF Root	0.03	
K _d	30 (l/kg)	Naturvårdsverket (1996a)
Human toxicology		
<u>Oral intake</u>		
MTDI (TRV)	1.1 E - 03 (mg/(kg·d))	IMM (1990)
Genotoxic risk based cancer (TRV)	6.0 E - 06 (mg/(kg·d))	WHO (1993)
<u>Inhalation</u>		
Genotoxic risk based cancer, RfC	2.5 E - 06 (mg/m ³)	WHO (1991)
<u>Dermal contact</u>		
f _{du}	3.00 E - 02	WHO (1993)
Reported Norwegian background values	0.7 – 8.0	Beck and Jaques (1993)
Detection limits	0.03 (mg/kg)	

14.1.2. Lead

Parameter	Data	Reference
Ecotoxicology		
<u>Terrestrial toxicity</u>		
Microorganisms NOEC	10-75000 (mg/kg)	Scott-Fordsmand and Pedersen (1993)
Plants NOEC	10-1000 (mg/kg)	
Animals NOEC	25 - >15996 (mg/kg)	
Safety Factor	1	
PNEC	10 (mg/kg)	
<u>Accumulation</u>		
BCF Fish	650	Beck and Jaques (1993)
BCF Stem	0.001	Naturvårdsverket (1996a)
BCF Root	0.03	
<u>Adsorption/phase distribution</u>		
K _d	1000 (l/kg)	Naturvårdsverket (1996a)
Human toxicology		
<u>Oral intake</u>		
MTDI (TRV)	1.0 E - 03 (mg/(kg·d))	UMS (1997)
<u>Inhalation</u>		
RfC	5.0 E - 04 (mg/m ³)	WHO (1991)
<u>Dermal contact</u>		
f _{du}	6.0 E - 03	MDEP (1994)
Reported Norwegian background values	8.5 - 107.4 (mg/kg)	Beck and Jaques (1993)
Detection limits	0.03 (mg/kg)	

14.1.3. Free Cyanide

Parameter	Data	Reference
Ecotoxicology		
<u>Terrestrial toxicity</u> Animals LC ₅₀	0.5 - 52 (mg/l)	IUCLID (1996)
<u>Aquatic toxicity</u> Fish LOEC Safety Factor PNEC Terrestrial	0.005 – 0.01 (mg/l) 50 0.0001 (mg/kg)	Envichem (1995)
<u>Accumulation</u> BCF Fish BCF Stem BCF Root	10 0.883 0.798	Beck and Jaques (1993) Naturvårdsverket (1996a)
<u>Adsorpsjon/phase distribution</u> K _d	1 (l/kg)	Naturvårdsverket (1996a)
Human toxicology		
<u>Oral intake</u> MTDI (TRV)	1.2 E - 02 (mg/(kg·d))	WHO (1993)
<u>Dermal contact</u> f _{du}	3.0 E - 01	MDEP (1994)
Reported Norwegian background values	m.d.	
Detection limits	0.1 (mg/kg)	

14.1.4. Cadmium

Parameter	Data	Reference
Ecotoxicology		
<u>Terrestrial toxicity</u> Microorganisms NOEC Plants NOEC Animals NOEC Safety Factor PNEC	2-1000 (mg/kg) 0.35-50 (mg/kg) 10-326 (mg/kg) 1 0.4 (mg/kg)	Scott-Fordsmand and Pedersen. (1993)
<u>Accumulation</u> BCF Fish BCF Stem BCF Root	3000 0.15 0.7	Beck and Jaques (1993) Naturvårdsverket (1996a)
<u>Adsorpsjon/phase distribution</u> K _d	30 (l/kg)	Naturvårdsverket (1996a)
Human toxicology		
<u>Oral intake</u> MTDI (TRV) <u>Inhalation</u> Genotoxic, RfC Risk based cancer, RfC	1.0 E - 03 (mg/(kg·d)) 5.0 E - 06 (mg/m ³) 5.6 E - 06 (mg/m ³)	WHO (1993) WHO (1991) IRIS (1995)
<u>Dermal contact</u> f _{du}	1.4 E - 01	MDEP (1994)
Reported Norwegian background values	0.1 - 1.7 (mg/kg)	Beck and Jaques, 1993
Detection limits	0.01 (mg/kg)	

14.1.5. Copper

Parameter	Data	Reference
Ecotoxicology		
<u>Terrestrial toxicity</u> Microorganisms NOEC Plants NOEC Animals NOEC Safety Factor PNEC	10-1445 (mg/kg) 20-400 (mg/kg) 13-131 (mg/kg) 1 10 (mg/kg)	Scott-Fordsmand and Pedersen (1993)
<u>Accumulation</u> BCF Fish BCF Stem BCF Root	9300 0.1 0.1	Beck and Jaques (1993) Naturvårdsverket (1996a)
<u>Adsorpsjon/phase distribution</u> K _d	500 (l/kg)	Naturvårdsverket (1996a)
Human toxicology		
<u>Oral intake</u> MTDI (TRV)	5.0 E - 01 (mg/(kg-d))	WHO (1993)
Reported Norwegian background values	6 - 27 (mg/kg)	Beck and Jaques (1993)
Detection limits	0.02 (mg/kg)	

14.1.6. Chromium (III & VI)

Parameter	Data	Reference
Ecotoxicology		
<u>Terrestrial toxicity</u> Microorganisms NOEC Plants NOEC Animals NOEC Safety Factor PNEC	III: 26-260 (mg/kg) VI: 2.6-520 (mg/kg) III: 50-1360 (mg/kg) VI: 2-230 (mg/kg) III: 32-320 (mg/kg) VI: 2 (mg/kg) III: 1 VI: 1 III: 26 (mg/kg) VI: 2 (mg/kg)	Scott-Fordsmand and Pedersen (1993)
<u>Accumulation</u> BCF Fish BCF Stem BCF Root	10 (III & VI) 0.002 (III & VI) 0.02 (III & VI)	Beck and Jaques (1993) Naturvårdsverket (1996a)
<u>Adsorpsjon/phase distribution</u> K _d	2000 (l/kg) (III), 30 (l/kg) (VI)	Naturvårdsverket (1996a)
Human toxicology		
<u>Oral intake</u> MTDI (TRV) III	1.0 (mg/(kg-d))	WHO (1993)
<u>Oral intake</u> MTDI (TRV) VI	1.0 (mg/(kg-d))	IMM (1990)
<u>Inhalation</u> RfC VI Genotoxic risk based cancer, RfC VI	5.0 E - 05 (mg/m ³)	UMS (1997)
<u>Dermal contact</u> f _{du} III f _{du} VI	3.0 E - 07 (mg/m ³) 4.0 E - 02 9.0 E - 02	UMS (1997) MDEP (1994) MDEP (1994)
Reported Norwegian background values III	3.0 - 30 (mg/kg)	Beck and Jaques (1993)
Detection limits III	0.02 (mg/kg)	

14.1.7. Mercury

Parameter	Data	Reference
Ecotoxicology		
<u>Terrestrial toxicity</u> Microorganisms NOEC Plants NOEC Animals NOEC Safety Factor PNEC	1 - 100 (mg/kg) 1 - 50 (mg/kg) 0.121 - 1 (mg/kg) 1 0.1 (mg/kg)	Scott-Fordsmand and Pedersen (1993)
<u>Accumulation</u> BCF Fish BCF Stem BCF Root	200 0.015 0.03	Beck and Jaques (1993) Naturvårdsverket (1996a)
<u>Adsorpsjon/phase distribution</u> K _d Henry's constant	200 (l/kg) 0.47	Naturvårdsverket (1996a)
Human toxicology		
<u>Oral intake</u> MTDI (TRV)	4.7 E - 04 (mg/(kg·d))	WHO (1993)
<u>Inhalation</u> RfC	1.0 E - 03 (mg/m ³)	WHO (1991)
<u>Dermal contact</u> f _{du}		MDEP (1994)
Reported Norwegian background values	0.05 - 0.2 (mg/kg)	Beck and Jaques (1993)
Detection limits	0.01 (mg/kg)	

14.1.8. Nickel

Parameter	Data	Reference
Ecotoxicology		
<u>Terrestrial toxicity</u> Microorganisms NOEC Plants NOEC Animals NOEC Safety Factor PNEC	29 - 1470 (mg/kg) 6.25 - 335 (mg/kg) 50 - 85 (mg/kg) 1 6.25 (mg/kg)	Scott-Fordsmand and Pedersen (1993)
<u>Accumulation</u> BCF Fish BCF Stem BCF Root	10 0.07 0.1	Beck and Jaques (1993) Naturvårdsverket (1996a)
<u>Adsorpsjon/phase distribution</u> K _d	100 (l/kg)	Naturvårdsverket (1996a)
Human toxicology		
<u>Oral intake</u> MTDI (TRV)	5.0 E - 03 (mg/(kg·d))	WHO (1993)
<u>Inhalation</u> RfC Genotoxic risk based cancer RfC	2.5 E - 05 (mg/m ³) 1.2 E - 05 (mg/m ³)	WHO (1991) UMS (1997)
<u>Dermal contact</u> f _{du}	3.5 E - 01	MDEP (1994)
Reported Norwegian background values	3.0 - 19 (mg/kg)	Beck and Jaques (1993)
Detection limits	0.02 (mg/kg)	

14.1.9. Zinc

Parameter	Data	Reference
Ecotoxicology		
Terrestrial toxicity		
Microorganisms NOEC	32 - 626 (mg/kg)	Scott-Fordsmand and Pedersen (1993)
Plants NOEC	10 - 800 (mg/kg)	
Animals NOEC	200 - 560 (mg/kg)	
Safety Factor	1	
PNEC	10 (mg/kg)	
Accumulation		
BCF Fish	500	Beck and Jaques (1993) Naturvårdsverket (1996a)
BCF Stem	0.1	
BCF Root	0.4	
Adsorption/phase distribution		
K_d	100 (l/kg)	Naturvårdsverket (1996a)
Human toxicology		
Oral intake		
MTDI (TRV)	1.0 (mg/(kg-d))	WHO (1993)
Dermal contact		
f_{du}	2.0 E - 02	MDEP (1994)
Reported Norwegian background values	25 - 104 (mg/kg)	
Detection limits	0.01 (mg/kg)	

14.2. Organic hazardous chemical substances

There is little to none terrestrial toxicity data available for PCB, pesticides (DDT, Lindane), many solvents, benzene, toluene and ethylbenzene. The terrestrial PNEC values for these substances are calculated from aquatic data.

14.2.1. Sum 16 PAH and benzo(a)pyrene

Parameter	Data		Reference
Ecotoxicology			
<u>Terrestrial toxicity</u>	∑ PAH (mg/kg)	Benzo(a)pyrene (mg/kg)	
Microorganisms NOEC	650	10-33	Jensen and Folker-Hansen (1995)
Plants NOEC	197-2000	1.5 - 3.3	
Animals NOEC	2000	19	
Safety Factor	10 (-)	1 (-)	
PNEC	19.7	1.5	
<u>Aquatic toxicity</u>			
Algae, NOEC	-	0.005 (mg/l)	Beck and Jaques (1993)
Shellfish, NOEC	-	0.0001 (mg/l)	
<u>Accumulation</u>			
log P _{ow}	-	6.4	Jensen and Folker-Hansen (1995) Naturvårdsverket (1996a)
BCF Fish	-	28200	
BCF Stem	-	2.01	
BCF Root	-	1584	
<u>Adsorpsjon/phase distribution</u>			
K _d		9160 (l/kg)	Naturvårdsverket (1996a)
K _{oc}	-	916000 (l/kg)	
H		3.4 E - 05	
Human toxicology Benzo(a)pyrene			
<u>Oral intake</u>			
MTDI (TRV)	1.0 E - 03 (mg/(kg-d))		IMM (1990)
Genotoxic risk based cancer (TRV)	1.4 E - 06 (mg/(kg-d))		UMS (1997)
<u>Inhalation</u>			
RfC	1.1 E - 07 (mg/m ³)		WHO (1991)
<u>Dermal contact</u>			
f _{du}	2.0 E - 01		MDEP (1994)
Reported Norwegian background values	∑ 16 PAH: 0.005 - 0.8 (mg/kg) Benzo(a)pyrene: 0.015-0.157 (mg/kg)		Beck and Jaques (1993)
Detection limits	∑ 16 PAH: 0.01 (mg/kg) Benzo(a)pyrene: 0.01 (mg/kg)		

14.2.2. Naphthalene

Parameter	Data	Reference
Ecotoxicology		
Terrestrial toxicity		
Microorganisms NOEC	25-33 (mg/kg)	Jensen and Folker-Hansen (1995)
Plants NOEC	8-10 (mg/kg)	
Animals NOEC	17 (mg/kg)	
Safety Factor	10	
PNEC	0.8 (mg/kg)	
Accumulation		
log P _{ow}	3.3	Naturvårdsverket (1996a)
BCF Fish	229	
BCF Stem	4.14	
BCF Root	12.5	
Adsorpsjon/phase distribution		
K _d	20 (l/kg)	Naturvårdsverket (1996a)
K _{oc}	2000 (l/kg)	
H	2.0 E - 02	
Human toxicology		
Oral intake		
MTDI (TRV)	4.0 E - 02 (mg/(kg·d))	Naturvårdsverket (1996a)
Dermal contact		
f _{du}	1.0 E - 01	
Reported Norwegian background values	m.d.	
Detection limits	0.01 (mg/kg)	

