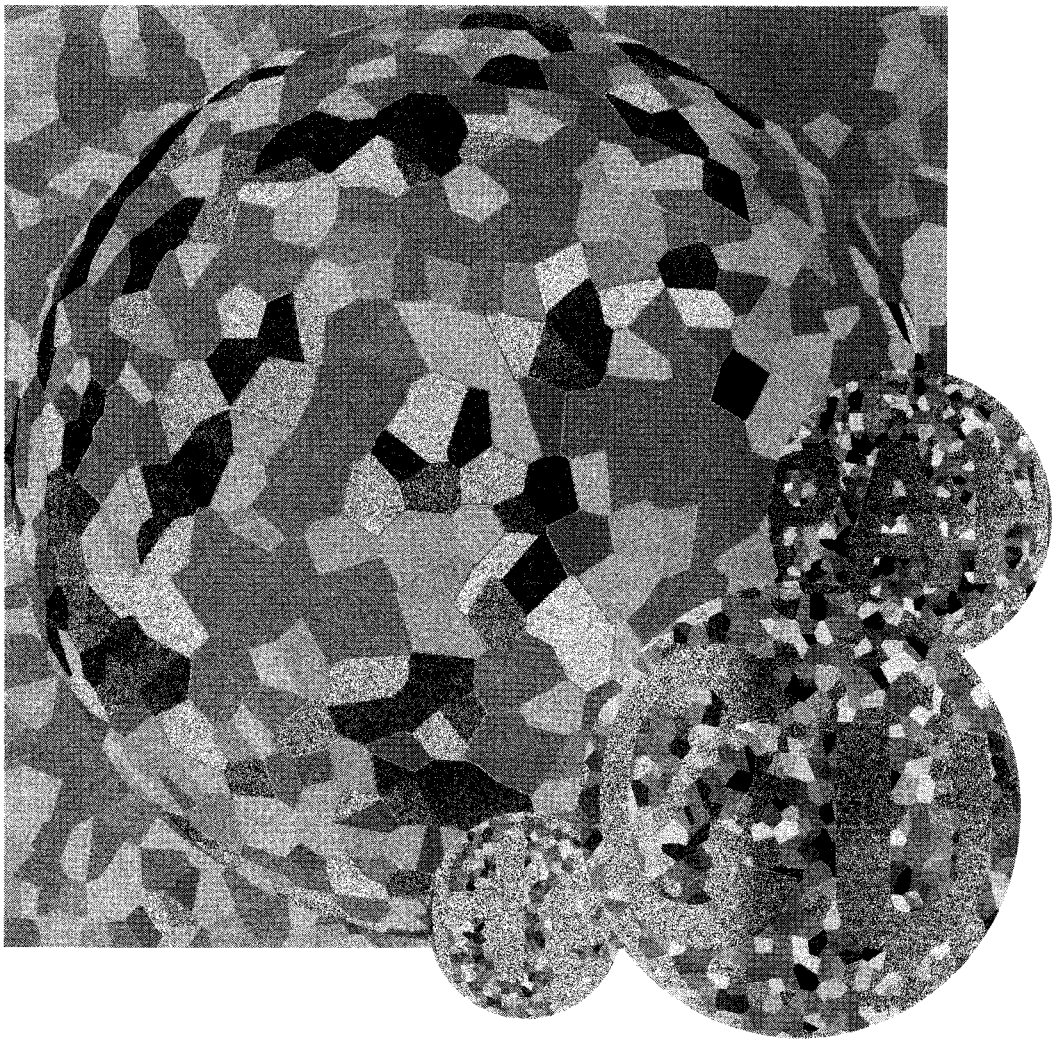
SWEDISH ENVIRONMENTAL PROTECTION AGENCY



Development of generic guideline values

Model and data used for generic guideline values
for contaminated soils in Sweden

REPORT 4639

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for contaminated soils in Swden

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Preface

The Swedish Environmental Protection Agency is currently developing a framework for the analysis of risks associated with contaminated soils. Guideline values are being developed as a part of this framework, and are intended to indicate contaminant concentrations above which undesirable effects on human health and/or the environment may occur. Generic guidelines have been developed for contaminated soils in Sweden [Naturvårdsverket, 1996a], considering both effects on human health and the effect on the environment.

This report forms the background documentation for the generic guideline values. The model and basic assumptions are presented together with the data used to evaluate distribution and transport of contaminants, exposure of humans, toxicological and ecotoxicological effects.

The guideline values are developed for typical Swedish conditions concerning exposure, geology, hydrology and the sensitivity of the site and will be suitable for a large number of sites in Sweden. However, for some sites the conditions may be such that the generic guideline values are not applicable. In these cases a site-specific analysis may be necessary.

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Stockholm December 1996

List of contents

Summary		**6**
Sammanfattning		**8**
1	**Introduction**	**10**
1.1	Background	10
1.2	Methods for development of guideline values	11
1.3	Principals and assumptions for the Swedish generic guideline values	12
2	**Distribution and transport of contaminants**	**14**
2.1	Distribution of contaminants	14
2.1.1	Mathematical description of contaminant distribution in the soil	15
2.2	Transport of contaminants	16
2.2.1	Transport of vapor from soil to indoor air	16
2.2.2	Transport of contaminants to a groundwater well	17
2.2.3	Transport of contaminants to surface waters	19
2.2.4	Transport of contaminants to plants	20
3	**Model for human health risks**	**22**
3.1	Toxicology	23
3.2	Exposure pathways	24
3.2.1	Intake of contaminated soil	25
3.2.2	Dermal contact with soil and dust	26
3.2.3	Inhalation of dust	28
3.2.4	Inhalation of vapors	29
3.2.5	Intake of drinking water	31
3.2.6	Intake of vegetables grown on the contaminated site	33
3.2.7	Intake of fish from nearby surface water	34
3.3	Integration of exposure from different pathways	34
3.3.1	Adjustment of values to correspond to tolerable daily intakes	35
3.3.2	Adjustment of values for background exposure	35
3.3.3	Adjustment of values for acutely toxic substances	36
4	**Model for environmental risk**	**37**
4.1	On-site effects	37
4.2	Off-site effects	38
5	**Other aspects**	**39**
6	**Integration of results**	**40**

7 Discussion 41

List of notations 43

References 47

Appendix 1. Generic guideline values for contaminated soils in Sweden A1:1

Appendix 2. Reference soil concentrations A2:1

Appendix 3. Physical and chemical data A3:1

Appendix 4. Toxicological data A4:1

Summary

This report describes the model and data used to derive the generic guideline values for contaminated soils in Sweden. Chapter 5 of the main report [Naturvårdsverket, 1996a] contains a detailed summary in Swedish. The set of guideline values is one of several tools currently being developed for risk assessments of contaminated sites in Sweden. The guideline values are intended to be used in assessments of contaminated sites to indicate contaminant levels which do not pose unacceptable risks to humans or the environment. They can also be used to indicate the degree of contamination on a site, to develop clean-up goals and to evaluate clean-up results.

Generic guideline values have been developed for a range of inorganic and organic substances of importance at contaminated sites: heavy metals, cyanides, phenols, chlorophenols, chlorobenzenes, chlorated hydrocarbons, PCB, dioxin, aromatics, polyaromatics.

The guideline values are developed for typical Swedish conditions concerning exposure, geology, hydrology and the sensitivity of the site and will be suitable for a large number of sites in Sweden. However, for some sites the conditions may be such that the generic guideline values are not applicable. In these cases a detailed site-specific analysis may be necessary.

For each substance generic guideline values are developed for three different types of land-use:

- Land with sensitive use, e.g. land used for residential areas, kindergarten, agriculture, groundwater extraction, etc.
- Land with less sensitive use and groundwater extraction, e.g. land used for offices, industry, roads, etc.
- Land with less sensitive use as above but with no groundwater extraction.

Human health effects as well as environmental effects are considered. For human health effects the following exposure pathways have been considered:

- direct intake of contaminated soil
- dermal contact with contaminated soil and dust
- inhalation of dust from the contaminated site
- inhalation of vapors
- intake of contaminated drinking water for land-use with groundwater extraction
- intake of vegetables grown on the contaminated site (land for sensitive use)
- intake of fish from nearby surface water (land for sensitive use)

Ecotoxicological effects both on the contaminated site and due to transport of contaminants from the site have been taken into account.

The basic principle for setting the generic guideline values is to choose the lowest of the human health based value and the ecotoxicologically based value. For substances where smell and odor problems can occur at lower concentrations this has been taken into consideration. However, a less conservative perspective is put on smell and odor problems compared to toxicological problems. Background concentration is taken into account in that no guideline value should be below the 90th percentile of the measured background concentration in rural environments.

Sammanfattning

Denna rapport beskriver den metod och de data som används för att ta fram generella riktvärden för förorenad mark i Sverige. I kapitel 5 av huvudrapporten [Naturvårdsverket, 1996a] ges en mer utförlig sammanfattning på svenska. De generella riktvärdena utgör en av flera verktyg som för närvarande utvecklas för riskbedömning av förorenade områden i Sverige. Riktvärdena är tänkta att ge vägledning vid uppskattning av vilken föroreningsnivå som bör underskridas för att undvika oönskade effekter för människa och miljö. De kan också användas för att bedöma graden av förorening på en plats, som underlag för åtgärdsmål samt för att utvärdera effekten av efterbehandlingsåtgärder.

De generella riktvärdena har tagits fram för en rad olika oorganiska och organiska föroreningar som förekommer vid förorenade markområden: tungmetaller, cyanider, fenoler, klorfenoler, klorbenser, klorerade kolväten, PCB, dioxin, aromater och polyaromater. Riktvärdena har utvecklats för typiskt svenska förhållanden vad gäller exponering, geologi, hydrologi och känslighet och är tillämpliga för ett stort antal platser i Sverige. För vissa platser är dock förhållandena sådana att de generella riktvärdena inte är tillämpliga och istället krävs en fördjupad platsspecifik riskanalys.

För varje förorening har generella riktvärden framtagits för tre typer av markanvänding:

- Känslig markanvändning - där markkvaliteten inte skall begränsa markanvändningen. Marken kan t ex användas till bostäder, daghem, odling, djurhållning och grundvattenuttag.
- Mindre känslig markanvändning med grundvattenskydd - t ex mark som används för kontor, industri eller vägar.
- Mindre känslig markanvändning utan grundvatten uttag - som ovan men inget grundvatten uttag sker inom påverkansområdet.

Effekter på människors hälsa (humantoxikologiska) och effekter på miljön (ekotoxikologiska) har beaktats. För effekter på människa har följande exponeringsvägar beaktats:

- direkt intag av förorenad jord
- hudkontakt med förorenad jord
- inandning av förorenat damm
- inandning av ångor
- intag av förorenat grundvatten
- intag av grönsaker som odlats på förorenad mark
- intag av fisk från ett närbeläget ytvatten

Ekotoxikologiska effekter både inom det förorenade området samt effekter orsakade av transport av föroreningar till ett närbeläget ytvatten har beaktats.

Det generella riktvärdet tas fram genom att välja det lägsta av ett beräknat humantoxikologiskt och ett beräknat ekotoxikologiskt värde. Detta värde kan justeras bland annat pga av att ämnets naturliga halter är höga i marken, att exponering för ämnet via födan är stor eller att ämnet är mycket akuttoxiskt. För ämnen där smak- och luktproblem kan uppstå vid lägre koncentrationer har detta beaktats, dock med en lägre grad av försiktighet än vid bedömning av de toxikologiska effekterna. Bakgrundshalter i mark har beaktats på så sätt att inget riktvärde har satts lägre än 90-percentilen av de bakgrundshalter som uppmätts på landsbygd.

1 Introduction

1.1 Background

The Swedish Environmental Protection Agency is currently developing a framework for the analysis of risks associated with contaminated soils. Guideline values are being developed as part of this framework. The guideline values are intended to be used in assessments of contaminated sites to indicate contaminant levels which do not pose unacceptable risks to humans or the environment. They may also be used to indicate the degree of contamination on a site, to develop clean-up goals and to evaluate clean-up results.

Generic guidelines have been developed, considering both effects on human health and the effect on the environment [Naturvårdsverket, 1996a]. The generic values have been derived using models and data which have been developed in other countries and by international organisations. The models and data were chosen, and in some cases adapted, so that the resulting generic guidelines are appropriate for typical Swedish conditions. However, at this stage, there has been no model development in order to develop a detailed "Swedish" model and only limited data collection.

The generic guideline values are intended to be generic in nature and applicable for typical Swedish conditions with respect to geology, hydrology, exposure conditions and the sensitivity of the site, and will be suitable for a large number of sites in Sweden. However, for some sites the conditions may be such that the generic guideline values are not applicable (eg. where the exposure conditions are different or there is a particularly sensitive ecosystem). In such cases, a site-specific analysis would be necessary.

The generic guidelines are calculated separately for individual contaminants, without consideration of the potential for interaction of each substance with other compounds present. If several contaminants with similar toxicological effects are present at levels near their respective guideline values, an analysis of the total risk should be made, taking into consideration the local circumstances (ie. a site-specific analysis).

This report forms the background documentation for the generic guidelines for contaminated soils in Sweden [Naturvårdsverket, 1996a]. The model and basic assumptions are presented together with the data used to evaluate distribution and transport of contaminants (Chapter 2), human exposure and human health risk (Chapter 3), and risks to the environment (Chapter 4). Other aspects which have been taken into account, (taste and smell of contaminants, background concentrations, detection limits) are described in Chapter 5. In Chapter 6, the integration of all these aspects to a single generic guideline value is described. Some suggestions for the further development of the model for generic guidelines are made in Chapter 7.

1.2 Methods for development of guideline values

Guideline values have been developed by the authorities in a number of countries for contaminants frequently found in soils. These values are based on models that estimate the potential effects on human health, and in some cases also the potential environmental effects. Though generic in nature, the models used in other countries have been developed specially for the environmental conditions and legislation of the respective country and are not necessarily applicable to Sweden. A number of models and evaluation systems from other countries have previously been evaluated regarding the suitability of models and model parameters for application to Swedish conditions [Elert et al, 1996; Jones, 1996]. The methodology used for the development of generic Swedish guideline values is based on the methodologies and data from the following countries, the Netherlands: CSOIL [van den Berg, 1991 and 1995], HESP [ECETOC, 1990 and 1992; Shell, 1994], the USA: Massachusetts Department of Environmental Protection [MDEP, 1994], US EPA Soil Screening Levels [USEPA, 1996], Canada: CCME [1994], Ontario MOEE [1994, 1996].

Models for estimation of guideline values address the following topics:

- distribution and transport of the contaminant in the environment
- pathways for exposure of humans to the contaminant
- estimation of toxicological risk from exposure
- estimation of ecotoxicological effects

Based on a potential future use of the site a set of exposure pathways are defined. In most cases the probability of the exposure pathways is not considered; it is assumed that exposure will occur, e.g. that there will be children who ingest soil, a garden plot producing vegetables for home-consupmtion or a well at the site. A typical set of exposure pathways is shown in Figure 1.1. For each of the pathways defined an estimate is made of the exposure using simple mathematical expressions. The exposure from the different pathways is added up and compared to certain toxicological criteria.

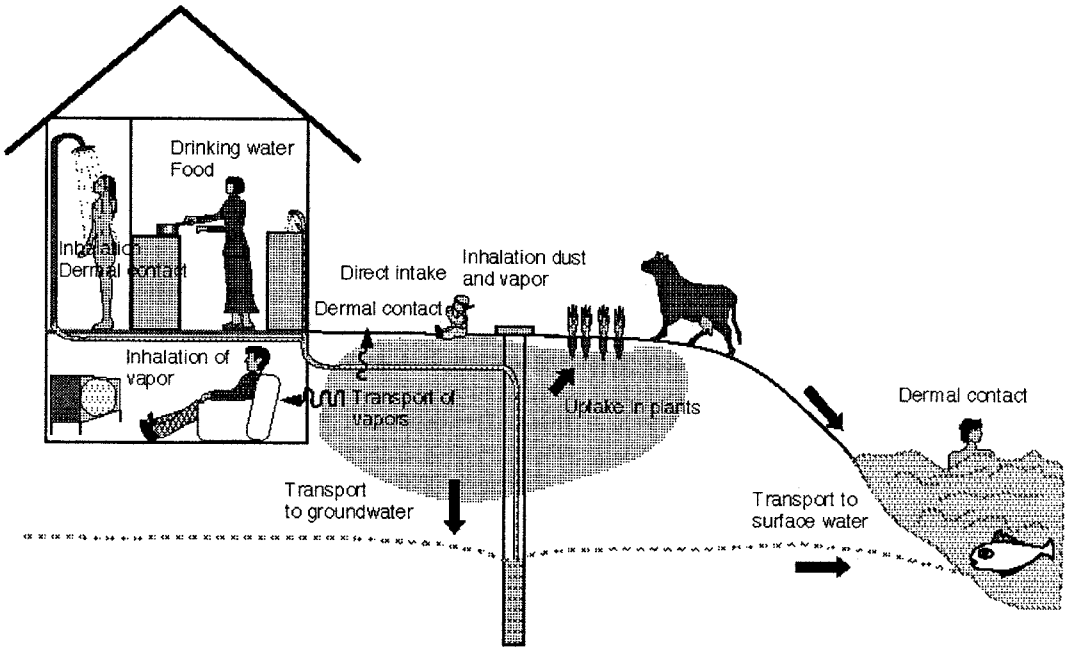

Figure 1.1 Possible transport and exposure pathways for a contaminated site

Models for estimation of ecotoxicological effects usually attempt to find a contamination level at which most of the animal and plant species in the soil are protected. The values are based on a statistical evaluation of the results of toxicity tests on a limited number of species. The statistical method is used to derive a contaminant concentration corresponding to the desired level of protection, expressed as the percentage of species that will not experience adverse effects.

1.3 Principals and assumptions for the Swedish generic guideline values

The Swedish generic guideline values should be valid for the whole of Sweden and should protect both man and the environment against undesirable effects. The guideline values are developed for three types of land use:

- Land with sensitive use (KM). All types of land use can be permitted, e.g. residential areas, kindergarten, agriculture, groundwater extraction, etc. The exposed persons may be children and adults permanently residing in the area. The exposed persons are assumed to have normal habits as regards consumption and activities (although not necessarily average). The on-site ecosystem, the ecosystem of recipient water bodies or downstream discharge zones, should be capable of supporting the full range of ecological functions.

- Land with less sensitive use and groundwater extraction (MKM GV). The land can be used for offices, industry, roads, etc. Groundwater extraction

occurs in the vicinity of the site. Adults are assumed to be in the area during working hours. Children are assumed to be in the area temporarily. The on-site ecosystem should be capable of supporting a limited range of ecological functions (e.g. growth of ornamental plant species, support transient animal species). The ecosystem in recipient water bodies or downstream discharge zones, should be capable of supporting the full range of ecological functions.

- Land with less sensitive use but no groundwater extraction (MKM). As above but without groundwater extraction in the area affected by the site.

Figure 1.2 shows the principal transport and exposure pathways considered in the model used for human exposure in the derivation of generic guideline values.

A generic model is used that can be applied for contaminants of different type. Generic guideline values have been developed for a range of inorganic and organic substances of importance at contaminated sites: heavy metals, cyanides, phenols, chlorophenols, chlorobenzenes, chlorated hydrocarbons, PCB, dioxin, aromatics, polyaromatics and hydrocarbons.