14.2.3. Flourene

Parameter	Data	Reference
Ecotoxicology		
Terrestrial toxicity		
Worm NOEC	57 (mg/kg)	Jensen and Folker-Hansen (1995)
Safety Factor	100	
PNEC	0.57 (mg/kg)	
Aquatic toxicity		
Algae, EC ₅₀	15.5 (mg/l)	Envichem (1995)
Fish, LC ₅₀	5.15 (mg/l)	
Accumulation		
log P _{ow}	4.2	Envichem (1995) Naturvårdsverket(1996a)
BCF Fish	1622	
BCF Stem	6.27	
BCF Root	53.5	
Adsorpsjon/phase distribution		
K _d	138 (l/kg)	Naturvårdsverket (1996a)
K _{oc}	13800 (l/kg)	
H	2.6 E - 03	
Human toxicology		
Oral intake		
MTDI (TRV)	4.0 E - 02 (mg/(kg·d))	Naturvårdsverket (1996a)
Dermal contact		
f _{du}	2.0 E - 01	
Reported Norwegian background values	m.d.	
Detection limits	0.01 (mg/kg)	

14.2.4. Fluorantene

Parameter	Data	Reference
Ecotoxicology		
<u>Aquatic toxicity</u> Shellfish LC ₅₀	320 (mg/l)	Envichem (1995)
<u>Terrestrial toxicity</u> Microorganisms, NOEC Plants, NOEC (mixture of fluoranthene, pyrene and benzo(a)anthrazene) Safety Factor PNEC	200 (mg/kg) 10 (mg/kg) 100 0.1 (mg/kg)	Jensen and Folker-Hansen (1995)
<u>Accumulation</u> log P _{ow} BCF Fish BCF Stem BCF Root	5.1 13200 5.3 266	Envichem (1995) Naturvårdsverket (1996a)
<u>Adsorpsjon/phase distribution</u> K _d K _{oc} H	1070 (l/kg) 107000 (l/kg) 6.6 E - 04	Naturvårdsverket (1996a)
Human toxicology		
<u>Oral intake</u> MTDI (TRV) <u>Dermal contact</u> f _{du}	4.0 E - 02 (mg/(kg·d)) 2.0 E - 01	Naturvårdsverket (1996a)
Reported Norwegian background values	m.d.	
Detection limits	0.01 (mg/kg)	

14.2.5. Pyrene

Parameter	Data	Reference
Ecotoxicology		
<u>Terrestrisk toxicity</u> Microorganisms NOEC Plants NOEC (mixture of fluoranthene, pyrene and benzo(a)anthrazene) Safety Factor PNEC	100-1000 (mg/kg) 10 (mg/kg) 100 0.1 (mg/kg)	Jensen and Folker-Hansen (1995)
<u>Aquatic toxicity</u> Fish, NOEC	0.0026 (mg/l)	Envichem (1995)
<u>Accumulation</u> log P _{ow} BCF Fish BCF Stem BCF Root	5.1 12900 5.33 261	Envichem (1995) Naturvårdsverket (1996a)
<u>Adsorpsjon/phase distribution</u> K _d K _{oc} H	1050 (l/kg) 105000 (l/kg) 4.51 E - 04	Naturvårdsverket (1996a)
Human toxicology		
<u>Oral intake</u> MTDI (TRV) <u>Dermal contact</u> f _{du}	3.0 E - 02 (mg/(kg·d)) 2.0 E - 01	Naturvårdsverket (1996a)
Reported Norwegian background values	m.d.	
Detection limits	0.01 (mg/kg)	

14.2.6. PCB

Parameter	Data	Reference
Ecotoxicology		
<u>Aquatic toxicity</u> Algae EC ₅₀ Shellfish NOEC Fish NOEC Safety Factor PNEC Terrestrial	0.01-0.2 (mg/l) 0.001 (mg/l) 0.0001 (mg/l) 50 0.003 (mg/kg)	Beck and Jaques (1993)
<u>Accumulation</u> log P _{ow} BCF Fish BCF Stem BCF Root	6.0 47000 3.71 620.3	Beck and Jaques (1993) Naturvårdsverket (1996a)
<u>Adsorpsjon/phase distribution</u> K _d K _{oc} H	1636 (l/kg) 163600 (l/kg) 3.4 E - 04	Naturvårdsverket (1996a)
Human toxicology		
<u>Oral intake</u> MTDI (TRV) Genotoxic risk based cancer (TRV)	5.3 E - 06 (mg/(kg·d)) 1.3 E - 06 (mg/(kg·d))	Naturvårdsverket (1996a) (10% of background exposure)
<u>Dermal contact</u> f _{du}	6.7 E - 02	UMS (1997) MDEP (1994)
Reported Norwegian background values	0.003 - 0.03 (mg/kg)	Beck and Jaques (1993)
Detection limits	0.005 (mg/kg) per isomer	

14.2.7. Pentachlorophenol

Parameter	Data	Reference
Ecotoxicology		
<u>Terrestrial toxicity</u> Microorganisms NOEC Plants NOEC Animals NOEC Safety Factor PNEC	0.7 - 10000 (mg/kg) 1.0 - 32 (mg/kg) 3.0 - 32 (mg/kg) 1.0 0.7 (mg/kg)	Jensen and Folker-Hansen (1995)
<u>Aquatic toxicity</u> Algae NOEC Shellfish/Fish NOEC	0.1 (mg/l) 0.002 - 0.14 (mg/l)	EnviChem (1995) Beck and Jaques (1994)
<u>Accumulation</u> log P _{ow} BCF Fish BCF Stem BCF Root	5.1 1250 5.42 247.3	Naturvårdsverket (1996a) Beck and Jaques (1993)
<u>Adsorpsjon/phase distribution</u> K _d K _{oc} H	5.7 (l/kg) 570 (l/kg) 5.8 E - 04	Naturvårdsverket (1996a)
Human toxicology		
<u>Oral intake</u> MTDI (TRV) Genotoxic risk based cancer (TRV)	3.0 E - 03 (mg/(kg·d)) 8.3 E - 05 (mg/(kg·d))	WHO (1993) UMS (1997)
<u>Inhalation</u> Genotoxic risk based cancer RfC	7.5 E - 06 (mg/m ³)	UMS (1997)
<u>Dermal contact</u> f _{du}	1.1 E - 01	MDEP (1994)
Reported Norwegian background values	<0.005 (mg/kg)	-
Detection limits	0.005 (mg/kg)	

14.2.8. DDT

Parameter	Data	Reference
Ecotoxicology		
<u>Aquatic toxicity</u> Algae LOEC Shellfish/Fish NOEC Safety Factor PNEC Terrestrial	0.001 - 0.01 (mg/l) 0.0005 (mg/l) 50 0.04 (mg/kg)	Beck and Jaques (1993) EnviChem (1995) EnviChem (1995)
<u>Accumulation</u> log P _{ow} BCF Fish BCF Stem BCF Root	6.2 30000 0.05 0.002	Jongbloed et al. (1994)
<u>Adsorption/phase distribution</u> K _d K _{oc} H	4086 (l/kg) 408600 (l/kg) 2.3 E - 03	UMS (1997)
Human toxicology		
<u>Oral intake</u> MTDI (TRV) Genotoxic risk based cancer (TRV)	1.0 E - 03 (mg/(kg-d)) 2.9 E - 05 (mg/(kg-d))	UMS (1997) UMS (1997)
<u>Inhalation</u> Genotoxic risk based cancer RfC	7.0 E - 03 (mg/m ³)	UMS (1997)
Reported Norwegian background values	0.0003 - 0.02 (mg/kg)	Beck and Jaques (1993)
Detection limits	0.001 (mg/kg)	

14.2.9. Lindane

Parameter	Data	Reference
Ecotoxicology		
<u>Terrestrial toxicity</u> Microorganisms NOEC	2 (mg/l)	EnviChem (1995)
Plants EC ₅₀ Animals LC ₅₀	66.5 - > 1000 (mg/kg) 0.004-0.33 (mg/kg)	
<u>Aquatic toxicity</u> Algae LOEC EC ₅₀ Shellfish NOEC Safety Factor PNEC Terrestrial	0.3 (mg/l) 0.2-2.5 (mg/l) 0.0008-16.5 (mg/l) 10 0.0005 (mg/kg)	EnviChem (1995) van der Meen et al. (1990)
<u>Accumulation</u> log P _{ow} BCF Fish BCF Stem BCF Root	3.61 730 0.15 0.86	Jongbloed et al. (1994)
<u>Adsorption/phase distribution</u> K _d K _{oc} H	10.8 (l/kg) 1080 (l/kg) 2.92 E - 06	UMS (1997)
Human toxicology		
<u>Oral intake</u> MTDI (TRV) Risk based cancer (TRV)	0.00033 (mg/(kg-d)) 0.0000075 (mg/(kg-d))	UMS (1997)
<u>Inhalation</u> Genotoxic risk based cancer, RfC	0.000026 (mg/m ³)	UMS (1997)
Reported Norwegian background values	0.002-0.03 (mg/kg)	Beck and Jaques (1993)
Detection limits	0.001 (mg/kg)	

14.2.10. Monochlorobenzene

Parameter	Data	Reference
Ecotoxicology		
Terrestrial toxicity Microorganisms NOEC	17 (mg/l)	EnviChem (1995)
Aquatic toxicity Algae LOEC Shellfish NOEC Safety Factor PNEC Terrestrial	120 (mg/l) 0.32 (mg/l) 50 0.01 (mg/kg)	EnviChem (1995)
Accumulation log P _{ow} BCF Fish BCF Stem BCF Root	2.8 40 2.48 5.07	Naturvårdsverket (1996a)
Adsorpsjon/phase distribution K _d K _{oc} H	2.04 (l/kg) 204 (l/kg) 1.8 E - 01	Naturvårdsverket (1996a)
Human toxicology		
Oral intake MTDI (TRV)	9.0 E - 02 (mg/(kg·d))	WHO (1993)
Inhalation Genotoxic risk based cancer, RfC	1.3 E - 01 (mg/m ³) 4.0 E - 01 (mg/m ³)	UMS (1997) UMS (1997)
Dermal contact f _{du}	1.0 E - 01	MDEP (1994)
Reported Norwegian background values	m.d.	
Detection limits	0.5 (mg/kg)	

14.2.11. 1,2-dichlorobenzene

Parameter	Data	Reference
Ecotoxicology		
Terrestrial toxicity Microorganisms EC ₅₀	4 (mg/l)	EnviChem (1995)
Aquatic toxicity Algae LOEC Fish NOEC Safety Factor PNEC Terrestrial	53 (mg/l) 0.37 (mg/l) 10 0.1 (mg/kg)	EnviChem (1995) IUCLID (1996)
Accumulation log P _{ow} BCF Fish BCF Stem BCF Root	3.5 230 4.41 14.4	Naturvårdsverket (1996a)
Adsorpsjon/phase distribution K _d K _{oc} H	3.8 (l/kg) 380 9.0 E - 02	Naturvårdsverket (1996a)
Human toxicology		
Oral intake MTDI (TRV)	4.3 E - 01 (mg/(kg·d))	WHO (1993)
Inhalation RfC	2.6 E - 01 (mg/m ³)	UMS (1997)
Dermal contact f _{du}	1.0 E - 01	MDEP (1994)
Reported Norwegian background values	m.d.	Beck and Jaques (1993)
Detection limits	0.5 (mg/kg)	

14.2.12. 1,4-dichlorobenzene

Parameter	Data	Reference
Ecotoxicology		
<u>Terrestrial toxicity</u> Microorganisms EC ₅₀	5.3 (mg/l)	
<u>Aquatic toxicity</u> Algae EC ₅₀ Fish NOEC Safety Factor PNEC Terrestrial	0.1 - 98 (mg/l) 0.1 - 0.76 (mg/l) 50 0.01 (mg/kg)	EnviChem (1995) Kemikalieinsp. (1989)
<u>Accumulation</u> log P _{ow} BCF Fish BCF Stem BCF Root	3.5 1800 4.31 13.6	Naturvårdsverket (1996a)
<u>Adsorpsjon/phase distribution</u> K _d K _{oc} H	5.2 (l/kg) 520 (l/kg) 0.13	Naturvårdsverket (1996a)
Human toxicology		
<u>Oral intake</u> MTDI (TRV) Genotoxic risk based cancer (TRV)	1.1 E - 01 (mg/(kg-d)) 4.0 E - 04 (mg/(kg-d))	WHO (1993) UMS (1997)
<u>Inhalation</u> RfC	1.5 E - 02 (mg/m ³)	UMS (1997)
<u>Dermal contact</u> f _{du}	1.0 E - 01	MDEP (1994)
Reported Norwegian background values	m.d.	
Detection limits	0.5 (mg/kg)	

14.2.13. 1,2,4-trichlorobenzene

Parameter	Data	Reference
Ecotoxicology		
<u>Terrestrial toxicity</u> Animals	0.93 (mg/l)	
<u>Aquatic toxicity</u> Algae EC ₅₀ Modelløkosystem NOEC Safety Factor PNEC Terrestrial	1.4 - 36.7 (mg/l) 0.04 (mg/l) 50 0.01 (mg/kg)	EnviChem (1995) IUCLID (1996) Beck and Jaques (1993)
<u>Accumulation</u> log P _{ow} BCF Fish BCF Stem BCF Root	4.2 1140 5.92 36.4	Naturvårdsverket (1996a)
<u>Adsorpsjon/phase distribution</u> K _d K _{oc} H	15 (l/kg) 1500 (l/kg) 1.1 E - 01	Naturvårdsverket (1996a)
Human toxicology		
<u>Oral intake</u> MTDI (TRV)	7.7 E - 03 (mg/(kg-d))	WHO (1993)
<u>Inhalation</u> RfC	9.0 E - 03 (mg/m ³)	UMS (1997) MDEP (1994)
<u>Dermal contact</u> f _{du}	8.0 E - 02	
Reported Norwegian background values	m.d.	
Detection limits	0.2 (mg/kg)	