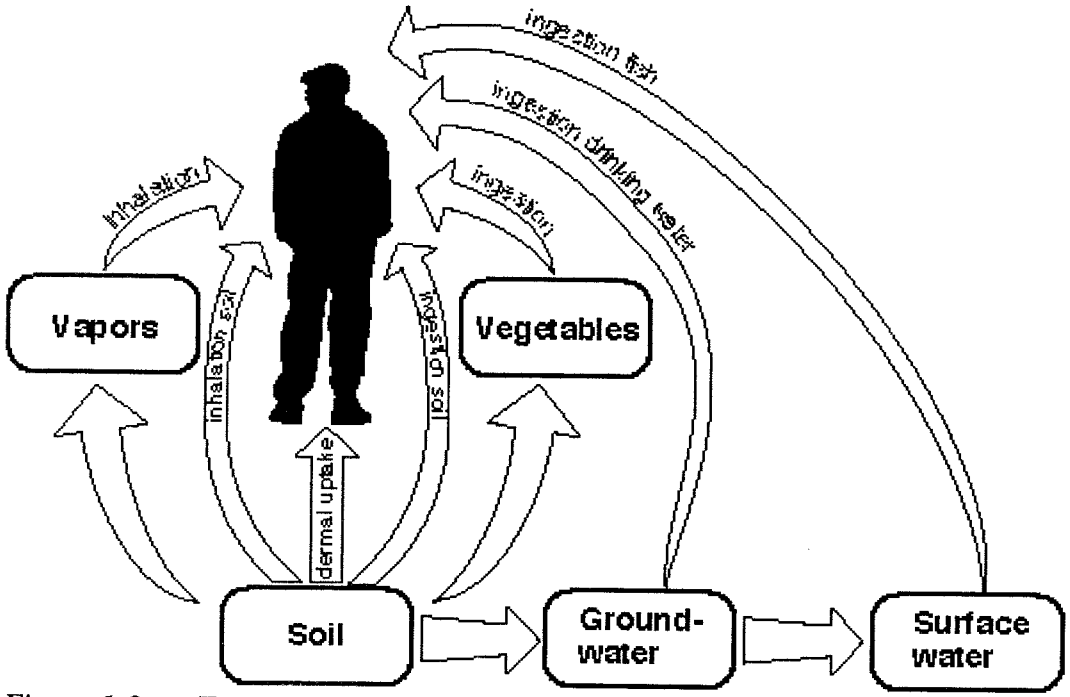

Figure 1.2 *Transport and exposure pathways considered for the Swedish generic guideline values*

2 Distribution and transport of contaminants

2.1 Distribution of contaminants

The distribution of the contaminant between different phases in the soil has an important effect on the rate of contaminant transport to media where exposure of man and the environment can occur. The approach used in the Swedish model is essentially the same as that used by models in the Netherlands, Canada, the United States and the United Kingdom. The following basic assumptions are used:

- The concentration in the soil is assumed to be constant with time, ie. no removal occurs by transport away from the site or degradation. This assumption is motivated by the very small effect of removal by transport and the very large uncertainties associated with predictions of degradation of organic substances. The assumption will be most conservative in the case of substances where the lifetime risk is of importance (ie genotoxic carcinogenic substances).

- The distribution of the contaminant between soil solids, pore water solution and pore air is assumed to be in equilibrium. The equilibrium concentrations are based on the fugacity model [Mackay and Paterson, 1981].

- The distribution of the contaminant between soil solids and soil solution is assumed to be in linear equilibrium, with respect to contaminant concentration, and is governed by a K_d-value.

- For metals and other inorganic substances, empirical K_d-values are used, see Appendix 3. The values have been chosen from the literature based on the general behavior of the substances in typical Swedish low sorbing soils. K_d-values are often very sensitive to pH. The values were chosen to be conservative within the pH-range 5 to 7 with respect to pathways for which transport via groundwater or surface water is important. Lower pH may increase mobility of many heavy metals, higher pH may increase mobility of arsenic.

- For organic substances, the K_d-value is related to the content of organic carbon in the soil, f_{oc},which is assumed to be 2% by weight.

  $$K_d = K_{oc} \cdot f_{oc}$$

  If available the distribution factor between water and organic carbon, K_{oc}, has been used. If this is not available, the K_{oc}-value is estimated from the

partitioning coefficient between water and octanol, K_{ow}. The value of K_{oc} is then given by the relationship below [van den Berg, 1995]:

$$K_{oc} = 0.411 \cdot K_{ow}$$

For ionizing organic substances the K_{oc}-value decreases with increasing pH. In this study values for a pH of 6.8 have been chosen and assumed to be reasonably conservative. The values used in the calculations are presented in Appendix 3.

- The distribution of the contaminant between the soil solution and the soil atmosphere is estimated using Henry's constant, ie the quotient between vapor pressure and solubility. The values of Henry's constant and their sources are given in Appendix 3.

2.1.1 Mathematical description of contaminant distribution in the soil

The starting point is the total concentration in the soil, C_s [mg/kg *dry weight*]. From C_s, the concentration in the pore water, C_w, [mg/l], is derived as:

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

where:

K_d is the distribution coefficient soil-water [l/kg]
θ_w is the soil water content [dm^3 water/dm^3 soil]
θ_a is the soil air content [dm^3 air/dm^3 soil]
H is Henry's constant [-]
ρ_b is the dry soil bulk density [kg/dm^3]

The vapor concentration in the pore air, C_a [mg/dm3], is given by:

$C_a = H \cdot C_w$

The values adopted for the basic soil parameters are given in Table 2.1.

Table 2.1 Basic soil parameters used in the calculation

Parameter	Value	Unit
Organic carbon content	2%	-
Bulk density	1.5	kg/dm^3
Water content	0.3	dm^3/dm^3 (tot)
Air content	0.2	dm^3/dm^3 (tot)

2.2 Transport of contaminants

A prerequisite for many of the exposure pathways considered in models for risk assessment of contaminated soils is the transport of the contaminant from the soil to other media where exposure of humans and other organisms can occur, for example transport to groundwater, surface waters, indoor and outdoor air, plants, fish and domestic animals. The contaminant concentration in these contact media is therefore calculated by the Swedish model for generic guideline values. The following transport pathways are considered in the model:

- transport of vapor from the soil to indoor air
- transport of contaminants to a groundwater well
- transport of contaminants to surface waters
- transport of contaminants to plants

Transport of vapors to outdoor air has not been considered as other studies have shown that the exposure of humans due to inhalation of vapors outdoors is negligible in comparison to exposure due to inhalation indoors [van den Berg, 1995].

2.2.1 Transport of vapor from soil to indoor air

Volatile and semi-volatile substances in the soil may be transported through the soil and penetrate into buildings where they may contaminate the indoor air and subsequently be inhaled by humans. Due to the limited transport of vapor through the soil and into buildings and to the dilution inside the building, the indoor concentration will be substantially less than the concentration in the pore air. It has been assumed that there is a constant relationship between the soil air concentration and the indoor air concentration which can be described by a dilution factor. The concentration in indoor air, C_{ia} [mg/dm^3], is given by:

$$C_{ia} = C_a DF_{ia}$$

where DF_{ia} is the dilution factor indoor air to soil air.

Two types of method are generally used to derive the dilution factor between soil air and indoor air. The first method (used in CSOIL and HESP) is based on theoretical models for the release of vapor from the soil and the dilution that occurs in indoor air, while the second method (used in MDEPs model) is based on the use of empirical relationships between the soil air and indoor air concentrations. The first method has the advantage of being able to take into account parameters such as contaminated soil depth, porosity and water content and substance dependent diffusivities. However, it is difficult to obtain values for a number of important parameters. It is also difficult to find reliable empirical

data for use with the second method. Most of the available data have been derived for radon, for which the relatively short half-life will limit the ability to penetrate into buildings.

The second method, based on the empirical data from MDEP [1994] has been used for the derivation of the generic Swedish guideline values. MDEP uses a dilution factor of 1/20 000 between soil air and indoor air, and this factor was thought to be most appropriate and therefore adopted here. As a comparison, the dilution factor used in CSOIL and HESP for an open floor basement is about 1/5000 and in HESP for a concrete floor basement about 1/70 000.

2.2.2 *Transport of contaminants to a groundwater well*

The leaching of contaminants from soils and transport to groundwater is a very site-specific process determined by a number of factors that may vary over a wide range. The model for the generic Swedish guideline values is based on a simplified model similar to that used by HESP and for the derivation of USEPA SSL-values. The model estimates the dilution between pore water concentration and the concentration in a well situated downstream from the contaminated site, either at the site boundary or some distance away from the site. The model assumes that the contaminants are leached by water infiltrating through the soil of the contaminated site and are transported down to the groundwater. The initial concentration in the leachate is assumed to be equal to the equilibrium pore water concentration. As the leachate reaches the groundwater it will be diluted by groundwater from upstream of the site, and if the well is placed far away from the site also by water infiltrating between the site and the well. The model contains several conservative assumptions:

- No sorption or degradation is considered during transport to the groundwater surface or to the well.
- Dilution by lateral dispersion in the aquifer is neglected, since the source may have a wide extent perpendicular to the flow direction

The concentration in the well water, C_{gw} [mg/l], is given by:

$$C_{gw} = DF_{gw}\ C_w$$

where:

$$DF_{gw} = \frac{L\ I}{kid_{mix} + (L+X)I}$$

L is the length of the contaminated area in the direction of the groundwater flow [m]

X is the distance from the contaminated area to the well [m]

I is the infiltration rate [m/a]
k is the hydraulic conductivity of the soil [m/a]
i is the hydraulic gradient [m/m]
d_{mix} is the thickness of the mixing zone in the aquifer [m]

The thickness of the mixing zone is given by:

$$d_{mix} = \sqrt{0.0112(L+X)^2} + d_a\left[1 - \exp\left(-\frac{LI}{kid_a}\right)\right]$$

where d_a is the aquifer thickness [m]. The thickness of the mixing zone cannot be greater than the aquifer thickness.

In the case of land for sensitive use (KM) the well is assumed to be located at the site boundary. In Table 2.2 a set of calculated examples is shown. A dilution factor 1/15 was chosen as reasonably conservative value for the calculation of the generic guideline values.

Table 2.2 Dilution factors for groundwater for well located at the site. Base case (shadowed) and parameter variations (in bold).

Length	Distance to well	Infiltration	k	d_a	d_{mix}	i	$1/DF_{gw}$
m	m	m/a	m/s	m	m	m/m	
50	**0**	**0.05**	**1.0E-5**	**10**	**5.4**	**0.02**	**14.7**
25	0	0.05	1.0E-5	10	2.7	0.02	14.7
100	0	0.05	1.0E-5	10	10.0	0.02	13.6
50	0	**0.1**	1.0E-5	10	5.4	0.02	7.9
50	0	**0.15**	1.0E-5	10	5.4	0.02	5.6
50	0	0.05	**1.0E-4**	10	5.3	0.02	134.9
50	0	0.05	**1.0E-6**	10	6.8	0.02	2.7
50	0	0.05	1.0E-5	**5**	5.0	0.02	13.6
50	0	0.05	1.0E-5	**20**	5.4	0.02	14.7
50	0	0.05	1.0E-5	10	5.4	**0.01**	7.9
50	0	0.05	1.0E-5	10	5.4	**0.05**	35.4

In the case of land for less sensitive use (MKM) the well is assumed to be located 500 meters from the site. A set of calculated examples is shown in Table 2.3. A dilution factor of 1/30 was chosen as a reasonably conservative value for the calculation of the generic guideline values.

Table 2.3 Dilution factors for groundwater for well located away from the site. Base case (shadowed) and parameter variations.

Length	Distance to well	Infiltration	k	da	d_{mix}	i	$1/DF_{gw}$
m	m	m/a	m/s	m	m	m/m	
50	0	0.05	1.0E-5	10	5.4	0.02	14.7
50	100	0.05	1.0E-5	10	5.8	0.02	17.5
50	200	0.05	1.0E-5	10	6.1	0.02	20.3
50	**500**	**0.05**	**1.0E-5**	**10**	**6.9**	**0.02**	**28.4**
50	1000	0.05	1.0E-5	10	8.1	0.02	41.5

2.2.3 *Transport of contaminants to surface waters*

The model for transport of contaminants to surface waters and the dilution in surface water is based on a simplification of a model used in HESP. In the model used for derivation of Swedish guideline values, the effect of surface erosion has been neglected. Leaching of contaminants from the soil is represented as described above in the model for transport of contaminants to groundwater. The groundwater is assumed to flow out into a lake or a river with a certain turnover time or annual flow rate. The dilution factor of 1/15 is used to represent dilution of groundwater at the site boundary by the surface water.

The concentration in the surface water, C_{sw} [mg/l] is given by:

$$C_{sw} = C_{gw} DF_{sw}$$

where:

$$DF_{sw} = \frac{Q_{di}}{Q_{sw}} = \frac{kid_{mix}L_w}{Q_{sw}}$$

Q_{di} is the discharge of groundwater from the contaminated site to the surface water [m^3/a]
Q_{sw} is the water flow rate in the surface water [m^3/a]
L_w is the width of the contaminated area perpendicular to the direction of the groundwater flow [m]

For lakes the water flow rate is determined as:

$$Q_{sw} = V_{sw} k_t$$

where:

V_{sw} is the volume of the lake [m^3]
k_t is the turnover rate of the lake [a^{-1}]

Assuming a groundwater discharge of 250 m^3/a and a water flow rate of 1 000 000 m^3/a in the surface water (0.03 m^3/s) a dilution factor of 1/4000 has been adopted

(a total dilution factor of 1/60 000 from pore-water to surface water). This factor is thought to be representative of dilution in a small size lake or stream.

2.2.4 Transport of contaminants to plants

Exposure due to the consumption of edible plants has been found to be an important pathway in several models used in other countries. However, methods to estimate the concentration in plants grown on a contaminated surface are still under development. The models are based on the assumption that the concentration of a contaminant in the plant is in equilibrium with the concentration in the soil. The equilibrium factor is called the bioconcentration factor or plant uptake factor, and represents the equilibrium contaminant concentration in the plant which has been taken up from the soil by a number of routes.

A simplification of the method used in the Netherlands (CSOIL and HESP) has been used in the Swedish model. The Dutch model estimates transfer of contaminants in two ways: direct uptake from the soil by root uptake and deposition of dust from the contaminated area on aerial plant parts. However, as the root uptake model appears to be conservative, and models for the estimation of contamination by airborne particles are very uncertain, the Swedish model considers the bioconcentration factor for direct uptake from soil to be sufficient to represent uptake via both pathways. Direct uptake from soil was shown to be dominant in the Dutch model.

Plant uptake factors depend to a large extent on environmental conditions, and for some contaminants, e.g. metals, clear relationships have been demonstrated between plant uptake and soil characteristics such as pH, redox status, organic matter and clay contents of the soils. These factors affect the fraction of the contaminant which is available for uptake and plant growth and metabolism. Models differ in the extent to which they take into account such relatively site specific factors, but in general, modelers have found it convenient to use different partition coefficients (e.g. K_d and K_{ow}) to express the availability of a contaminant for plant uptake.

For metals the empirical plant uptake factors given by HESP have been used. Separate plant uptake factors are used for the roots and shoots of the plant. The factors are given in Appendix 3 expressed in mg/kg *dry plant* per mg/kg *dry soil*. The plant uptake factors are converted to fresh plant weight assuming a ratio dry weight to fresh weight of 0.202 and 0.117 in root crops and leafy crops, respectively.

For other inorganic contaminants (cyanide), the concentration in the fluid of the leaf and stem of the plant and the root of the plant is assumed to be equal to that of

the soil pore water. Thus, the fresh weight concentration of leafy crops and root crops is 88% and 80% of that in the soil pore water, respectively.

The uptake of organic substances from soils is represented according to the relationship between K_{ow} and the bioconcentration factor, BCF, described by Briggs et al. [1982, 1983]. This approach, which is adopted in the Dutch CSOIL model and the HESP model, is based on the concentration of the contaminant in the soil pore water, C_w (determined from the soil concentration and the K_d value). The bioconcentration factor for the stem (mg /kg *fresh plant*)/(mg/l *pore water*) is given by:

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

and the bioconcentration factor for the root (mg/kg *fresh plant*)/(mg/l *pore water*) by:

$$BCF_{root} = 10^{(0.77\log K_{ow}-1.52)} + 0.82$$

The total plant concentration factor (mg /kg *fresh plant*)/(mg/kg *dry soil*) is calculated as:

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

where:

f_{leaf} is the fractional consumption of leaf and stem vegetables
f_{root} is the fractional consumption of root vegetables in the consumption

Vegetable consumption is assumed to comprised 50% leaf and stem vegetables and 50% root vegetables. The last part of the equation relates the concentration in the soil pore water to the total soil concentration.

3 Model for human health risks

The estimation of human health risk is based on the potential exposure of humans through a set of selected pathways. The selection of the most important exposure pathways for the Swedish model was based on the experience from foreign studies. However, the importance of the exposure pathways varies substantially between different contaminants. It is therefore difficult to make an a-priori choice of exposure pathways. The selected exposure pathways are:

- direct intake of contaminated soil
- dermal contact with contaminated soil and dust
- inhalation of dust from the contaminated site
- inhalation of vapors
- intake of contaminated groundwater
- intake of vegetables grown on the contaminated site
- intake of fish from nearby surface water

Exposure due to intake of domestic animal products (e.g. meat, milk, eggs) has been excluded at this stage, although it may be important for some contaminants. However, because of the lack of models and parameter values needed to estimate exposure with sufficient accuracy, this pathway has not been included in the model for generic guideline values.

A different selection of exposure pathways has been made for the three types of land-use considered: land for sensitive use, e.g. residential areas, playgrounds, etc. and land for less sensitive use, e.g. offices, industry, roads, etc. The pathways selected for the different types of land-use are presented in Table 3.1.

Table 3.1 Exposure pathways used for land for sensitive use (KM), land for less sensitive use with groundwater extraction (MKM GV) and land for less sensitive use without groundwater extraction (MKM).

Exposure pathway	KM	MKM GV	MKM
Direct intake of soil	X	X	X
Dermal contact	X	X	X
Inhalation of dust	X	X	X
Inhalation of vapors	X	X	X
Intake of groundwater	X	X	
Intake of vegetables	X		
Intake of fish	X		

The health risk based guideline values are estimated by performing a backward exposure calculation. For each exposure pathway a reference soil concentration is calculated that will result in an exposure corresponding to a certain toxicological

reference value. The methodology used to set the toxicological reference values is described in Section 3.1. The models and data used to derive the reference soil concentrations for the different exposure pathways are described in detail in Section 3.2. The method used for integrating the allowable soil concentrations into guideline values, taking into account the background exposure is presented in Section 3.3.

3.1 Toxicology

The assessment of health risk associated with exposure to a given contaminant is based upon information on the dose-effect or dose-response relationship for man. The dose-response data is used to identify a safe dose or a threshold toxic level for a particular adverse effect. The threshold level is established from the results of experiments and epidemiological studies. Safety factors are used to allow for the uncertainties inherent in the data. For most contaminants, this threshold level is expressed as a tolerable daily intake (TDI, expressed in mg/kg body weight/day) for the oral exposure pathways. For the inhalation pathway, a reference air concentration (RfC, expressed in mg/m^3) is used.

For genotoxic carcinogenic contaminants, it is not possible to express a "safe" or threshold dose as even low doses can imply a cancer risk. Increased doses do not affect the severity of the effect, but do increase the risk of the effect occurring. Therefore, mathematical extrapolation models which are linear in the low dose region are used to determine the exposure to a chemical which is equivalent to an acceptable risk level. The risk level used in this report is a lifetime excess cancer risk of 1 in 100 000 (10^{-5}).

The values chosen for the toxicological parameters are given in Appendix 4, together with the source of the chosen value. The toxicological data are chosen from information available by the end of 1996. However, toxicological parameters are continuously being revised and updated and therefore revised values may later appear in the literature.

For oral intake of non carcinogenic contaminants, a value for the tolerable daily intake TDI, (mg/kg body weight/day) was taken, where available, from WHO [1993]. For some substances the TDI was derived from the provisional tolerable weekly intake PTWI. Where no WHO value is available, values were taken from the USEPA database, IRIS [1995]. For some contaminants, where values were not available from the above sources, TDI values were obtained from the CSOIL model [van den Berg, 1995]. For some contaminants, values from [IMM, 1990] and [Nord, 1988] were thought to be more appropriate than the above sources. For PCBs no tolerable daily intake was found, therefore the tolerable exposure from the site was instead set at a level corresponding to 10% of the average exposure from other sources [SLV, 1995].