14.2.14. 1,2,4,5-tetrachlorobenzene

Parameter	Data	Reference
Ecotoxicology		
<u>Aquatic toxicity</u> Algae EC ₅₀ Fish LOEC Safety Factor PNEC Terrestrial	7.1 - 52.9 (mg/l) 0.18 (mg/l) 100 0.4 (mg/kg)	EnviChem (1995)
<u>Accumulation</u> log P _{ow} BCF Fish BCF Stem BCF Root	4.9 4830 6.22 126.4	Naturvårdsverket (1996a)
<u>Adsorpsjon/phase distribution</u> K _d K _{oc} H	206 (l/kg) 20600 (l/kg) 1.0 E - 02	Naturvårdsverket (1996a)
Human toxicology		
<u>Oral intake</u> MTDI (TRV)	3.0 E - 04 (mg/(kg·d))	IRIS (1995)
Reported Norwegian background values	m.d.	
Detection limits	0.01 (mg/kg)	

14.2.15. Pentachlorobenzene

Parameter	Data	Reference
Ecotoxicology		
<u>Aquatic toxicity</u> Shellfish NOEC Safety Factor PNEC Terrestrial	0.01 (mg/l) 50 0.1 (mg/kg)	EnviChem (1995)
<u>Accumulation</u> log P _{ow} BCF Fish BCF Stem BCF Root	5.2 260000 5.15 289.8	Naturvårdsverket (1996a)
<u>Adsorpsjon/phase distribution</u> K _d K _{oc} H	608 (l/kg) 60790 (l/kg) 6.0 E - 02	Naturvårdsverket (1996a)
Human toxicology		
<u>Oral intake</u> MTDI (TRV)	8.0 E - 04 (mg/(kg·d))	IRIS (1995)
Reported Norwegian background values	m.d.	
Detection limits	0.01 (mg/kg)	

14.2.16. Hexachlorobenzene

Parameter	Data	Reference
Ecotoxicology		
<u>Terrestrial toxicity</u> Plants NOEC Plants EC ₅₀ Animals LC ₅₀	> 1 (mg/l) >1000 (mg/kg) >1000 (mg/kg)	EnviChem (1995)
<u>Aquatic toxicity</u> Algae EC ₅₀ Shellfish NOEC Safety Factor PNEC Terrestrial	0.01 - 0.03 (mg/l) 0.0013 (mg/l) 10 0.05 (mg/kg)	Beck and Jaques (1993) IUCLID (1996) EnviChem (1995)
<u>Accumulation</u> log P _{ow} BCF Fish BCF Stem BCF Root	6.5 30000 4.05 522.1	Naturvårdsverket (1996a)
<u>Adsorpsjon/phase distribution</u> K _d K _{oc} H	375 (l/kg) 37500 2.0 E - 02	Naturvårdsverket (1996a)
Human toxicology		
<u>Oral intake</u> MTDI (TRV) Genotoxic carcinogenic (TRV)	3.0 E - 05 (mg/(kg-d)) 3.3 E - 05 (mg/(kg-d))	UMS (1997) WHO (1993)
<u>Inhalation</u> RfC Genotoxic carcinogenic RfC	3.0 E - 03 (mg/m ³) 2.0 E - 04 (mg/m ³)	UMS (1997) UMS (1997)
<u>Dermal contact</u> f _{du}	1.3 E - 01	MDEP (1994)
Reported Norwegian background values	0.0004 - 0.006 (mg/kg)	Beck and Jaques (1993)
Detection limits	0.01 (mg/kg)	

14.2.17. Dichloromethane

Parameter	Data	Reference
Ecotoxicology		
<u>Terrestrial toxicity</u> Microorganisms EC ₅₀ Plants NOEC	1000 - 2800 (mg/kg) 0.1 (mg/kg)	EnviChem (1995) IUCLID (1996)
<u>Aquatic toxicity</u> Algae EC ₅₀ Fish LC ₅₀ Safety Factor PNEC Terrestrial	662 - 1000 (mg/l) 193 (mg/l) 1000 0.06 (mg/kg)	EnviChem (1995) IUCLID (1996)
<u>Accumulation</u> log P _{ow} BCF Fish BCF Stem BCF Root	1.25 5.0 1.06 1.65	Naturvårdsverket (1996a)
<u>Adsorpsjon/phase distribution</u> K _d K _{oc} H	0.3 (l/kg) 30 (l/kg) 8.0 E - 02	Naturvårdsverket (1996a)
Human toxicology		
<u>Oral intake</u> MTDI (TRV) Genotoxic carcinogenic (TRF)	6.0 E - 03 (mg/(kg-d)) 1.3 E - 03 (mg/(kg-d))	WHO (1993) UMS (1994)
<u>Inhalation</u> RfC	3.5 E - 01 (mg/m ³)	IMM (1990)
Reported Norwegian background values	m.d.	
Detection limits	0.05 (mg/kg)	

14.2.18. Trichloromethane

Parameter	Data	Reference
Ecotoxicology		
<u>Terrestrial toxicity</u> Microorganisms EC ₅₀ Animals LC ₅₀	125 - 1013 (mg/l) >1000 (mg/kg)	EnviChem (1995) IUCLID (1996)
<u>Aquatic toxicity</u> Algae EC ₅₀ Fish NOEC Safety Factor PNEC Terrestrial	185 (mg/l) 0.02 (mg/l) 10 0.001 (mg/kg)	Beck and Jaques (1993)
<u>Accumulation</u> log P _{ow} BCF Fish BCF Stem BCF Root	1.97 13 1.13 1.78	Naturvårdsverket (1996a)
<u>Adsorpsjon/phase distribution</u> K _d K _{oc} H	0.56 (l/kg) 56 (l/kg) 1.6 E - 01	Naturvårdsverket (1996a)
Human toxicology		
<u>Oral intake</u> MTDI (TRV) Gentoxic carcinogenic TRV <u>Inhalation</u> RfC Gentoxic carcinogenic RfC <u>Dermal contact</u> f _{du}	1.3 E - 02 (mg/(kg-d)) 1.64 E - 04 (mg/(kg-d)) 1.7 E - 02 (mg/m ³) 4.4 E - 04 (mg/m ³) 1.0 E - 01	WHO (1993) UMS (1997) UMS (1997) UMS (1997) MDEP (1994)
Reported Norwegian background values	m.d.	
Detection limits	0.01 (mg/kg)	

14.2.19. Trichloroethylene

Parameter	Data	Reference
Ecotoxicology		
<u>Terrestrial toxicity</u> Microorganisms EC ₅₀ Plants EC ₅₀ Animals EC ₅₀	65 - 530 (mg/l) 1000 (mg/kg) 1000 (mg/kg)	EnviChem (1995)
<u>Aquatic toxicity</u> Algae NOEC Shellfish NOEC Safety Factor PNEC Terrestrial	175 (mg/l) 0.15 (mg/l) 10 0.01 (mg/kg)	EnviChem (1995) IUCLID (1996)
<u>Accumulation</u> log P _{ow} BCF Fish BCF Stem BCF Root	2.3 17 1.74 3.08	Naturvårdsverket (1996a)
<u>Adsorpsjon/phase distribution</u> K _d K _{oc} H	0.9 (l/kg) 90 (l/kg) 4.3 E - 01	Naturvårdsverket (1996a)
Human toxicology		
<u>Oral intake</u> MTDI (TRV) <u>Inhalation</u> RfC <u>Dermal contact</u> f _{du}	2.4 E - 02 (mg/(kg-d)) 5.4 E - 01 (mg/m ³) 1.0 E - 01	WHO (1993) IMM (1990) MDEP(1994)
Reported Norwegian background values	m.d.	
Detection limits	0.01 (mg/kg)	

14.2.20. Tetrachloroethylene

Parameter	Data	Reference
Ecotoxicology		
<u>Terrestrial toxicity</u> Microorganisms LOEC Animals NOEC Safety Factor PNEC	51 (mg/l) 32 (mg/kg) 50 0.64 (mg/kg)	EnviChem (1995) IUCLID (1996)
<u>Aquatic toxicity</u> Algae NOEC Shellfish/Fish NOEC	1 (mg/l) 0.45 (mg/l)	IUCLID (1996)
<u>Accumulation</u> log P _{ow} BCF Fish BCF Stem BCF Root	2.8 77.1 1.96 3.61	Naturvårdsverket (1996a)
<u>Adsorpsjon/phase distribution</u> K _d K _{oc} H	3 (l/kg) 300 (l/kg) 7.1 E - 01	Naturvårdsverket (1996a)
Human toxicology		
<u>Oral intake</u> MTDI (TRV) Gentoxic carcinogenic TRV <u>Inhalation</u> RfC Gentoxic carcinogenic RfC <u>Dermal contact</u> f _{du}	1.4 E - 02 (mg/(kg-d)) 2.0 E - 04 (mg/(kg-d)) 6.8 E - 01 (mg/m ³) 5.5 E - 03 (mg/m ³) 1.0 E - 01	WHO (1993) UMS (1997) IMM (1990) UMS (1997) MDEP (1994)
Reported Norwegian background values	-	
Detection limits	0.01 (mg/kg)	

14.2.21. 1,1,1-trichloroethane

	Data	Reference
Ecotoxicology		
<u>Terrestrial toxicity</u> Microorganisms EC ₅₀ Plants NOEC Animals LC ₅₀	8-18.2 (mg/l) 6.9 (mg/l) 4400 - 38554 (mg/kg)	Beck and Jaques (1993) EnviChem (1995) IUCLID (1996)
<u>Aquatic toxicity</u> Algae EC ₅₀ Shellfish NOEC Safety Factor PNEC Terrestrial	5 - 669 (mg/l) 1.3 (mg/l) 10 0.13 (mg/kg)	IUCLID (1996), EnviChem (1995) IUCLID (1996)
<u>Accumulation</u> log P _{ow} BCF Fish BCF Stem BCF Root	2.49 9 1.72 3.03	Naturvårdsverket (1996a)
<u>Adsorpsjon/phase distribution</u> K _d K _{oc} H	1.0 (l/kg) 100 (l/kg) 7.6 E - 01	Naturvårdsverket (1996a)
Human toxicology		
<u>Oral intake</u> MTDI (TRV) <u>Inhalation</u> RfC <u>Dermal contact</u> f _{du}	7.0 E - 02 (mg/(kg-d)) 8.0 E - 01 (mg/m ³) 1.0 E - 01	UMS (1997) IMM (1990) MDEP (1994)
Reported Norwegian background values	m.d.	
Detection limits	0.01 (mg/kg)	

14.2.22. Benzene

Parameter	Data	Reference
Ecotoxicology		
<u>Terrestrial toxicity</u> Microorganisms LOEC Plants Animals	92 (mg/l) 900 - 1300 (mg/l) 105 - 120 (mg/kg)	EnviChem (1995) IUCLID (1996)
<u>Aquatic toxicity</u> Algae NOEC Shellfish NOEC Fish NOEC Safety Factor PNEC Terrestrial	600 (mg/l) 0.2 (mg/l) 3.1 - 5.3 (mg/l) 50 0.002 (mg/kg)	EnviChem (1995) IUCLID (1996)
<u>Accumulation</u> log P _{ow} BCF Fish BCF Stem BCF Root	2.1 10.9 1.32 2.15	Naturvårdsverket (1996a)
<u>Adsorpsjon/phase distribution</u> K _d K _{oc} H	0.57 (l/kg) 57 (l/kg) 2.2 E - 01	Naturvårdsverket (1996a)
Human toxicology		
<u>Oral intake</u> Gentoxic carcinogenic (TRV)	3.3 E - 04 (mg/(kg.d))	UMS (1997)
<u>Inhalation</u> RfC	1.3 E - 03 (mg/m ³)	IMM (1990)
<u>Dermal contact</u> f _{du}	8.0 E - 02	MDEP (1994)
Reported Norwegian background values	m.d.	
Detection limits	0.005 (mg/kg)	

14.2.23. Toluene

Parameter	Data	Reference
Ecotoxicology		
<u>Terrestrial toxicity</u> Microorganisms LOEC Plants	29 (mg/l) 2000 (mg/l)	EnviChem (1995) IUCLID (1996)
<u>Aquatic toxicity</u> LOEC Fish LOEC Safety Factor PNEC Terrestrial	105 (mg/l) 6 (mg/l) 10 0.8 (mg/kg)	
<u>Accumulation</u> log P _{ow} BCF Fish BCF Stem BCF Root	2.7 39 2.2 4.24	Naturvårdsverket (1996a)
<u>Adsorpsjon/phase distribution</u> K _d K _{oc} H	1.3 (l/kg) 130 2.5 E - 01	Naturvårdsverket (1996a)
Human toxicology		
<u>Oral intake</u> MTDI (TRV)	2.2 E - 01 (mg/(kg.d))	WHO (1993)
<u>Inhalation</u> RfC	4.0 E - 02 (mg/m ³)	IMM (1990)
<u>Dermal contact</u> f _{du}	1.2 E - 01	MDEP (1994)
Reported Norwegian background values	m.d.	
Detection limits	0.005 (mg/kg)	

14.2.24. Ethylbenzene

Parameter	Data	Reference
Ecotoxicology		
<u>Terrestrial toxicity</u> Microorganisms LOEC Plants EC ₅₀	12 (mg/l) 27 - 48 (mg/l)	IUCLID (1996) EnviChem (1995)
<u>Aquatic toxicity</u> Algae LOEC Shellfish/Fish LC ₅₀ Safety Factor PNEC Terrestrial	33 (mg/l) 0.49 - 1030 (mg/kg) 100 0.7 (mg/kg)	IUCLID (1996) EnviChem (1995)
<u>Accumulation</u> log P _{ow} BCF Fish BCF Stem BCF Root	3.1 86 3.4 8.48	Naturvårdsverket (1996a)
<u>Adsorpsjon/phase distribution</u> K _d K _{oc} H	2.2 (l/kg) 220 (l/kg) 3.2 E - 01	Naturvårdsverket (1996a)
Human toxicology		
<u>Oral intake</u> MTDI (TRV)	1.0 E - 01 (mg/(kg-d))	WHO (1993)
<u>Inhalation</u> RfC	4.0 E - 02 (mg/m ³)	IMM (1990)
<u>Dermal contact</u> f _{du}	2.0 E - 01	MDEP (1994)
Reported Norwegian background values	m.d.	
Detection limits	0.005 (mg/kg)	

14.2.25. Xylene

Parameter	Data	Reference
Ecotoxicology		
<u>Aquatic toxicity</u> Algae EC ₅₀ Fish NOEC Safety Factor PNEC Terrestrial	0.35 - 1080 (mg/l) 1.3 (mg/l) 100 0.03 (mg/kg)	IUCLID (1996) EnviChem (1995)
<u>Accumulation</u> log P _{ow} BCF Fish BCF Stem BCF Root	3.2 105 3.37 8.34	Naturvårdsverket (1996a)
<u>Adsorpsjon/phase distribution</u> K _d K _{oc} H	2.6 (l/kg) 260 (l/kg) 2.5 E - 01	Naturvårdsverket (1996a)
Human toxicology		
<u>Oral intake</u> MTDI (TRV)	1.8 E - 01 (mg/(kg-d))	WHO (1993)
<u>Inhalation</u> RfC	4.0 E - 02 (mg/m ³)	IMM (1990)
<u>Dermal contact</u> f _{du}	1.2 E - 01	MDEP (1994)
Reported Norwegian background values	m.d.	
Detection limits	0.005 (mg/kg)	

14.2.26. Aliphatics C5-C6

Parameter	Data	Reference	
Ecotoxicology			
Applies to C ₅ – C ₆ Ecotoxicological based soil quality guidelines, terrestrial	50 (mg/kg)	Naturvårdsverket (1998)	
<u>Accumulation</u>			
log P _{ow}	3.3	Naturvårdsverket (1998)	
BCF Fish	190		
BCF Stem	3.88		
BCF Root	10.93		
<u>Adsorpsjon/phase distribution</u>			
K _d	8 (l/kg)	Naturvårdsverket (1998)	
K _{oc}	800 (l/kg)		
H	34		
Human toxicology			
<u>Oral intake</u>			
MTDI (TRV)	5 (mg/(kg·d))	Naturvårdsverket (1998)	
<u>Inhalation</u>			
RfC	18.4 (mg/m ³)		
<u>Dermal contact</u>			
f _{du}	0.2		
Reported Norwegian background values	m.d.		
Detection limits			

14.2.27. Aliphatics >C6-C8

Parameter	Data	Reference	
Ecotoxicology			
Applies to C ₆ – C ₈ Ecotoxicological based soil quality guidelines, terrestrial	50 (mg/kg)	Naturvårdsverket (1998)	
<u>Accumulation</u>			
log P _{ow}	3.99	Naturvårdsverket (1998)	
BCF Fish	970		
BCF Stem	5.92		
BCF Root	36.28		
<u>Adsorpsjon/phase distribution</u>			
K _d	40 (l/kg)	Naturvårdsverket (1998)	
K _{oc}	4000 (l/kg)		
H	51		
Human toxicology			
<u>Oral intake</u>			
MTDI (TRV)	5 (mg/(kg·d))	Naturvårdsverket (1998)	
<u>Inhalation</u>			
RfC	18.4 (mg/m ³)		
<u>Dermal contact</u>			
f _{du}	0.2		
Reported Norwegian background values	m.d.		
Detection limits			

14.2.28. Aliphatics >C8-C10

Parameter	Data	Reference
Ecotoxicology		
Applies to C ₈ – C ₁₀ Ecotoxicological based soil quality guidelines, terrestrial	100 (mg/kg)	Naturvårdsverket (1998)
<u>Accumulation</u>		
log P _{ow}	4.89	Naturvårdsverket (1998)
BCF Fish	7700	
BCF Stem	5.90	
BCF Root	175.64	
<u>Adsorpsjon/phase distribution</u>		
K _d	320(l/kg)	Naturvårdsverket (1998)
K _{oc}	32000 (l/kg)	
H	82	
Human toxicology		
<u>Oral intake</u>		
MTDI (TRV)	0.1 (mg/(kg·d))	Naturvårdsverket (1998)
<u>Inhalation</u>		
RfC	1 (mg/m ³)	
<u>Dermal contact</u>		
f _{du}	0.2	
Reported Norwegian background values	m.d.	
Detection limits		

14.2.29. Aliphatics >C10-C12

Parameter	Data	Reference
Ecotoxicology		
Applies to C ₁₀ – C ₁₂ Ecotoxicological based soil quality guidelines, terrestrial	100 (mg/kg)	Naturvårdsverket (1998)
<u>Accumulation</u>		
log P _{ow}	5.78	Naturvårdsverket (1998)
BCF Fish	60000	
BCF Stem	3.09	
BCF Root	850.35	
<u>Adsorpsjon/phase distribution</u>		
K _d	2500(l/kg)	Naturvårdsverket (1998)
K _{oc}	250000 (l/kg)	
H	130	
Human toxicology		
<u>Oral intake</u>		
MTDI (TRV)	0.1 (mg/(kg·d))	Naturvårdsverket (1998)
<u>Inhalation</u>		
RfC	1 (mg/m ³)	
<u>Dermal contact</u>		
f _{du}	0.2	
Reported Norwegian background values	m.d.	
Detection limits		

14.2.30. Aliphatics >C12-C16

Parameter	Data	Reference
Ecotoxicology		
Applies to C ₁₂ – C ₁₆ Ecotoxicological based soil quality guidelines, terrestrial	100 (mg/kg)	Naturvårdsverket (1998)
<u>Accumulation</u> log P _{ow} BCF Fish BCF Stem BCF Root	7.08 1200000 0.38 8531	Naturvårdsverket (1998)
<u>Adsorpsjon/phase distribution</u> K _d K _{oc} H	50000 (l/kg) 5000000 (l/kg) 540	Naturvårdsverket (1998)
Human toxicology		
<u>Oral intake</u> MTDI (TRV) <u>Inhalation</u> RfC <u>Dermal contact</u> f _{du}	0.1 (mg/(kg·d)) 1 (mg/m ³) 0.2	Naturvårdsverket (1998)
Reported Norwegian background values	m.d.	
Detection limits		

14.2.31. Aliphatics >C16-C35

Parameter	Data	Reference
Ecotoxicology		
Applies to C ₁₆ – C ₃₅ Ecotoxicological based soil quality guidelines, terrestrial	100 (mg/kg)	Naturvårdsverket (1998)
<u>Accumulation</u> log P _{ow} BCF Fish BCF Stem BCF Root	9.30 200000000 0.0004 438322	Naturvårdsverket (1998)
<u>Adsorpsjon/phase distribution</u> K _d K _{oc} H	10000000(l/kg) 1000000000 (l/kg) 6400	Naturvårdsverket (1998)
Human toxicology		
<u>Oral intake</u> MTDI (TRV) <u>Inhalation</u> RfC <u>Dermal contact</u> f _{du}	2 (mg/(kg·d)) m.d. (mg/m ³) 0.2	Naturvårdsverket (1998)
Reported Norwegian background values	m.d.	
Detection limits		

14.2.32. MTBE

Parameter	Data	Reference
Ecotoxicology		
Ecotoxicological based soil quality guidelines, terrestrial	60 (mg/kg)	Naturvårdsverket (1998)
<u>Accumulation</u> log P _{ow} BCF Fish BCF Stem BCF Root	1.30 2 0.69 1.12	Naturvårdsverket (1998)
<u>Adsorpsjon/phase distribution</u> K _d K _{oc} H	0.082(l/kg) 8.2 (l/kg) 0.02	Naturvårdsverket (1998)
Human toxicology		
<u>Oral intake</u> MTDI (TRV) <u>Inhalation</u> RfC <u>Dermal contact</u> f _{du}	0.1 (mg/(kg·d)) 3 (mg/m ³) 0.1	Naturvårdsverket (1998)
Reported Norwegian background values	m.d.	
Detection limits		

14.2.33. 1,2-dichloethane

Parameter	Data	Reference
Ecotoxicology		
Ecotoxicological based soil quality guidelines, terrestrial	60 (mg/kg)	Naturvårdsverket (1998)
<u>Accumulation</u> log P _{ow} BCF Fish BCF Stem BCF Root	1.48 3 0.79 1.23	Naturvårdsverket (1998)
<u>Adsorpsjon/phase distribution</u> K _d K _{oc} H	0.12(l/kg) 12 (l/kg) 0.05	Naturvårdsverket (1998)
Human toxicology		
<u>Oral intake</u> Gentoxic carcinogenic MTDI (TRV) <u>Inhalation</u> Gentoxic carcinogenic RfC <u>Dermal contact</u> f _{du}	0.001 (mg/(kg·d)) 0.00038 (mg/m ³) 0.1	Naturvårdsverket (1998)
Reported Norwegian background values	m.d.	
Detection limits		

14.2.34. 1,2-dibromoethane

Parameter	Data	Reference
Ecotoxicology		
	m.d.	
<u>Accumulation</u> log P _{ow} BCF Fish BCF Stem BCF Root	1.96 9.1 1.13 1.79	Naturvårdsverket (1998)
<u>Adsorpsjon/phase distribution</u> K _d K _{oc} H	0.37(l/kg) 37 (l/kg) 0.03	Naturvårdsverket (1998)
Human toxicology		
<u>Oral intake</u> Gentoxic carcinogenic MTDI (TRV)	0.00000012 (mg/(kg·d))	Naturvårdsverket (1998)
<u>Inhalation</u> Gentoxic carcinogenic RfC	0.000046 (mg/m ³)	
<u>Dermal contact</u> f _{du}	0.1	
Reported Norwegian background values	m.d.	
Detection limits	0.004 (mg/kg)	Naturvårdsverket (1998)

14.2.35. Tetraethyllead

Parameter	Data	Reference
Ecotoxicology		
	m.d.	
<u>Accumulation</u> log P _{ow} BCF Fish BCF Stem BCF Root	3.00 100 3.04 6.99	Naturvårdsverket (1998)
<u>Adsorpsjon/phase distribution</u> K _d K _{oc} H	4.18(l/kg) 418 (l/kg) 0.05	Naturvårdsverket (1998)
Human toxicology		
<u>Oral intake</u> MTDI (TRV)	0.0000001 (mg/(kg·d))	Naturvårdsverket (1998)
<u>Inhalation</u> RfC	m.d. (mg/m ³)	
<u>Dermal contact</u> f _{du}	0.1	
Reported Norwegian background values	m.d.	
Detection limits	0.001 (mg/kg)	Naturvårdsverket (1998)

15. Definitions

This chapter contains definitions for the most important words/phrases that are used in this report. They are sorted alphabetically.

Acceptance criteria: Criteria based on regulations, standards, national and regional directives, experience and/or theoretical knowledge used as a basis for decisions about acceptable risk. Acceptance criteria may be expressed verbally or numerically.

Acute toxicity: The manifestation of a toxic effect over a short period relative to the life span of the organism.

ADI (Acceptable Daily Intake): Estimate of the amount of a chemical substance which can be ingested daily by humans without appreciable health risk. Generally used for additives to food and drinking water.

Aquifer: Groundwater-bearing formations.

Background level: The concentration of a substance which is naturally present. For heavy metals which are geologically naturally present, the background concentration may vary from site to site.

BCF (Bioconcentration Factor): The ratio of the test substance concentration in (part of) an organism to the concentration in a medium (water or soil) at steady state.

Bioaccumulation: When a substance bioaccumulates in an organism, the substance resides in the organism (most often in an organ) until the concentration becomes higher in the organisms than in the surrounding environment (for example, in water).

Bioavailable: When a substance is bioavailable, it exists in a form that it is available for intake into a living organism. Processes that can reduce a substances' bioavailability in water are for example, adsorption to suspended particles, sediments, humus and other macromolecules as well as the formation of colloidal suspensions and complexations.

Bioconcentration: The process leading to a higher concentration of a substance in an organism than in the environmental media to which it is exposed.

Biological degradation: Transformation of organic compounds to simpler compounds (such as carbon dioxide) with the help of living organisms. The organisms can be microorganisms or plants.

Biomagnification: The process by which the concentration of a chemical substance in biota increases at higher trophic levels in the food-chain.

Carcinogenic substances: Substances/chemicals that have the ability to cause the development of cancer in humans or experimental animals.