For non-genotoxic carcinogenic contaminants, TDI values were used which were derived using a threshold model to determine the oral intake at which there will be an excess cancer risk. WHO's TDI values were used where available [WHO 1993]. For genotoxic carcinogenic contaminants, WHO's cancer risk factors, derived from an extrapolation model, were used to calculate the daily intake (mg/kg body weight/d) which is equivalent to a lifetime excess cancer risk of 10^{-5} [WHO, 1993].

For the inhalation of non-carcinogenic and non-genotoxic carcinogenic contaminants, reference air concentrations (mg/m^3) were taken, in order of preference from [IMM, 1991], [WHO, 1987] and [UBA, 1993]. For genotoxic carcinogenic contaminants an air concentration corresponding to a lifetime excess cancer risk of 10^{-5} was derived from cancer risk factors given by WHO [1987] and IRIS [1995].

For dermal contact, relative absorption factors, were taken from [MDEP, 1994]. These factors represent the relative absorption of the contaminant via the skin from contaminated soil compared to the absorption due to ingestion.

For the drinking water pathway, drinking water concentration limits from the Swedish Food Administration (Livsmedelsverket) [SLV, 1993] were used where available, otherwise, values were taken from WHO [1993]. For many contaminants, the drinking water concentration limits have been set assuming that drinking water may contribute only to a certain fraction of the TDI. This fraction, given in Appendix 4, is adjusted for in the final integration of exposure via different pathways, see Section 3.3.

For the fish consumption pathway, protection was assumed to be sufficient if the surface water concentration was below the "residue value" of USEPAs Ambient Water Quality Criteria [USEPA, 1980 - 1993; IRIS, 1995]. These criteria represent the concentration of a contaminant in freshwater below which fish living in the water are not expected to accumulate contaminants to a concentration above the limit assessed to be suitable for human consumption.

In addition to chronic effects acute effects have been considered for arsenic and cyanide. Values for the acute toxicity were taken from IMM [1990].

3.2 Exposure pathways

This section describes the models used to calculate the health based soil concentrations for the different exposure pathways. The methodology for chronic exposure can be described generally as follows. The average daily exposure to the contaminated media is estimated per kg of body weight, e.g. the ingestion of contaminated soil per body weight and day. The average daily exposure is then

used to derive the soil contaminant concentration resulting in an exposure which corresponds to the toxicological reference value. This concentration is referred to as *the reference soil concentration*. Factors for the distribution, transport and dilution of the contaminant and unit conversion factors are used in the calculations.For most exposure pathways the chronic exposure is based on the estimated exposure of a child with a body weight of 15 kg.

A separate calculation is made for integrated lifetime exposure, which is used for genotoxic carcinogenic substances. The integrated lifetime exposure is based on the time-weighted average of the exposure of a child (0-6 years) and the exposure of an adult (7-64 years). The body weight of the child was assumed to be 15 kg and the body weight of the adult 70 kg. This corresponds to the assumptions used for the derivation of the Dutch intervention values, with the important exception that for the intervention values the integrated lifetime exposure was used for all substances genotoxic or not. The approach used for the Swedish model will result in a more conservative estimate for non-genotoxic substances.

3.2.1 Intake of contaminated soil

Oral exposure to contaminants in soils is assumed to occur as direct intake or via fingers and hands that are put in the mouth. Important parameters are average daily soil intake and bioavailability of the contaminant. The intake is age dependant and is considered to be highest for small children. The bioavailability of the contaminant in the soil is assumed to correspond to the bioavailability considered when deriving the toxicological data. For metals this is usually the bioavailability when present in food.

The model for land for sensitive use (KM) is based on the model used in CSOIL, where a separate estimation is made for children and adults (Table 3.2). The values used in the equation for the reference soil concentration are given in bold.

Table 3.2 Parameters used for the soil ingestion exposure calculations for land for sensitive use (KM).

Parameter	Child	Adult
Average daily soil intake (mg/d)	150	50
Long-term soil intake per unit body weight (mg/kg,d)	**10**	0.7
Integrated lifetime soil intake (mg/kg,d)	**1.5**	

In the case of land for less sensitive use (MKM), the model of MDEP for soil category S-2 was used, in which the intake of soil is calculated as 50 mg/d during 5 days per week during six summer months and is expressed as an integrated soil ingestion rate of 8 mg,a/(kg,d). A summary of the data used for the calculations is

given in Table 3.3. The values used in the equation for the reference soil concentration are given in bold.

Table 3.3 Parameters used for the soil ingestion exposure calculations for land for less sensitive use (MKM).

Parameter	Long-term	Integrated lifetime
Integrated soil ingestion rate (mg,a/kg,d)	8	8
Exposure time (a)	27	75
Daily soil intake (mg/kg,d)	**0.3**	**0.1**

The reference soil concentration for the soil ingestion pathway, C_{is} [mg/kg], is calculated as:

$$C_{is} = \frac{TRV}{R_{is}} \cdot 10^6$$

where

TRV is the toxicological reference value, [mg/kg body weight, d]
(ie, TDI for non-genotoxic substances and risk based daily intake for genotoxic substances)

R_{is} is the average daily soil intake, [mg soil/kg body weight,d]
(ie, long-term soil intake for non-genotoxic substances and integrated lifetime soil intake for genotoxic substances)

3.2.2 Dermal contact with soil and dust

Contaminants adhering to the skin surface may penetrate the skin and be taken up by the blood. The main exposed areas are hands, arms, feet and legs. Important parameters are: the area of the skin exposed, amount of soil per skin area, and the uptake of contaminants through the skin.

The model for exposure due to dermal contact with soil and dust is based on the model used in CSOIL. However, the absorption through the skin has been calculated using the method from MDEP with substance specific absorption factors. Furthermore, a soil exposure of 0.51 mg/cm^2 is used for children as well as adults. The exposure time on land for less sensitive use (MKM) is assumed to be a third of the exposure time on land for sensitive use (KM). Tables 3.4 and 3.5 give a summary of the data used for the exposure estimates. The values used in the equation for the reference soil concentration are given in bold.

Table 3.4 Parameters used for the dermal exposure calculations for land for sensitive use (KM).

Parameter	Child	Adult
Soil exposure (mg/m²)	5100	5100
Exposed skin area (m2)	0.28	0.17
Daily soil exposure (mg/d)	1400	900
Exposure time (d/a)	80	45
Long-term dermal soil exposure per body weight (mg/kg,d)	**20**	1.5
Integrated lifetime dermal soil exposure (mg/kg,d)	**3**	

Table 3.5 Parameters used for the dermal exposure calculations for land for less sensitive use (MKM).

Parameter	Child	Adult
Soil exposure (mg/m²)	5100	5100
Exposed skin area (m²)	0.28	0.17
Daily exposure (mg/d)	1400	900
Exposure time (d/a)	27	15
Long-term dermal soil exposure per body weight (mg/kg,d)	**7**	0.5
Integrated lifetime dermal soil exposure (mg/kg,d)	**1**	

The reference soil concentration for the dermal pathway, C_{du} [mg/kg], is calculated as:

$$C_{du} = \frac{TRV}{f_{du} R_{du}} \cdot 10^6$$

where

TRV is the toxicological reference value, [mg/kg body weight, d] (ie, TDI for non-genotoxic substances and risk based daily intake for genotoxic substances)

f_{du} is the substance specific relative absorption factor for dermal uptake

R_{du} is the average daily dermal exposure, [mg soil/kg body weight,d] (ie, long-term dermal exposure for chronic exposure for non-genotoxic substances and integrated lifetime dermal exposure for genotoxic substances)

3.2.3 *Inhalation of dust*

Fine dust particles dispersed from the contaminated soil may be inhaled by humans. Particles greater than 10 μm are to a great extent retained by the cilia in the bronchi, but can later be swallowed. Important parameters for exposure are the number of particles in inhaled air, respirable particle fraction, breathing rate and exposure time.

Two approaches are used for the exposure due to inhalation of dust from the contaminated site. The first is used for substances where a toxicologically based reference air concentration is available. The second is used for the other substances where an estimate is made of the daily average amount of dust that is inhaled. The exposure time on land for less sensitive use (MKM) is assumed to be a third of the exposure time on land for sensitive use (KM).

The average concentration of contaminated dust in the inhaled air is estimated to be 41 $\mu g/m^3$ based on data from CSOIL. The used parameters are presented in Table 3.6. The values used in the equation for the reference soil concentration are given in bold.

Table 3.6 Data used for derivation of annual average air concentration

Parameter	Indoors	Outdoors
Concentration of respirable dust (mg/m^3)	0.052	0.070
Fraction of dust originating from the contaminated area	80%	50%
Fraction of time	88%	12%
Average concentration of contaminated dust in inhaled air (mg/m^3)	**0.041**	

For substances where a reference air concentration is available, the reference soil concentration, C_{id} [mg/kg], for the dust inhalation pathway is calculated as:

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

where

RfC is the toxicological reference concentration for non-genotoxic substances and the risk based concentration for genotoxic substances [mg/m^3]

f_{exp} is the fraction of time spent on the site. In the case of land for sensitive use $f_{exp} = 1$, and for land for less sensitive use $f_{exp} = 0.33$.

C_{ad} is the annual average concentration in inhaled air [mg/m^3]

For substances where no toxicologically based reference air concentration is available an estimate of the exposure is made according to the methodology used in CSOIL. Tables 3.7 and 3.8 give a summary of the data used for the exposure estimates. The values used in the equation for the reference soil concentration are given in bold.

Table 3.7 Parameters used for the dust inhalation exposure calculations for land for sensitive use (KM).

Parameter	Child	Adult
Contaminant air concentration (mg/m³)	0.041	0.041
Breathing rate (m³/d)	7.6	20
Lung retention	75%	75%
Exposure time (d/a)	365	365
Long-term inhalation per body weight (mg/kg,d)	**0.016**	0.009
Integrated lifetime inhalation (mg/kg,d)	**0.01**	

Table 3.8 Parameters used for the dust inhalation exposure calculations for land for less sensitive use (MKM).