Causal analysis: A systematic procedure for describing and/or calculating the probability of causes for undesirable events.

Chronic toxicity: The manifestation of a toxic effect (life threatening disease or depreciation of bodily function) over a relatively long period of exposure to a substance. Substances that display chronic toxicity are usually carcinogenic, genotoxic, harmful to reproduction as well as to the foster.

Consequence: A possible result of an undesirable event. Consequences may be expressed verbally or numerically to describe the extent of injury to humans, or environmental or material damage.

Criteria for decision: Criteria that affect decisions that are to be made, for example acceptance criteria, financial terms, time available and political acceptability.

Degradation: Substances' ability to decompose in the environment. The degradation may be biotic depending on the microorganisms' ability to decompose the compound, or abiotic depending on the conditions such as pH, light, temperature, chemical compounds and water content.

Effect: In this instance, the influence of soil contamination on human beings and the environment. The effect can be a measurable change in the soil or recipient in relation to the expected condition as a result of the influence from the contaminated site. The effect includes concentrations above the natural background level and the influence on life generally. Effects may be negative, positive or neutral with respect to life and health.

Environmental objective: The defined ambition level for the desired condition of the environment. The expression can be used as a category for the condition/state of soil, water or air, or as a qualitative description of its condition/state that does not conflict with existing or future land use. Qualitative objectives are concretised when expressed as acceptance criteria.

Environmentally hazardous substance: Substances that can give harmful effect to the environment, even at low concentrations. The hazards are due to the substance's inherent characteristics such as acute and chronic toxicity, persistence (low degradation) and accumulation in the food-web.

Episode: In this context episode is defined as unusual (extreme) events that can affect soil contamination. Episodes are important for risk tied to soil contaminants that are otherwise stable under normal conditions. Particular attention should be paid to spring episodes.

Exposure assessment: Determination of discharge, type and amount, as well as the transformation or degradation that is necessary to calculate the concentrations that human beings and the ecosystem can be exposed to.

Exposure characterisation: Identification of the conditions of contact between a chemical substance and a receptor (humans, animals or the ecosystem). Exposure characterisations may involve identifying routes of uptake, concentrations and organisms at risk.

Exposure estimation: Estimate of the amount and duration of contact between a chemical substance and a receptor (organism).

Exposure pathway: The route by which a receptor comes into contact with a contaminant.

Exposure: Contact between a chemical substance and a receptor (human beings or the ecosystem).

Extent of contamination: The migration of existing contamination that can lead to exposure to humans or defined biotopes/ecosystems.

Groundwater: Subsurface water beneath the water table in fully saturated geological formations.

LC₅₀/LD₅₀: Lethal concentration or lethal dose. Measure of acute toxicity. LD₅₀ indicates the dosage that results in 50% of the test organism's mortality. LC₅₀ indicates the concentration in water or air that is causing death in 50% of the test organisms. The LC₅₀ value also indicates the time span that the exposure occurred, for example LC₅₀-96h where 96h refers to 96 hours exposure. EC₅₀/ED₅₀ = effect concentration / effect dose is analogous to LC₅₀/LD₅₀ but with other endpoints than mortality.

Leaching: Process by which contaminants in the soil matrix dissolve into the pore water. This can be divided into potential leaching and actual leaching depending on local conditions.

Measure to eliminate causes: A measure intended to eliminate the causes of undesirable events.

Measure to mitigate risk: A measure intended to reduce the likelihood and/or consequence of undesirable events.

Migration: In this context refers to the migration of hazardous substances in soil from the original deposition site or source. Migration includes migration in the soil (soil, pore water and vapour space).

Mobilisation: Processes that lead to the migration of the contaminant from the source where the contamination was originally located.

MTD (Maximum Tolerable Dose): The highest dosage level that can demonstrate traces of toxicity without a large effect on the ability to survive in relation to the test.

NOEC (No Observed Effect Concentration): The concentration of a substance that does not demonstrate harmful effects to organisms using a chronic exposure test.

Norm/standard: Threshold value which is not legally binding, but which is used by the environmental authorities in their assessment of a site or its potential land use. When evaluating the different contaminated cases the norm/standard values can be made binding.

Organic compounds: Chemical substances that contain carbon, oxygen, hydrogen and/or nitrogen/sulphur. For example, ethanol CH₃CH₂OH. Heavy metals such as lead may chemically combine with organic groups and therefore be called organic lead.

PEC (Predicted Environmental Concentration): Predicted concentration of a substance where exposure to organisms in the environment is expected. PEC is calculated or measured, if possible, at the exposure point for the organisms to be protected.

Permeability: The measure of a soil volume's capacity to transmit liquids or vapour.

Persistent compounds: Substances that are resistant to chemical changes in nature.

PNEC (Predicted No Effect Concentration): The calculated concentration of a substance where no harmful effects to the environment are expected. PNEC is derived from all available test results for a substance. When the extent of available data is limited, safety factors are utilised to take the uncertainty in the data/information into consideration.

Problem owner: The owner of the problem is the one the authorities hold responsible for the contamination. This will firstly be the one causing the contamination, but can also be the site owner or others that can be held responsible according to the national pollution control laws.

Receptors: General description of human beings, animals, birds, plants, fungi, algae, fish, crustaceans, shellfish and bacteria.

Risk analysis: A systematic approach for describing and/or calculating risk. Risk analysis involves the identification of undesirable events, and the causes and consequences of these events.

Risk assessment: The comparison of the results from a risk analysis with the defined acceptance criteria for risk.

Risk: Risk designates the danger that undesirable events represent for humans, the environment (ecosystem) or material values. Risk is expressed as the probability and consequences of the undesirable events.

Sensitive area: Areas where there is an especially high risk that humans can experience health hazards, or nature areas that have a high intrinsic value. This includes areas that have a high probability of exposure to the contaminated compounds or the sensitivity for exposure is especially high, for example for children. Examples of sensitive areas include residential areas, day care centres, play grounds, recreation and sports arenas, beaches as well as nature reserves.

Sensitivity analysis: A systematic procedure to describe and/or calculate the effect on the final result of variations in the input data.

Series of consequences: Possible sequences of events that result from an undesirable event, and which lead to given consequences.

Soil contamination: In this context soil contamination is limited to environmentally hazardous substances tied to soil, groundwater, rock formations and landfills.

Soil: Normally defined as the unconsolidated material on the immediate surface of the earth and mineral deposits. The material may be of natural origin or manmade masses.

Source: Location and content of priority pollutants in the ground, supplied by deposition or contamination from anthropogenic activities. The source refers to the original placement and contents of the contaminant, independent of distribution and degradation.

Stratigraphy: The arrangement of strata.

Subject for analysis: The technical, organisational, environmental and human systems/conditions covered by the risk analysis.

Toxicity: A chemical substance's toxic effect and level of toxicity.

Transport (mechanism): The different mechanisms leading to the migration of the contaminant (for example in the air, soil or water phase).

Undesirable event: An event or condition that can cause human injury or environmental or material damage.

16. Alphabetic list of parameters

ε	=	soil's porosity.
ρ_s	=	soil's density (kg/l).
θ_a	=	air water content (l air/l soil).
θ_w	=	soil water content (l water/l soil).
A	=	area under the house (m ²).
BCF_{fish}	=	bioconcentration factor for fish ((mg/kg fish) / (mg/l water)).
BCF_{root}	=	bioconcentration factor (plant uptake factor) in the root portion of the plant (l/kg wet weight).
BCF_{stem}	=	bioconcentration factor (plant uptake factor) in the stem portion of the plant (l/kg wet weight).
C_a	=	concentration of contaminant in pore air at the source (mg/l).
C_{ad}	=	average concentration of dust in inhaled air (mg/m ³).
C_{du}	=	reference soil concentration for dermal contact to soil.
C_{gw}	=	concentration of contaminant in groundwater (mg/l).
C_{ia}	=	concentration of contaminant in indoor air (mg/l).
C_{id}	=	reference soil concentration for inhalation of dust (mg/kg).
C_{if}	=	reference soil concentration for consumption of fish/shellfish (mg/kg).
C_{ig}	=	reference soil concentration for consumption of vegetables (mg/kg).
C_{is}	=	reference soil concentration for ingestion of soil (mg/kg).
C_{iv}	=	reference soil concentration for inhalation of soil vapour (mg/kg).
C_{iw}	=	reference soil concentration for intake of drinking water (mg/kg).
C_s	=	concentration of contaminant in soil (mg/kg).
C_{sw}	=	concentration of contaminant in surface water (mg/l).
C_w	=	concentration of contaminant in pore water at the source (mg/l).
D	=	diffusivity of air in soil (m ² /d).
D_0	=	diffusivity in pure air (m ² /d).
d_a	=	thickness of aquifer (m).
d_{mix}	=	thickness of mixing zone in aquifer (m).
DF_{gw}	=	dilution factor for pore water to groundwater.
DF_{ia}	=	dilution factor from pore air to indoor air.
DF_{sw}	=	dilution factor from groundwater to surface water.
DI_{du}	=	average daily dermal exposure for soil (mg/d).
DI_{if}	=	average daily consumption of fish and shellfish (kg/d).
DI_{ig}	=	average daily consumption of vegetables (kg/d).
DI_{is}	=	average daily ingestion of soil (mg/d).
DI_{iw}	=	average daily intake of drinking water (l/d).
f_{blad}	=	fraction of leaf/stem vegetables in total vegetable consumption.
f_{du}	=	relative chemical specific absorption factor for dermal uptake.
f_{exp}	=	fraction exposure time (d/year).
f_f	=	fraction of consumption of fish and shellfish from nearby recipient.
f_h	=	fraction of consumption of vegetables grown at the contaminated site.
f_{oc}	=	fraction organic carbon in soil.
f_{root}	=	fraction of root vegetables in total vegetable consumption.
H	=	Henry's constant.
I	=	infiltration rate (m/year).
i	=	hydraulic gradient (m/m).
k	=	soil's hydraulic conductivity (m/year).
K_d	=	soil/water partition coefficient (l/kg).
K_{oc}	=	organic carbon-water partition coefficient (l/kg).
K_{pl}	=	total plant concentration calculated according to equation (16).

k_t	=	theoretical retention time in the lake (year^{-1}).
KV	=	body weight (kg).
/	=	lipid content of fish (%).
I	=	replacement rate for air in the house (d ⁻¹).
L	=	intrusion rate of pore air (m^3/d).
L_{gw}	=	length of the contaminated site in direction of groundwater flow (m).
L_{sw}	=	width of contaminated area perpendicular to the direction of groundwater flow (m).
LR	=	lung retention (%).
PH	=	breathing rate (m^3/d).
P_{ow}	=	octanol-water partition coefficient.
Q_{di}	=	discharge of groundwater from the contaminated area to surface water (m^3/year).
Q_{sw}	=	water flow rate in surface water (m^3/year).
R_{du}	=	daily dermal exposure per kg body weight ($\text{mg}/(\text{kg}\cdot\text{d})$).
R_{id}	=	daily inhalation of dust per kg body weight ($\text{mg}/(\text{kg}\cdot\text{d})$).
R_{if}	=	daily consumption of fish and shellfish per kg body weight ($\text{kg}/(\text{kg}\cdot\text{d})$).
R_{ig}	=	daily consumption of vegetables per kg body weight ($\text{kg}/(\text{kg}\cdot\text{d})$).
R_{is}	=	daily intake of soil per kg body weight ($\text{mg}/(\text{kg}\cdot\text{d})$).
R_{iv}	=	daily intake of vapour per kg body weight ($\text{mg}/(\text{kg}\cdot\text{d})$).
R_{iw}	=	daily intake of drinking water per kg body weight ($\text{l}/(\text{kg}\cdot\text{d})$).
R_{fC}	=	toxicological reference concentration (mg/m^3).
TRV	=	toxicological reference value ($\text{mg}/(\text{kg}\cdot\text{d})$).
V_{house}	=	inside volume of the house (m^3).
V_{sw}	=	volume of the lake (m^3).
X	=	distance from the contaminated site to the well (m).
Z	=	depth to the contaminant (m).

17. Adjusted standard value for different types of soil

Table 17 shows the adjusted standard values for different types of soil that can be utilised when information is available on the soil type and a more thorough risk analysis (Tier 2) is to be accomplished.

Table 17. The soil's hydraulic conductivity (k), porosity (ϵ), air content (θ_a), water content (θ_w), and infiltration rate (I) for different types of soil.

Soil type	k (m/s)	ϵ	θ_a (l air/l soil)	θ_w (l water/l soil)	I (cm/year)
sand	10^{-3} to $5 \cdot 10^{-5}$	0.41	0.334	0.076	$1.8 \cdot 10^{-3} \cdot P^2$
silt	10^{-5} to 10^{-9}	0.46	0.16	0.3	$9.8 \cdot 10^{-4} \cdot P^2$
clay	$5 \cdot 10^{-9}$ to 10^{-12}	0.38	0	0.38	$1.8 \cdot 10^{-3} \cdot P^2$

Per average precipitation in cm/year

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19. Calculated Soil Quality Guidelines

Preparation of the soil quality guidelines are completed according to the following procedure:

In preparing the suggested health related soil quality guidelines the following exposure pathways are taken into consideration; ingestion of soil and dust, dermal contact to soil and dust, inhalation of dust, inhalation of soil vapour, intake of drinking water (groundwater), consumption of vegetables grown at the site and consumption of fish/shellfish from a nearby seawater recipient. The algorithms are based on the algorithms used in Naturvårdsverket's model (1996a), with some modifications. 100% bioavailability is used for intake from soil. The soil quality guidelines are slightly modified based on the information for % absorption in the organism for those chemical substances where bioavailability data is available.

In preparing the ecotoxicological related soil quality guidelines, data from terrestrial toxicity tests at three trophic levels are preferably used to calculate PNEC values. When terrestrial data is not available, the $PNEC_{soil}$ is calculated from aquatic data and available soil and water partition coefficients. The lowest reported NOEC value from chronic tests is used when available. Data from acute tests are used when nothing else is available. Safety factors as reported in EU's guidelines for risk assessments are used. When chronic tests with terrestrial organisms at three trophic levels are performed, the lowest NOEC or LOEC value is used for the $PNEC_{soil}$ value and no safety factor is utilised. When toxicity tests are carried out for water soluble metal salts, the ecotoxicological based soil quality guideline is assumed to be ten times higher than the calculated $PNEC_{soil}$ value (assuming 10% bioavailability of metals in soil compared to available test data). For other substances besides metals, 100% bioavailability is used and the calculated $PNEC_{soil}$ value is utilised as the ecotoxicological based soil quality guideline. The soil quality guidelines for aliphatic hydrocarbons and additives to gasoline and oil are based on the Swedish guidelines from (Naturvårdsverket, 1998).

Ideal soil quality guidelines are derived from the health based and ecotoxicological based soil quality guidelines. The ideal soil quality guideline for each substance is the lower of the two. The ideal soil quality guideline value is thereafter adjusted for the detection limit for the most probable analytical method. If the soil quality guideline is lower than the reported Norwegian background values, an assessment is completed based on the different exposure pathways and the available information. The soil quality guidelines are then adjusted to what is referred to as the "prevailing soil quality guidelines."

Table 18 presents an overview for the different substances and the resulting soil quality guidelines. As shown in Table 18, the soil quality guidelines are adjusted considerably for arsenic, cyanide, PAH and BTEX due to the detection limits. These substances are therefore discussed separately. Soil quality guidelines for hydrocarbons and additives to gasoline and oil products were determined to be included during the last stages of the work with the guidance manual. These are therefore also discussed separately in this chapter. Table 19 gives the available information for the individual health related soil quality guidelines.

Table 18. Acceptable concentration for human beings and the ecosystem, reported information for Norwegian soil, previous SFT standards and soil quality guidelines for most sensitive land use.

Substance	Reported background values in soil for Norway ¹⁾ mg/kg	Previous soil Quality Guidelines SFT (1995) mg/kg	Health related soil quality guidelines (acceptable terskel-dose)		Ecotox related soil quality guidelines (acceptable terskel-dose)		Ideal soil quality guidelines mg/kg	Detection limit for most usual analytical method mg/kg	Soil quality guidelines adjusted for detection limit mg/kg	Prevailing soil quality guidelines mg/kg
			Sum all exposure pathways mg/kg	Exclusive Drinking water mg/kg	PNEC-soil value mg/kg	Adjusted value (10%) mg/kg				
Arsenic	0.7-8.8	20	0.06	1.7	0.2	2	0.06	0.03	0.06	2
Lead (inorganic)	8.5-107.4	50	60.5	96	10	100	60.5	0.03	60	60
Cadmium	0.1-1.7	1	3.5	11.7	0.4	4	3.5	0.01	3	3
Mercury	0.05-0.20	1	0.8	0.9	0.1	1	0.8	0.01	1	1
Copper	6-27	100	18400	33400	10	100	100	0.02	100	100
Zinc	25-104	150	12400	52400	10	100	100	0.01	100	100
Chromium (III)	3-30 (total)	100	71800	92000	26		26	0.02	25	25 (total)
Chromium (VI)	3-30 (total)		7.3	7.3	1.8		1.8		1.8	-
Nickel	3-19	30	50.9	135	6.25	63	50.9	0.02	50	50
Free Cyanide	m.d	0.1	1.5	4.6	0.0001		0.0001	0.1	0.1	1
PCB (per congene)	0.003-0.03 CAS1336-36-3							0.001	0.001	-
Σ7 PCB	0.003-0.03 CAS1336-36-3	0.02	0.0047	0.0047	0.003		0.003	0.007	0.007	0.01
Pentachlorophenol	<0.005		0.0026	0.0026	0.7		0.0025	0.005	0.005	0.005
Lindane	0.002-0.03		0.02	0.1	0.0005		0.0005	0.001	0.001	0.001
DDT	0.0003-0.02		9.2	11.9	0.04		0.04	0.001	0.04	0.04
Monochlorobenzene	m.d.		5	5.9	0.01		0.01	0.5	0.5	0.5
1,2-dichlorobenzene	m.d.		15	15.5	0.1		0.1	0.5	0.5	0.5
1,4-dichlorobenzene	m.d.		0.12	0.14	0.01		0.01	0.5	0.5	0.5
1,2,4-trichlorobenzene	m.d.		1.0	1.05	0.01		0.01	0.2	0.2	0.2
1,2,4,5-tetrachlorobenzene	m.d.		0.29	0.3	0.4		0.3	0.01	0.3	0.3
Pentachlorobenzene	m.d.		0.9	0.9	0.1		0.1	0.01	0.1	0.1
Hexachlorobenzene	0.0004-0.006		0.03	0.03	0.05		0.03	0.01	0.03	0.03
Dichloromethane	m.d.		0.1	0.3	0.06		0.06	0.05	0.06	0.06
Trichloromethane	0.001		0.003	0.003	0.001		0.001	0.01	0.01	0.01
Trichloroethylene	0.001		1.1	1.5	0.01		0.01	0.01	0.01	0.01
Tetrachloroethylene	0.01		0.03	0.04	0.6		0.03	0.01	0.03	0.03
1,1,1-trichloroethane	0.001		1.7	1.9	0.13		0.13	0.01	0.1	0.1
Aromatic hydrocarbons:										
Σ16 PAH	0.005-0.8	5	0.20 ²⁾		19.7		0.20	0.01	0.20	2
Benzo(a)pyrene	0.015-0.157	0.1	0.01	0.01	1.5		0.01	0.01	0.01	0.1
Naphthalene			22	26	0.8		0.8	0.01	0.8	0.8
Fluorene			56	60	0.6		0.6	0.01	0.6	0.6
Fluoranthene			99	101	0.1		0.1	0.01	0.1	0.1
Pyrene			74	76	0.1		0.1	0.01	0.1	0.1
Benzene	<0.1	0.05	0.006	0.007	0.002		0.002	0.005	0.005	0.005

Substance	Reported background values in soil for Norway ¹⁾ mg/kg	Previous soil Quality Guidelines SFT (1995) mg/kg	Health related soil quality guidelines (acceptable terskel-dose)		Ecotox related soil quality guidelines (acceptable terskel-dose)		Ideal soil quality guidelines mg/kg	Detection limit for most usual analytical method mg/kg	Soil quality guidelines adjusted for detection limit mg/kg	Prevailing soil quality guidelines mg/kg
			Sum all exposure pathways mg/kg	Exclusive Drinking water mg/kg	PNEC-soil value mg/kg	Adjusted value (10%) mg/kg				
Toluene	0.32	0.05	0.4	0.4	0.8		0.4	0.005	0.4	0.5
Ethylbenzene	<0.1	0.05	0.5	0.5	0.7		0.5	0.005	0.5	0.5
Xylene	<0.1	0.05	0.8	0.8	0.03		0.03	0.005	0.03	0.5
<u>Aliphatic hydrocarbons:</u>										
Aliphatics C5-C6			11	10	50 ³⁾		7			7
Aliphatics >C6-C8			30	30	50 ³⁾					
Aliphatics >C8-C10			7	7	100 ³⁾					
Aliphatics >C10-C12			31	31	100 ³⁾		31			30
Aliphatics >C12-C16			119	119	100 ³⁾		100			100
Aliphatics >C16-C35			7850	7850	100 ³⁾					
<u>Additives to gasoline and oil products</u>										
MTBE			2.2	6.3	60 ³⁾		2.2			2
1,2-dichloroethane			0.003	0.003	60 ³⁾		0.003			0.003
1,2-dibromoethane			0.00001	0.00003	-		0.00001		0.004	0.004
Tetraethyllead			0.00002	0.00003	-		0.00003		0.001	0.001

1) Data is taken from Beck and Jaques (1993).

2) Based on the values for most toxic PAH-compound, benzo(a)pyrene.

3) Based on the values from Naturvårdsverket and the Swedish Petroleum Institute (1998).

Table 19. Overview of the individual concentrations for most sensitive land use (calculated from the methods described in Chapter 10, 11 and 12).

Substance	Ingestion of soil C_{is} mg/kg	Dermal contact of soil C_{du} mg/kg	Inhalation of dust C_{id} mg/kg	Inhalation of vapour C_{iv} mg/kg	Intake of drinking water C_{iw} mg/kg	Consumption of vegetables C_{ig} mg/kg	Consumption of fish C_{if} mg/kg	Total all exposure mg/kg	Total excluding intake of drinking water mg/kg
Arsenic	3.75	5.94E+01	6.1E+01	n.r.	6.1E-02	5.7E+00	8.0E+00	5.89E-02	1.67
Lead (inorganic)	1.0E+02	7.99E+03	1.22E+04	n.r.	1.63E+02	2.15E+04	6.6E+03	6.05E+01	96.1
Cadmium	1.0E+02	3.42E+02	1.37E+02	n.r.	4.91E+00	2.36E+01	4.3E+01	3.45E+00	11.7
Mercury	4.7E+01	4.5E+02	2.68E+04	0.891	1.53E+01	1.39E+03	2.02E+03	8.25E-01	0.87
Copper	5.0E+04	m.d.	3.21E+7	n.r.	4.08E+04	8.34E+05	1.15E+05	1.84E+04	3.34E+4
Zinc	1.0E+05	2.4E+06	6.42E+7	n.r.	1.63E+04	1.33E+05	8.58E+05	1.24E+04	5.24E+4
Chromium (III)	1.0E+05	1.2E+06	6.42E+07	n.r.	3.26E+05	6.06E+07	8.57E+8	7.18E+04	92000
Chromium (VI)	1.0E+05	5.33E+05	7.32	n.r.	4.91E+03	9.13E+05	1.29E+7	7.31	7.32
Nickel	5.0E+02	6.85E+02	2.93E+02	n.r.	8.16E+01	1.96E+03	2.15E+05	5.09E+01	135
Free Cyanide	1.2E+03	1.92E+03	7.7E+05	3.88E+1	2.19E+00	5.32E+00	5.75E+03	1.49E+00	4.64
PCB CAS1336-36-3	8.13E-01	5.76E+00	8.34E+01	2.35E+1	7.18E-01	4.83E-03	4.02E-01	4.71E-03	4.74E-03
Pentachlorophenol	5.19E+01	2.24E+02	1.83E+02	1.41E-1	1.62E-01	2.70E-03	3.41E+00	2.6E-03	2.64E-03
Lindane	4.69E+00	m.d.	6.34E+2	1.84E+2	2.77E-02	0.12	9.96E+01	2.17E-02	1.01E-01
DDT	1.81E+01	m.d.	1.71E+05	2.37E+4	4.0E+01	3230	3.51E+01	9.17	11.9
Monochlorobenzene	9.0E+03	4.31E+04	9.76E+06	8.97	3.2E+01	1.73E+01	2.1E+04	4.98E+00	5.9
1,2-dichlorobenzene	4.3E+04	2.06E+05	6.34E+06	21.10	2.73E+02	5.93E+01	3.12E+04	1.5E+01	1.55E+1
1,4-dichlorobenzene	2.5E+02	1.19E+03	3.66E+05	1.15	7.15E-01	1.68E-01	1.04E+01	1.2E-01	1.44E-1
1,2,4-trichlorobenzene	7.7E+02	4.61E+03	2.2E+05	2.41	1.95E+01	1.88E+00	4.50E+02	9.99E-01	1.05
1,2,4,5-tetrachlorobenzene	3.0E+01	m.d.	1.93E+04	2.32E+01	1.01E+01	3.11E-01	5.49E+01	2.93E-01	3.02E-01
Pentachlorobenzene	8.0E+01	m.d.	5.13E+04	3.05E+01	7.93E+01	1.1E+00	8.02E+00	9.16E-01	9.26E-01
Hexachlorobenzene	2.06E+01	7.54E+01	4.88E+03	7.14	4.18E+00	3.34E-02	3.66E+00	3.26E-02	3.28E-02
Dichloromethane	8.13E+02	m.d.	8.54E+06	3.12	1.87E-01	2.91E-01	9.86E+02	1.1E-01	2.66E-01
Trichloromethane	1.03E+02	4.87E+02	1.07E+04	3.35E-03	3.86E-02	5.57E-02	7.8E+01	2.92E-03	3.16E-03
Trichloroethylene	2.4E+03	1.15E+04	1.32E+07	2.48	4.34E+00	3.68E+00	6.71E+03	1.1E+00	1.48
Tetrachloroethylene	1.25E+02	5.94E+02	1.34E+05	4.6E-02	2.16E-01	1.63E-01	7.37E+01	3.07E-02	3.58E-02
1,1,1-trichloroethane	7.0E+03	3.35E+04	1.95E+07	2.23	1.37E+01	1.18E+01	3.99E+04	1.65E+00	1.87
Benzo(a)pyrene	8.76E-01	2.08E+00	2.68E+00	5.64E+1	4.33E+00	1.15E-02	4.04E+00	1.11E-02	1.12E-02
Naphtalene	4.00E+03	1.92E+04	2.57E+06	1.51E+02	1.31E+02	3.23E+01	1.51E+04	2.19E+01	2.63E+01
Fluorene	4.00E+03	9.59E+03	2.57E+06	7.98E+03	9.01E+02	6.16E+01	1.46E+04	5.59E+01	5.96E+01
Fluoranthene	4.00E+03	9.59E+03	2.57E+06	2.44E+05	6.98E+03	1.05E+02	1.39E+04	9.93E+01	1.01E+02
Pyrene	3.00E+03	7.19E+03	1.93E+06	2.62E+05	5.14E+03	7.89E+01	1.05E+04	7.44E+01	7.55E+01
Benzene	2.06E+02	1.22E+03	3.17E+04	7.36E-03	7.95E-02	9.62E-02	1.92E+02	6.3E-03	6.84E-03
Toluene	2.2E+04	8.79E+04	9.76E+05	4.25E-01	5.23E+01	3.32E+01	3.52E+04	4.17E-01	4.2E-01
Ethylbenzene	1.0E+04	2.4E+04	9.76E+05	5.48E-01	3.86E+01	1.33E+01	1.18E+04	5.19E-01	5.26E-01
Xylene	1.8E+04	7.19E+4	9.76E+05	8.18E-01	8.06E+01	2.82E+01	2.02E+04	7.87E-01	7.95E-01
Aliphatics C5-C6	5.00E+05	1.20E+06	4.49E+08	1.07E+01	9.88E+03	2.73E+03	1.37E+06	1.07E+01	1.07E+01
Aliphatics >C6-C8	5.00E+05	1.20E+06	4.49E+08	2.99E+01	3.76E+04	3.64E+03	1.02E+06	2.97E+01	2.97E+01
Aliphatics >C8-C10	1.00E+04	2.40E+04	2.44E+07	7.56E+00	5.38E+03	1.21E+02	1.84E+04	7.10E+00	7.11E+00