Parameter	Child	Adult
Contaminant air concentration (mg/m³)	0.041	0.041
Breathing rate (m³/d)	7.6	20
Lung retention	75%	75%
Exposure time (d/a)	122	122
Long-term inhalation per body weight (mg/kg,d)	**0.005**	0.003
Integrated lifetime inhalation (mg/kg,d)	**0.003**	

The reference soil concentration for the dust inhalation pathway, C_{id} [mg/kg], is calculated as:

$$C_{id} = \frac{TRV}{R_{id}} \cdot 10^6$$

where

TRV is the toxicological reference value, [mg/kg body weight, d] (ie, TDI for non-genotoxic substances and risk based daily intake for genotoxic substances)

R_{id} is the average daily inhalation of dust [mg soil/kg body weight,d] (ie, long-term inhalation for non-genotoxic substances and integrated lifetime inhalation for genotoxic substances)

3.2.4 Inhalation of vapors

Volatile contaminants in soils may be transported to the atmosphere or into buildings on the site. This model only treats vapors that penetrate into buildings. Important factors for exposure are: rate of transport from the soil, dilution in indoor air, breathing rate and exposure time.

The same two approaches are used for inhalation of vapors as for the exposure due to inhalation of dust from the contaminated site. For substances where a toxicologically based reference air concentration is available, this concentration is compared with the estimate indoor air concentration. For the other substances an estimate is made of the daily average amount of vapor that is inhaled. The exposure time on land for less sensitive use (MKM) is assumed to be a third of the exposure time on land for sensitive use (KM).

For substances where a reference air concentration is available, the reference soil concentration for the vapor inhalation pathway, C_{iv} [mg/kg], is calculated as:

$$C_{iv} = \frac{RfC}{f_{exp} H}\left[K_d + \frac{(\theta_w + \theta_a H)}{\rho_b}\right]\frac{1}{DF_{ia}}\frac{1}{1000}$$

where

RfC is the toxicological reference concentration for non-genotoxic substances and the risk based concentration for genotoxic substances [mg/m^3]
f_{exp} is the fraction of time spent on the site. In the case of land for sensitive use f_{exp} = 1, and for land for less sensitive use f_{exp} =0.33.
K_d is the distribution coefficient soil-water [l/kg]
θ_w is the soil water content [dm^3 water/dm^3 soil]
θ_a is the soil air content [dm^3 air/dm^3 soil]
H is Henry's constant [-]
ρ_b is the soil bulk density [kg/dm^3]
DF_{ia} the dilution factor for indoor air

The methodology used to derive the dilution factor for indoor air is described in Section 2.2.1.

For substances where no toxicologically based reference air concentration is available an estimate of the exposure is made according to the methodology used in CSOIL. The exposure is in this case expressed as exposure per unit concentration, ie mg of contaminant inhaled per kg of body weight and day with a concentration of 1 g/m^3. Tables 3.9 and 3.10 give a summary of the data used for the exposure estimates. The values used in the equation for the reference soil concentration are given in bold.

Table 3.9 Parameters used for the vapor inhalation exposure calculations for land for sensitive use (KM).

Parameter	Child	Adult
Breathing rate (m^3/d)	7.6	20
Exposure time (d/a)	365	365
Long-term inhalation per body weight (mg/kg,d)/(g/m^3)	**500**	285
Integrated lifetime inhalation (mg/kg,d)/(g/m^3)	**300**	

Table 3.10 Parameters used for the exposure calculations for land for less sensitive use (MKM).

Parameter	Child	Adult
Breathing rate (m^3/d)	7.6	20
Exposure time (d/a)	122	122
Long-term inhalation per body weight (mg/kg,d)/(g/m^3)	**170**	95
Integrated lifetime inhalation (mg/kg,d)/(g/m^3)	**100**	

The reference soil concentration for the vapor inhalation pathway, C_{iv} [mg/kg], is calculated as:

$$C_{iv} = \frac{TRV}{R_{iv} H} \left[K_d + \frac{(\theta_w + \theta_a H)}{\rho_b} \right] \frac{1}{DF_{ia}}$$

where

TRV is the toxicological reference value, [mg/kg body weight, d] (ie, TDI for non-genotoxic substances and risk based daily intake for genotoxic substances)

R_{iv} is the average daily inhalation of vapor [(mg/kg body weight,d)/(g/m^3)] (ie, long-term inhalation for non-genotoxic substances and integrated lifetime inhalation for genotoxic substances)

3.2.5 Intake of drinking water

Drinking water may be contaminated either by contamination of a groundwater well or by penetration of plastic water pipes in the contaminated soil. For the Swedish generic guideline values only the direct contamination of well water is considered. Important parameters for exposure are: the concentration in the well water and the consumption of drinking water.

The reference soil concentration for the drinking water exposure pathway can be estimated either from toxicologically based drinking water guidelines, if these are available, or by estimating the exposure and comparing that with the toxicological reference value.

For substances where a toxicologically based drinking water guideline value is available, the reference soil concentration for the drinking water pathway, C_{iw} [mg/kg], is calculated as:

$$C_{iw} = DWG \left[K_d + \frac{(\theta_w + \theta_a H)}{\rho_b} \right] \frac{1}{DF_{gw}}$$

where

DWG	is the toxicological drinking water guideline, [mg/l]
K_d	is the distribution coefficient soil-water [l/kg]
θ_w	is the soil water content [dm^3 water/dm^3 soil]
θ_a	is the soil air content [dm^3 air/dm^3 soil]
H	is Henry's constant [-]
ρ_b	is the soil bulk density [kg/dm^3]
DF_{gw}	the dilution factor for well water

The methodology used to derive the dilution factor for well water is described in Section 2.2.2.

For substances where no toxicologically based drinking water guideline is available an estimate of the exposure is made according to the methodology used in CSOIL. Table 3.11 give a summary of the data used for the exposure estimates. The values used in the equation for the reference soil concentration are given in bold.

Table 3.11 Parameters used for the drinking water exposure calculations for land for sensitive use (KM) and for less sensitive use with groundwater use (MKM GV).

Parameter	Child	Adult
Water consumption (l/d)	1	2
Exposure time (d/a)	365	365
Long-term water consumption per body weight (l/kg,d)	**0.067**	0.028
Integrated lifetime consumption (l/kg,d)	**0.03**	

The reference soil concentration for the drinking water pathway, C_{gw} [mg/kg], is calculated as:

$$C_{gw} = \frac{TRV}{R_{iw}} \left[K_d + \frac{(\theta_w + \theta_a H)}{\rho_b} \right] \frac{1}{DF_{gw}}$$

where

TRV is the toxicological reference value, [mg/kg body weight, d]
(ie, TDI for non-genotoxic substances and risk based daily intake for genotoxic substances)

R_{iw} is the average daily water consumption [l/kg body weight,d]
(ie, long-term consumption for non-genotoxic substances and integrated lifetime consumption for genotoxic substances)

3.2.6 Intake of vegetables grown on the contaminated site

Plants grown on the site may take up contaminants through the roots or be contaminated by deposition of dust. In the Swedish model, a single uptake factor is used to represent plant uptake. Important parameters for exposure are: concentration in the edible parts of the plant, consumption of vegetables and fraction of consumed vegetables that are grown on the site.

This exposure pathway is only considered in the case of land for sensitive use (KM). The model for exposure due to intake of vegetables is based on the model used in CSOIL and in HESP. The methodology used to estimate the concentration in the plants is described in Section 2.2.4.

The exposure is estimated from data provided from CSOIL and SCB [1995]. A summary of the data is given in Table 3.12. Furthermore, it is assumed that 30% of the consumed vegetables are grown on the site. The values used in the equation for the reference soil concentration are given in bold.

Table 3.12 Parameters used for the vegetable ingestion exposure calculations for land for sensitive use (KM).

Parameter	Child	Adult
Average consumption (kg/d)	0.15	0.29
Exposure time (d/a)	365	365
Long-term consumption per body weight (kg/kg,d)	**0.01**	0.004
Integrated lifetime consumption (kg/kg,d)	**0.005**	

The reference soil concentration for the vegetable consumption pathway, C_{ig} [mg/kg], is calculated as:

$$C_{ig} = \frac{TRV}{R_{ig} f_h K_{pl}}$$

where

TRV is the toxicological reference value, [mg/kg body weight, d]

(ie, TDI for non-genotoxic substances and risk based daily intake for genotoxic substances)

R_{ig} is the average daily consumption [kg vegetables/kg body weight,d] (ie, long-term consumption for non-genotoxic substances and integrated lifetime consumption for genotoxic substances)

f_h is the fraction of vegetables grown on the site

K_{pl} is the plant-soil concentration ratio [(mg/kg plant)/(mg/kg soil)

The methodology used to derive the plant-soil concentration ratio is described in Section 2.2.4.

3.2.7 Intake of fish from nearby surface water

This exposure pathway is only considered in the case of land for sensitive use (KM). The reference soil concentration for the fish exposure pathway, C_{if} [mg/kg], is calculated as the soil concentration that is estimated to give a water concentration in a nearby surface water equivalent to the USEPA Ambient Water Quality Criteria for fish consumption from fresh water (Section 3.1). The following expression is used:

$$C_{if} = \frac{AWQC}{DF_{sw} \cdot DF_{gw}} \left[K_d + \frac{(\theta_w + \theta_a H)}{\rho_b} \right]$$

where

$AWQC$ Ambient Water Quality Criteria for fish consumption from fresh water [mg/l]

DF_{sw} is the dilution factor groundwater to surface water

DF_{gw} is the dilution factor soil pore water to groundwater

For contaminants for which no AWQC is available, exposure due to intake of fish has been neglected. However, exposure due to ingestion of fish was not found to be significant for any of the contaminants where values were available.