Substance	Ingestion of soil C_{is} mg/kg	Dermal contact of soil C_{du} mg/kg	Inhalation of dust C_{id} mg/kg	Inhalation of vapour C_{iv} mg/kg	Intake of drinking water C_{iw} mg/kg	Consumption of vegetables C_{ig} mg/kg	Consumption of fish C_{if} mg/kg	Total all exposure mg/kg	Total excluding intake of drinking water mg/kg
Aliphatics>C10-C12	1.00E+04	2.40E+04	2.44E+07	3.67E+01	4.10E+04	1.96E+02	1.80E+04	3.07E+01	3.08E+01
Aliphatics >C12-16	1.00E+04	2.40E+04	2.44E+07	1.76E+02	8.16E+05	3.91E+02	1.79E+4	1.19E+02	1.190E+02
Aliphatics >C16-35	2.00E+05	4.79E+05	1.28E+08	1.17E+04	3.26E+09	3.04E+04	4.29E+5	7.85E+03	7.85E+03
MTBE	1.00E+04	4.79E+04	7.32E+07	4.36E+01	3.29E+00	7.41E+00	4.33E+04	2.17E+00	6.33E+00
1,2-dichloroethane	6.26E+02	2.97E+093	9.27E+03	2.79E-03	8.22E-02	1.71E-01	7.21E+02	2.65E-03	2.74E-03
1,2-dibromoethane	7.51E-02	3.56E-01	1.12E+03	1.29E-03	1.99E-05	2.85E-05	5.75E-02	1.16E-05	2.79E-05
Tetraethyllead	1.00E-02	4.79E-02	6.42E+00	6.21E-04	7.01E-05	2.86E-05	1.84E-02	1.96E-05	2.72E-05

Arsenic

The health related soil quality guideline determined the soil quality guideline for arsenic. As Table 19 shows, the sum of the individual concentrations from the different exposure pathways is very low (0.06 mg/kg) compared to the reported natural background values of arsenic (0.7-8.8 mg/kg). The most important exposure pathway is drinking water, whereas the individual concentrations of ingestion of soil and dust, consumption of vegetables and consumption of fish and shellfish each have the same order of magnitude as the background values. The reason for this is the low reported MTDI-value for cancer risk for oral intake of $6 \cdot 10^{-6}$ mg/kg. Since the health based guidelines for arsenic were greatly influenced (much lower) when contaminated drinking water was included, it was decided to investigate arsenic in more detail. The reported MTDI-value turns out to be not well documented. It originates from a Thai fish study. It is known that arsenic becomes methylated in fish. Studies have shown that natural arsenic does not exist in the groundwater even with naturally high contents in the ground. After discussions with the health authorities, the exposure pathway from drinking water has been omitted in determining the prevailing soil quality guideline for arsenic.

Cyanide

The ecotoxicological based guidelines will normally determine the soil quality guidelines for cyanide. Table 18 shows that the lowest NOEC-value is 0.005 mg/l for free cyanide. This originates from a fish test (*Lepomis macrochirus*). A safety factor of 50 and a K_d -value equal to 1 were selected to determine the PNEC value. The PNEC-value for free cyanide is calculated to **0.0001 mg/kg**, this is the suggested ecotoxicological based soil quality guideline. Terrestrial ecotoxicological data does not exist for cyanide. The authorities have therefore chosen to omit the ecotoxicological based guidelines when deriving the soil quality guidelines. Therefore the health based guideline value is utilised for the prevailing soil quality guidelines. Cyanide is however, extremely toxic for water living organisms and therefore a special assessment must be completed if this exposure pathway is relevant.

Aromatic hydrocarbons

Individual soil quality guidelines are not calculated for the different aromatic hydrocarbon fractions. Instead, BTEX and the PAH-compounds; benzo(a)pyrene, naphthalene, fluorene, fluoranthene and pyrene are selected as representatives for the aromatic hydrocarbons in regard to the soil quality guidelines.

Benzo(a)pyrene is the starting point in the calculation of the soil quality guidelines for **PAH**. The authorities have chosen to omit the consumption of vegetables as an exposure pathway for benzo(a)pyrene and Σ PAH. Benzo(a)pyrene has its own soil quality guideline value and the soil quality guideline value for Σ PAH (Σ 16) is assumed equal to twenty times this. A special assessment must be completed if the consumption of vegetables becomes a relevant exposure pathway. Guidelines are calculated for the remaining PAH compounds where MTDI-values have been available: naphthalene, fluorene, fluoranthene and pyrene. These soil quality guidelines are calculated using the previously defined method.

BTEX: The soil quality guidelines for benzene are adjusted based on the detection limit. There is adequate chronic ecotoxicological data for ethylbenzene and toluene, however there is fewer data for xylene. Therefore the safety factor for xylene is high. This resulting soil quality guideline for xylene has been adjusted, similar to ethylbenzene and toluene. The final value is rounded off to 0.5 mg/kg as it is expected that these three substances will behave similarly. Regardless this correction, the soil quality guideline for xylene will be lower than the health related soil quality guideline.

Aliphatic hydrocarbons

Soil quality guidelines are calculated for several aliphatic hydrocarbon fractions. There are chosen based on the suggestions from Naturvårdsverket and the Swedish Petroleum Insti-

tute (that are based on the work performed from the TPHWG (1997a, b, c). The same methods that are utilised to determine the Norwegian soil quality guidelines for most sensitive land use are utilised to determine the soil quality guidelines for the aliphatic hydrocarbons. Therefore, the health based guidelines for these substances are not necessarily the same as the given Swedish guideline values.

The ecotoxicological based soil quality guidelines are however the same as the Swedish guidelines. Aquatic data has also been assessed for those substances since data from terrestrial tests are not available. The reported NOEC-values from aquatic tests are however extremely low, presumably because oil products with unknown BTEX content has been tested. This data is therefore not utilised in the determination of the soil quality guidelines. The data from Naturvårdsverket is used instead. Their data is based on reported soil quality criteria for most sensitive land use from the Netherlands and Canada. The ecotoxicological based guidelines appear to have little meaning compared to the health based guidelines for the most toxic substances.

A larger division of hydrocarbon fractions is used to derive the Norwegian soil quality guidelines than used by Naturvårdsverket. The grouping is based on level of toxicity (Table 18). The soil quality guidelines are developed for the following hydrocarbon fractions: C5-C10, >C10-C12, >C12-C35. A comparison between the Swedish and Norwegian values is given in Table 20.

Table 20: Comparison of the Swedish and the Norwegian soil quality guidelines for aliphatic hydrocarbons and additives to gasoline and oil products.

Substance	Swedish soil quality criteria for most sensitive land use (mg/kg)	Norwegian soil quality guidelines (mg/kg)
Aliphatics C5-C8	50 ³⁾	7 ^{2) 4)}
Aliphatics >C8-C10	100 ³⁾	
Aliphatics >C10-C12	100 ³⁾	30 ⁴⁾
Aliphatics >C12-C16	100 ³⁾	100 ^{3) 4)}
Aliphatics >C16-C35	100 ³⁾	
MTBE	6 ⁴⁾	2 ⁴⁾
1,2-dichloroethane	0.05 ⁴⁾	0.003 ⁴⁾
1,2-dibromoethane	0.00002 ^{1) 4)}	0.004 ⁴⁾
Tetraethyllead	0.00004 ^{1) 4)}	0.001 ⁴⁾

1) The detection limit for 1,2-dibromoethane is 0.004 mg/kg and 0.001 mg/kg for tetraethyllead.

2) Lowest value: >C8-C10 gives a health based value equal to 7 mg/kg. This is selected.

3) Ecotoxicological value is decisive for the soil quality guidelines.

4) Human data is decisive for the soil quality guidelines

The differences between the Swedish and the Norwegian human toxicological soil quality guidelines is due to the differences in the input parameters used for most sensitive land use. This difference is firstly from the effect of inhalation of vapour. Norway utilised a air content in soil value equal to 0.2 dm³ air/dm³ soil for most sensitive land use, while Sweden used a value equal to 0.09 dm³ air/dm³.

Additives to gasoline and oil products

Soil quality guidelines are calculated for MTBE, 1,2-dichloroethane, 1,2-dibromoethane and tetraethyllead. These are chosen based on the suggestions from Naturvårdsverket and the Swedish Petroleum Institute. Ecotoxicological data is not found for 1,2-dibromoethane and tetraethyllead. Human toxicity data is therefore selected in the derivation of the soil quality guidelines. The health based values are however very low and will regardless have determined the soil quality guidelines. The Norwegian soil quality guidelines from the additives are determined utilising the same methods as for all the other chemical substances.

20. Check-list for the problem description

20.1. Problem description

The problem description is based on the review of previous information without having to excavate, bore or take samples. The information will contain:

- Information about the site
 - Identification
 - Owner
 - Land use
 - Overview of ditches and cabling
 - Location of the contaminant
 - Local environmental objective (present and future land use, present and future use of groundwater and surface recipients, other relevant conditions and important restrictions, etc.)
- Background for the site investigation
- Description of the source (expected contaminants)
 - Primary sources (based on present and earlier land use)
 - Contaminant (amount, environmentally related substance information)
 - Secondary sources (contaminated surface soil (< 1 m deep), mineral soil (> 1 m deep), groundwater, free-phase, surface water, sediment (freshwater/marine))
 - Possible location of primary and secondary sources
 - Other relevant information (time aspects for possible contamination and other activities that may have influenced primary and secondary sources)
 - References/uncertainty in available information
- Migration/transport related information
 - Possible migration routes (soil, water, air)
 - Topographical conditions, soil type, clay, homogeneity, etc.
 - Climatic conditions
 - Probable extent of and the processes affecting migration
- Effect related information (based on the present land use and planned land use)
 - Possible recipients of the contaminant (human beings, ecosystem, groundwater, surface water, sediment) and secondary recipients (plants, fish, animals)
 - Existing condition of the relevant recipients (groundwater and surface water quality, natural background quality of the soil, quality of the sediments, plants and microorganisms in soil, fish and other useful resources)

20.2. Tier 1 risk assessment

A justification will be given for each answer.

Problem description

Problem description completed (Y/N):

Is the assessment of the source sufficient with respect to:

- other sources or environmental hazardous substances that ought to be analysed?
- extent and degree of detail in relation to what is considered adequate?
- limitations of the contaminants breadth?
- stability, natural degradation and possibility of migration/transport?

Uncertainty

Identified points of uncertainty are more closely investigated (Y/N)

Investigations

Are the investigations sufficient (Y/N):

- Are the samples representative for the defined area/volume?
- Are expectations set for precision and uncertainty of the samples, analyses and the results?
- Is the sample handling carried out correctly during the entire process of taking the samples, storing the sample and delivering the sample for analysis?
- Is there an agreement between the laboratory to ensure correct handling of the samples?

Describe additional investigations:

.....

.....

.....

.....

Extent of the investigations

Description:

.....

Minimum required data:

Description:

.....

(Maximum concentration of the contaminant for every source ought to be determined)

Relevant analytical parameters

- If heavy metals are expected as the contaminant (for example: mining, galvanic or metallurgical work place, electronic or metallurgic industry), 8 heavy metals will be analysed as a minimum.
- If hydrocarbon contamination is expected, analysis for PAH, BTEX and aliphatic hydrocarbons will be completed. If gasoline is the expected contaminant, it ought to be assessed whether it is necessary to run an analysis for typical additives such MTBE, tetra-

ethyllead, 1,2-dichloroethane and 1,2-dibromoethane. "Old" oils ought to also be analysed for PCB contamination.

- If the contaminant is expected to come from wood impregnation, Cu, Cr, As and PAH (identification of 16 PAH-compounds) will be analysed.
- When the contents are unknown (for example landfills) the investigation will consist of 8 heavy metals, PAH, mineral oil and EOX (sum of the extractable chlorinated organic compounds).

A justification will be given to explain why certain substances are analysed and others are not. SFT's guidance manual 91:01 gives examples for groups of substances that are applicable for the different industries

20.3. Tier 2 risk assessment

In a Tier 2 risk assessment it is necessary to determine how the contaminant decreases from the identified exposure points. Standard values from the models are usually utilised because site specific definitions is missing. Measured data will be reported if it is used. Typical data that will be assessed include:

- Extent of the sources (primary and secondary).

Lateral and vertical boundaries to the contaminated site; representative concentrations of the substances of concern.

- Hydrogeologic site specific conditions.

The area's stratigraphy, soil surface conditions, rate and direction of groundwater flow, dilution factor, etc.

- Relevant exposure points.

Distance from the source to the receptor of the contaminant (most probable point for contact with the contaminated soil, water or air).

A justification will be given for all choices that are made. Tables 21 and 22 will be filled out.

Problem description

Problem description completed (Y/N):

Maximum concentrations at the source

Maximum concentrations and relevant contaminants investigated at the source (Y/N):

Are all of the sources identified with certainty (Y/N):

Is the assessment of the source sufficient with respect to:

- other sources or environmental hazardous substances that ought to be analysed?
- extent and degree of detail in relation to what is considered adequate?
- limitations of the contaminants breadth?
- stability, natural degradation and possibility of migration/transport?

Uncertainty

Are uncertainties with the investigation assessed (Y/N):

- Are the samples representative for the defined area/volume?
- Are expectations set for precision and uncertainty of the samples, analyses and the results?
- Is the sample handling carried out correctly during the entire process of taking the samples, storing the sample and delivering the sample for analysis?
- Is there an agreement between the laboratory to ensure correct handling of the samples?
- Are the chosen detection limits and the uncertainty in the analysis satisfactory?
- Are the most relevant parameters analysed?

Probable migration/transport of the contaminants

Is the migration/transport and the probability of this assessed (Y/N):

- Are the most probable migration routes and possible variations based on natural processes that influence transport assessed?
- Are other migration/transport routes that can influence human beings or the ecosystem assessed?
- Has an assessment been completed to determine if the contaminant can be influenced by other conditions than those that are described?
- Has an assessment been completed to determine how the migration/transport will occur (evenly throughout the year, unevenly between seasons or shorter episodes such as discharges, precipitation and tidal effects)?
- Is undesirable migration/transport identified?

Exposure

Tick off the boxes in the exposure form for relevant exposure pathways.

Primary Sources	Secondary Sources	Transport Mechanisms	Migration-media	Exposure	Organisms Influenced	
Storage Tanks <input type="checkbox"/>	Surface Contamination (0.01m) <input type="checkbox"/>	Water Erosion <input type="checkbox"/>	Surface Water <input type="checkbox"/>	Direct Contact, Water <input type="checkbox"/>	Humans <input type="checkbox"/>	Environment <input type="checkbox"/>
Pipes <input type="checkbox"/>	Buried Contamination (>1.0m) <input type="checkbox"/>	Leaching <input type="checkbox"/>	Groundwater <input type="checkbox"/>	Direct Contact, Soil <input type="checkbox"/>	Residents at the Site <input type="checkbox"/>	Sensitive Environment <input type="checkbox"/>
Operation of Installation <input type="checkbox"/>	Free Phase Contamination <input type="checkbox"/>	Mechanical Erosion <input type="checkbox"/>	Soil <input type="checkbox"/>	Ingestion, Soil <input type="checkbox"/>	Neighbours (Residents) <input type="checkbox"/>
Landfill <input type="checkbox"/>		Degassing <input type="checkbox"/>	Dust <input type="checkbox"/>	Inhalation of Dust <input type="checkbox"/>	Recreation <input type="checkbox"/>	Surface Water <input type="checkbox"/>
Other <input type="checkbox"/>		Transport <input type="checkbox"/>	Air <input type="checkbox"/>	Inhalation of vapour (outside) <input type="checkbox"/>	Employees at the Site <input type="checkbox"/>
				Inhalation of vapour (inside) <input type="checkbox"/>	Users of Groundwater <input type="checkbox"/>	Animals <input type="checkbox"/>
					Other <input type="checkbox"/>	Plants <input type="checkbox"/>
					Other <input type="checkbox"/>
						Birds <input type="checkbox"/>
					
						Other <input type="checkbox"/>
					

Possible consequences

Are the consequences assessed in relation to conflicts tied to the requirements and local environmental objective (Y/N):

- Are the consequences using another land use than that used in the investigation assessed?
- Are the consequences of the hazards from individual substances or mixtures of the substances assessed?
- Are the consequences of potential environmental short and long-term effects assessed?
- Are the consequences of a deterioration in the situation assessed due to changes in the existing boundaries (from building, erosion or other degradation of barriers)?

Environmental objective and acceptance criteria

Is the environmental objective clearly stated (Y/N):

Are the acceptance criteria defined (Y/N):

Risk analysis

Is the risk analysis completed (Y/N):

- Are relevant sources, migration routes and possible effects assessed?
- Are user conflicts identified and assessed?
- Is the data/information sufficient with acceptable uncertainty behind the conclusions?
- Is the data/information and the conclusion in agreement?

Risk assessment

Is the risk assessment completed (Y/N):

- Are the acceptance criteria and the environmental objective identified for the relevant site?
- Is the data/information sufficient to compare the risk analysis with the acceptance criteria?

Table 21. The parameters utilised in the transport and reaction mechanisms (all values that are different from the standard values used to calculate the acceptance criteria will be noted and justified)?

Parameter	Symbol	"Default value"	Used value	Justification ¹⁾
<u>Soil specific data:</u>				
soil water content	θ_w	0.2 l water/l soil		
air water content	θ_a	0.2 l air/l soil		
soil's density	ρ_s	1.7 kg/l		
fraction organic carbon in soil	f_{oc}	0.01 (1%)		
soil's porosity	ϵ	0.4		
<u>Dilution to indoor air:</u>				
inside volume of the house	V_{house}	240 m ³		
intrusion rate of pore air	L	2.4 m ³ /d		
area under the house	A	100 m ²		
depth to the contaminant	Z	0.5 m		
replacement rate of air in the house	I	12 d ⁻¹		
diffusivity to pure air	D_o	0.7 m ² /d		
<u>Dilution to groundwater:</u>				
soil's hydraulic conductivity	k	10 ⁻⁵ m/s		
length of the contaminated site in direction of groundwater flow	L_{gw}	50 m		
distance from the contaminated site to the well	X	0 m		
hydraulic gradient	i	0.02 m/m		
infiltration rate	I	0.075 m/year		
thickness of aquifer	d_a	10 m		
thickness of mixing zone in aquifer	d_{mix}	5.87 m		
<u>Dilution to surface water:</u>				
water flow rate in surface water	Q_{sw}	500,000 m ³ /year		
width of contaminated area perpendicular to the direction of the groundwater flow	L_{sw}	7.34 m		
calculated discharge of groundwater from the contaminated area to surface water	Q_{di}	271.7 m ³ /year		

1) Describe which data is used. Justify all deviations from the "default values" for most sensitive land use.

Table 22. Parameters and exposure pathways utilised in the exposure of human beings. All adjusted values will be noted and justified.

Parameter	Symbol	"Default value"	Used value	Justification ¹⁾
<u>Ingestion of soil ²⁾:</u>				
Average daily ingestion, child	DI _{is}	150 mg/d		
Average daily ingestion, adult	DI _{is}	50 mg/d		
Fraction exposure time	f _{exp}	1 (365 d/year)		
Long-term ingestion pr. kg body weight, child	R _{is}	10 mg/(kg-d)		
Long-term ingestion pr. kg body weight, adult	R _{is}	0.714 mg/(kg-d)		
Integrated lifetime ingestion of soil	R _{is}	1.599 mg/(kg-d)		
<u>Dermal contact ²⁾:</u>				
Exposure for soil, child		5100 mg/m ²		
Exposure for soil, adult		5100 mg/m ²		
Exposed skin surface, child		0.28 m ²		
Exposed skin surface, adult		0.17 m ²		
Average daily dermal exposure for soil, child	DI _{du}	1428 mg/d		
Average daily dermal exposure for soil, adult	DI _{du}	867 mg/d		
Fraction exposure time, child	f _{exp}	0.219 (80 d/year)		
Fraction exposure time, adult	f _{exp}	0.123 (45 d/year)		
Long-term dermal exposure pr. body weight, child	R _{du}	20.866 mg/(kg-d)		
Long-term dermal exposure pr. body weight, adult	R _{du}	1.525 mg/(kg-d)		
Integrated lifetime dermal exposure	R _{du}	3.369 mg/(kg-d)		
<u>Inhalation of dust ²⁾:</u>				
Concentration of dust in inhaled air, child	C _{ad}	0.041 mg/m ³		
Concentration of dust in inhaled air, adult	C _{ad}	0.041 mg/m ³		
Breathing rate, child	PH	7.6 m ³ /d		
Breathing rate, adult	PH	20 m ³ /d		
Lung retention, child	LR	75%		
Lung retention, adult	LR	75%		
Fraction exposure time	f _{exp}	1 (365 d/year)		
Long-term inhalation of dust pr. body weight, child	R _{id}	0.0156		
Long-term inhalation of dust pr. body weight, adult	R _{id}	0.0088 mg/(kg-d)		
Integrated lifetime inhalation of dust	R _{id}	0.0094 mg/(kg-d)		
<u>Inhalation of vapour ²⁾:</u>				
Breathing rate, child	PH	7.6 m ³ /d		
Breathing rate, adult	PH	20 m ³ /d		
Fraction exposure time	f _{exp}	1 (365 d/år)		
Long-term inhalation of vapour pr. body weight, child	R _{iv}	507 (m ³ /(kg-d)) / (g/m ³)		
Long-term inhalation of vapour pr. body weight, adult	R _{iv}	286 (m ³ /(kg-d)) / (g/m ³)		
Integrated lifetime inhalation of vapour	R _{iv}	307 (m ³ /(kg-d)) / (g/m ³)		
<u>Intake of drinking water ²⁾:</u>				
Average daily intake of drinking water, child	DI _{iw}	1 l/d		
Average daily intake of drinking water, adult	DI _{iw}	2 l/d		
Fraction exposure time	f _{exp}	1 (365 d/year)		
Long-term intake of drinking water pr. body weight, child	R _{iw}	0.067 l/(kg-d)		

Parameter	Symbol	"Default value"	Used value	Justification ¹⁾
Long-term intake of drinking water pr. body weight, adult	R _{iw}	0.028 l/(kg-d)		
Integrated lifetime intake of drinking water	R _{iw}	0.032 l/(kg-d)		
Consumption of vegetables ²⁾:				
Average daily consumption of vegetables, child	D _{lig}	0.15 kg/d		
Average daily consumption of vegetables, adult	D _{lig}	0.29 kg/d		
Fraction exposure time	f _{exp}	1 (365 d/year)		
Fraction of consumption of vegetables grown at the contaminated site	f _h	0.3 (30%)		
Fraction of stem/leaf-vegetables in total vegetables	f _{stem}	0.5 (50%)		
Fraction of root vegetables in total vegetables	f _{root}	0.5 (50%)		
Long-term consumption of vegetables pr. body weight, child	R _{ig}	0.01 kg/(kg-d)		
Long-term consumption of vegetables pr. body weight, adult	R _{ig}	0.004 kg/(kg-d)		
Integrated lifetime consumption of vegetables	R _{ig}	0.0047 kg/(kg-d)		
Consumption of fish/shellfish ²⁾:				
Average daily consumption of fish and shellfish, child	D _{lif}	0.07 kg/d		
Average daily consumption of fish and shellfish, adult	D _{lif}	0.14 kg/d		
Fraction exposure time	f _{exp}	1 (365 d/year)		
Fraction of fish from nearby recipient	f _f	1 (100%)		
Lipid content of fish	l	10%		
Long-term consumption of fish and shellfish pr. body weight, child	R _{if}	0.0047 kg/(kg-d)		
Long-term consumption of fish and shellfish pr. body weight, adult	R _{if}	0.002 kg/(kg-d)		
Integrated lifetime consumption of fish and shellfish	R _{if}	0.0022 kg/(kg-d)		

1) Describe which exposure pathways that are included and which data is used. Justify all deviations from the "default values" for most sensitive land use.

2) Utilised for the calculations: child's body weight 15 kg, age 0-6 years and total exposure time 6 years, adult's body weight 70 kg, age 7-64 years and total exposure time 57 years.

20.4. Tier 3 risk assessment

A Tier 3 risk assessment is carried out in those instances a Tier 2 is not applicable or not sufficient. One or several of the points from Tier 2 can be investigated further in a Tier 3 assessment. This means that more detailed and site specific information is collected and appropriate models (numerical) are used.

Tier 3 typically entails the requirement of much more data. Therefore, the costs tied to data collection will be much higher for Tier 3 than for Tier 1 and 2. This tier is therefore used in complex situations where the costs to complete detailed remedial measures are very large. Since Tier 3 is not described in detail in the guidance manual, a check list is not completed.

21. Form to order the final reports from the EU project

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