3.3 Integration of exposure from different pathways

A reference soil concentration is calculated for each of the exposure pathways considered, ie 7 for land with sensitive use and 4/5 for land with less sensitive use depending on the presence or absence of groundwater use. The reference soil concentration for an exposure pathway corresponds to the level of contamination in the soil that is estimated to give an exposure equivalent to the tolerable daily intake or acceptable risk level considering **only** that single exposure pathway. The calculated values are presented in Appendix 2. However, the guideline value is presumed to consider simultaneous exposure through all possible exposure

pathways. Thus, the exposure through the different pathways should be added and an integrated guideline value determined.

The integrated human health value is taken as the inverse of the sum of the inverted reference soil concentrations, or for land with sensitive use (KM):

$$C_{KM} = \frac{1}{\frac{1}{C_{is}} + \frac{1}{C_{du}} + \frac{1}{C_{id}} + \frac{1}{C_{iv}} + \frac{1}{C_{iw}} + \frac{1}{C_{ig}} + \frac{1}{C_{if}}}$$

for land with less sensitive use, but groundwater supply (MKM GV):

$$C_{MKMGV} = \frac{1}{\frac{1}{C_{is}} + \frac{1}{C_{du}} + \frac{1}{C_{id}} + \frac{1}{C_{iv}} + \frac{1}{C_{iw}}}$$

and for land with less sensitive use (MKM):

$$C_{MKM} = \frac{1}{\frac{1}{C_{is}} + \frac{1}{C_{du}} + \frac{1}{C_{id}} + \frac{1}{C_{iv}}}$$

3.3.1 Adjustment of values to correspond to tolerable daily intakes

The integrated guideline values are presumed to be at such a level that the estimated total exposure corresponds to the tolerable daily intake (TDI) or acceptable risk. However, drinking water guidelines are sometimes set to correspond to an intake of a specified percentage (10-50%) of the TDI (Table A4.1). For substances where drinking water guidelines are used and exposure through that pathway is important this can lead to an integrated human health value corresponding to an exposure considerably less than the TDI. In these cases the integrated value is adjusted **upwards** to obtain an integrated human health value corresponding to 100% of the TDI. However, because drinking water guidelines are to be followed, an upward limit is set at the soil concentration that is estimated to give a water concentration in a nearby well equal to the drinking water guideline (ie, the lowest of the integrated human health value and the value derived from the drinking water guideline is adopted)..

3.3.2 Adjustment of values for background exposure

Humans are also exposed to certain substances from sources other than the contaminated site, primarily from food. This background exposure already accounts for part of the tolerable daily intake. A **downward** adjustment of the integrated guideline value is made for substances with a high background exposure in such a way that the sum of the background exposure and the estimated exposure from the site does not exceed the tolerable daily intake.

For the generic guideline values, adjustment for background exposure is made for lead, cadmium, mercury, nickel and dioxin. For PCBs, no TDI-value is available. Instead the tolerable exposure from the site is set at level corresponding to 10% of the average exposure from other sources [SLV, 1995].

Table 3.13 Values for background exposure of certain contaminants.

Substance	Background exposure in percentage of TDI	Sources of data
Lead	33%	IMM, 1990
Cadmium	25%	WHO, 1993
Mercury	70%	Skare and Engqvist, 1992
Nickel	50%	WHO, 1993
Dioxin	90%	SLV, 1995

3.3.3 Adjustment of values for acutely toxic substances

A few contaminants,eg arsenic and cyanide, have such high acute toxicity that the ingestion of relatively small amounts of soil can be dangerous. The highest risks are experienced by small children, who are more likely to ingest soil and have a lower body weight. The guideline values have been adjusted to protect a child with a weight of 10 kg who at a single instance ingests 5 grams of contaminated soil. This type of adjustment was only found to be necessary for cyanide in the case of land with less sensitive use (MKM). An intake of 5 grams of soil with a concentration of free cyanide of 20 mg/kg will give a dose less than a hundredth of the lethal dose (1 mg/kg body weight).

4 Model for environmental risk

In the calculation of environmental risk based guideline values, effects on both the contaminated site itself (on-site) and due to transport of contaminants from the site (off-site) have been considered for the different land-uses (sensitive and less sensitive). For on-site effects the level of protection differs between the two types of land-use.

4.1 On-site effects

The ecotoxicological value for on-site effects represents the level at which there will be no serious disturbance of the soil's capacity to carry out a range of ecological functions.

If most of the plant and animal species in the soil are protected, the soil function will also be protected. (If the percentage of species which is disturbed is small, then the chance that the disturbed species is important in terms of ecosystem function is small). Soil function is assumed to be endangered if the species composition is severely changed.

The values are based on an extrapolation of the results of toxicity tests on a limited number of species. The results of toxicological tests which are reported in the literature are reviewed and assessed for their relevance to chronic exposure of soil organisms. Studies reporting no-observed effect concentrations (NOECs) from long-term experiments are given priority. The NOECs for a range of organisms, representative of the range found in soil, are used to construct a distribution curve. This distribution is used to identify the contaminant concentration corresponding to the desired level of protection, expressed as the percentage of species which will not be affected by the contaminant at that concentration.

The ecotoxicological values used are based on the ecotoxicological intervention values derived in the Netherlands, which are derived from the most comprehensive available ecotoxicological database. The Dutch intervention values correspond to the soil concentration above which serious disturbance to soil function will occur. The level of protection chosen for the intervention values is equivalent to protection of 50% species.

The ecotoxicological values for on-site effects, E_{KM} [mg/kg], used to derive the generic guideline values for contaminated soils in Sweden for land for sensitive use (KM) are set at half the intervention value used in the Netherlands, since protection of only 50% species in the soil ecosystem was considered insufficient protection of the soil functions required for this land use, i.e:

$$E_{KM} = 0.5 \cdot E_{NL}$$

where

E_{NL} is the ecotoxicological intervention value from the Netherlands

The ecotoxicological values are set to protect the majority of ecosystems, but not all. This implies that the most sensitive ecosystems may be affected at these levels.

In the case of land for less sensitive use (MKM) (ie land used for offices, industry, etc) the elimination of biological activity in the soil ecosystem is not considered to be acceptable. However, the level of protection may be somewhat lower than for sensitive land use. An ecotoxicological value equal to the Netherlands value has been adopted, which is assumed to be sufficiently protective of the soil functions important for this land use (e.g.. growth of ornamental species, protection of transient animal species, etc). In addition, this value is thought to be protective of off-site effects arising from contamination of groundwater and transport of contaminants to a discharge zone. Thus, the ecotoxicological values, E_{MKM} [mg/kg], are given as:

$$E_{MKM} = E_{NL}$$

4.2 Off-site effects

The effects in nearby surface waters are assessed by comparing the calculated concentrations in surface waters with Canadian Water Quality criteria for the protection of freshwater aquatic life [CCME, 1996]. The Canadian guidelines are set at concentrations which are protective of all forms of freshwater aquatic life and all aspects of the aquatic life cycles, and are based on the available data on the toxicity of substances to all components of the aquatic system. The ecotoxicological value, E_{sw} [mg/kg] is given by:

$$E_{sw} = \frac{CWQC}{DF_{sw} \cdot DF_{gw}} \left[K_d + \frac{(\theta_w + \theta_a H)}{\rho_b} \right]$$

where

$CWQC$	Canadian Water Quality Criteria for freshwater aquatic life [mg/l]
DF_{sw}	is the dilution factor groundwater to surface water
DF_{gw}	is the dilution factor soil pore water to groundwater

5 Other aspects

For some contaminants, concentrations in water and air which are detectable by taste or smell (organoleptic parameters) have been taken into account. The values of the concentration limit which are thought to cause a nuisance have been obtained from WHO [1993], SLV [1993], Miljøstyrelsen [1995a] and HSDB [1995].

Many contaminants are present either as natural substances or as a result of diffuse anthropogenic releases. Background levels of contaminants in soils have been taken into account in so far as no guideline value has been set under the 90th percentile of the measured background concentration in rural environments. Information on the background levels of metals in urban and rural environments has been obtained from Andersson [1977] and Naturvårdsverket [1996b and 1996c]. For dioxins only limited information is available on the background contamination levels in Sweden. In this case background levels measured in Germany have also been considered [LABO, 1995].

6 Integration of results

The basic principle for setting the generic guideline values is to choose the lowest of the human health based value and the ecotoxicologically based value. For substances where smell and odor problems can occur at lower concentrations this has been taken into consideration. However, a less conservative perspective is put on smell and odor problems compared to toxicological problems.

No values are set below the 90th percentile for the background concentration in natural environments. No value is set below the detection limit for the appropriate analytical method. The adopted generic guideline values are presented in Appendix 1.

7 Discussion

The model used for the derivation of generic guideline values is based on methods and data developed in countries with many years of experience in evaluating risks from contaminated soils. Despite the extensive research on which these models are based, there are a number of areas where uncertainties remain. In some cases these uncertainties have little impact on the overall result, in other cases, they are dominating. The general approach adopted for accounting for potentially important uncertainties is the use of conservative assumptions and data in the modelling. This may lead to a series of conservative assumptions and as a consequence some guideline values may be set with too much precaution. However, in some cases the uncertainties are so great that the degree of conservatism in the assumptions is not evident. Areas where the further development of the methods used in this report would be most useful are:

- uptake of contaminants by plants
- transport of vapors into buildings
- bioavailability of contaminants
- dermal uptake of contaminants
- ecotoxicological effects

The methods and data have to some extent been adapted to suit Swedish conditions. However, no comprehensive analysis of data has been performed. A possible method to determine the need for and direction of further data collection would be to perform an uncertainty and sensitivity study. Dominating parameters for different substances and different types of land use could thereby be identified. Parameters which already have been identified as important for the final result are:

- dilution factor for groundwater
- dilution factor for indoor air
- plant uptake factors
- soil ingestion rates

In addition toxicological data and ecotoxicological data naturally have a great impact on the risk evaluation. The toxicological data are chosen from information available by the end of 1996. However, toxicological parameters are continuously being revised and updated and therefore revised values may later appear in the literature.

The ecotoxicological values are based on an analysis of available data, therefore it is important that sufficient, relevant, good quality data is available for the development of reliable guideline values. For many contaminants, data reporting the dose-response relationship for relevant effects over appropriate time periods are not available for a sufficiently wide range of species.

List of notations

$AWQC$	the Ambient Water Quality Criteria for fish consumption from fresh water [mg/l]
BCF_{root}	the bioconcentration factor for the root (mg *contaminant*/kg *fresh plant*)/(mg *contaminant*/l *pore water*)
BCF_{stem}	the bioconcentration factor for the stem (mg *contaminant*/kg *fresh plant*)/(mg *contaminant*/l *pore water*)
C_a	the vapor concentration in the pore air [mg/m^3]
C_{ad}	the annual average dust concentration in inhaled air [mg/dm^3]
C_{du}	the reference soil concentration for the dermal pathway [mg/kg]
C_{ia}	the concentration in indoor air [mg/dm^3]
C_{id}	the reference soil concentration for the dust inhalation pathway [mg/kg]
C_{if}	the reference soil concentration for the fish ingestion pathway [mg/kg]
C_{ig}	the reference soil concentration for the vegetable ingestion pathway [mg/kg]
C_{is}	the reference soil concentration for the soil ingestion pathway [mg/kg]
C_{iv}	the reference soil concentration for the vapor inhalation pathway [mg/kg]
C_{iw}	the reference soil concentration for the drinking water pathway [mg/kg]
C_{KM}	the integrated human health value for land with sensitive use (KM) [mg/kg]
C_{MKM}	the integrated human health value for land with less sensitive use, without groundwater supply [mg/kg]
C_{MKMGV}	the integrated human health value for land with less sensitive use, and groundwater supply [mg/kg]
C_s	the total concentration in the soil [mg/kg]
C_{sw}	the concentration in the surface water [mg/l]
C_w	the concentration in the pore water [mg/l]
$CWQC$	Canadian Water Quality Criteria for fish freshwater aquatic life [mg/l]
d_a	the aquifer thickness [m]
DF_{gw}	the dilution factor for well water [-]
DF_{gw}	the dilution factor soil pore water to groundwater [-]
DF_{ia}	the dilution factor for indoor air [-]
DF_{sw}	the dilution factor groundwater to surface water [-]
d_{mix}	the thickness of the mixing zone in the aquifer [m]
DWG	the toxicological drinking water guideline, [mg/l]
E_{KM}	the ecotoxicological value for on-site effects on land for sensitive use [mg/kg]
E_{MKM}	the ecotoxicological value for on-site effects on land for less sensitive use [mg/kg]
E_{NL}	the ecotoxicological intervention value from the Netherlands [mg/kg]
E_{sw}	the ecotoxicological value for off-site effects [mg/kg]

f_{du} the substance specific relative absorption factor for dermal uptake [-]
f_{exp} the fraction of time spent on the site [-]
f_h the fraction of vegetables grown on the site [-]
f_{leaf} the fractional consumption of leaf and stem vegetables [-]
f_{root} the fractional consumption of root vegetables [-]
H Henry's constant [-]
i the hydraulic gradient [m/m]
I the infiltration rate [m/a]
k the hydraulic conductivity of the soil [m/a]
K_d the distribution coefficient soil-water [l/kg]
K_{oc} the distribution factor between water and organic carbon [l/kg]
K_{ow} the partitioning coefficient between water and octanol [-]
K_{pl} the plant-soil concentration ratio [(mg/kg *plant*)/(mg/kg *soil*)]
k_t the turnover rate of the lake [a^{-1}]
L the length of the contaminated area in the direction of the groundwater flow [m]
L_w the width of the contaminated area perpendicular to the direction of the groundwater flow [m]
Q_{di} the discharge of groundwater from the contaminated site to the surface water [m^3/a]
Q_{sw} the water flow rate in the surface water [m^3/a]
R_{du} the average daily dermal exposure, [mg soil/kg body weight,d] long-term dermal exposure for chronic exposure for non-genotoxic substances and integrated life-time dermal exposure for genotoxic substances
R_{id} the average daily inhalation of dust [mg soil/kg body weight,d] long-term inhalation for non-genotoxic substances and integrated life-time inhalation for genotoxic substances
R_{ig} the average daily consumption [kg vegetables/kg body weight,d] long-term consumption for non-genotoxic substances and integrated life-time consumption for genotoxic substances
R_{is} the average daily soil intake, [mg soil/kg body weight,d] long-term soil intake for non-genotoxic substances and integrated life-time soil intake for genotoxic substances
R_{iv} the average daily inhalation of vapor [(mg/kg body weight,d)/(g/m^3)] long-term inhalation for non-genotoxic substances and integrated life-time inhalation for genotoxic substances
R_{iw} the average daily water consumption [l/kg body weight,d] long-term consumption for non-genotoxic substances and integrated life-time consumption for genotoxic substances
RfC the toxicological reference concentration , [mg/m^3] TDI for non-genotoxic substances and the risk based concentration for genotoxic substances

TRV	the toxicological reference value, [mg/kg body weight, d] TDI for non-genotoxic substances and risk based daily intake for genotoxic substances
V_{sw}	the volume of the lake [m^3]
X	the distance from the contaminated area to the well [m]
θ_a	the soil air content [dm^3 air/dm^3 soil]
θ_w	the soil water content [dm^3 water/dm^3 soil]
ρ_b	the soil bulk density [kg/dm^3]

References

Andersson A (1977): Heavy Metals in Swedish Soils: On their retention, distribution and amounts. Swedish Journal of Agricultural Science, 7, 7-20.

Briggs G, Bromilow R, Evans A (1982): Relationship between lipophilicity and root uptake and translocation of non-ionised chemicals by barley, Pesticide Science, 13, 495-504.

Briggs G, Bromilow R, Evans A, Williams M (1983): Relationship between lipophilicity and the distribution of non-ionised chemicals in barley shoots following uptake by the roots, Pesticide Science, 14, 492-500.

CCME (1996): Canadian Water Quality Guidelines. Canadian Council of Resource and Environment Ministers for the Environment.

CCME (1994): A protocol for derivation of ecological effects-based and human-health-based soil quality criteria for contaminated sites, Final draft, Canadian Council of Ministers for the Environment.

Denneman CAJ and van Gestel CAM (1990); Bodemverontreiniging en bodemecosystemen: voorstel voor C-(toetsings)waarden op basis van ecotoxicologische risico's. Bijlage bij rapportnr. 725201001. RIVM (National Institute of Public Health and Environmental Protection), Netherlands.

ECETOC (1990): Hazard assessments of chemical contaminants in soil, 40, European chemical industry ecology and toxicology centre.

ECETOC (1992): Hazard assessments of chemical contaminants in soil, 40, Revised appendix 3. European chemical industry ecology and toxicology centre.

Elert M, Jones C and Dock L (1994): Hälsoriskbaserade bedömningsmodeller för förorenad mark, Rapport nr 4641, Swedish Environmental Protection Agency, Stockholm (In Swedish).

EPRI (1988): Chemical data for predicting the fate of organic compounds in water, Volume 2: Database, EPRI EA-5818 V2, Electric Power Research Institute, Palo Alto, Ca.

HSDB (1995): Hazardous Substances Database, CD-ROM, US National Library of Medicine, update of October 1995.

IMM (1990): Hälsoriskbedömning av vissa ämnen i industrikontaminerad mark. IMM rapport 4/90. Institutet för miljömedicin. Karolinska Institutet (In Swedish).

IMM (1991): Hälsoeffekter av luftföroreningar i utomhusluft. IMM rapport 2/91. Institutet för miljömedicin. Karolinska Institutet (In Swedish).

IRIS (1995): Integrated Risk Information System. US EPA, update of October 1995.

Jones C (1996): Ecotoxicologically based models for the risk assessment of contaminated land- A survey of models used in other countries, Rapport nr 4642, Swedish Environmental Protection Agency, Stockholm.

Kreule P, van den Berg R, Waitz M F W and Swartjes F A (1995): Calculation of human-toxicological serious soil contamination concentrations and proposal for intervention values for clean-up of soil and groundwater: Third series of compunds, Report no 715810010. RIVM (National Institute of Public Health and Environmental Protection), Netherlands.

LABO (1995): Soil background and reference values in Germany, Report by Joint Federal States Working Group for Soil Protection (Bund-Länder Arbeitsgruppe Bodenschutz), LABO, Ed: Bayerische Staatsministerium für Landesentwicklung und Umweltfragen.

Mackay D, Patterson S (1981): Calculating fugacity, Environmental Science Technology, 15, 9, 1006-1014.

MDEP (1994): Background documentation for the development of MCP numerical standards. Massachusetts Department of Environmental Protection, USA.

Miljøstyrelsen (1995a): Toksikologiske kvalitetskriterier for jord og drikkevand. Projekt om jord och grundvand fra Miljøstyrelsen. Nr 12. Miljø- og Energiministeriet, Danmark.

Miljøstyrelsen (1995b): Økotoksikologiske jordkvalitetskriterier. Projekt om jord och grundvand fra Miljøstyrelsen. Nr 13. Miljø- og Energiministeriet, Danmark.

Naturvårdsverket (1990): Provtagnings- och analysmetoder för slam från kommunala avloppsreningsverk. NV rapport 3829, Swedish Environmental Protection Agency, Stockholm (In Swedish).

Naturvårdsverket (1996a): Generella riktvärden för förorenad mark - beräkningsprinciper och vägledning för tillämpning. NV rapport 4638, Swedish Environmental Protection Agency, Stockholm (In Swedish).

Naturvårdsverket (1996b): Bakgrundshalter i mark - halter av vissa metaller och organiska ämnen i jord i tätort och på landsbygd, NV Report nr 4640, Swedish Environmental Protection Agency, Stockholm (In Swedish).

Naturvårdsverket (1996c): Förorenade områden - vägledning för översiktliga inventeringar och riskklassningar, Preliminary version. Swedish Environmental Protection Agency, Stockholm (In Swedish).

Nord (1988): Nordisk dioxinriskbedömning. Miljörapport. Nord 1988:7, Nordiska Ministerrådet.

Nord (1992): Risk assessment of polychlorinated biphenyls (PCBs). Nordic environmental cooperation report; Nord 1992:26.

Ontario MOEE (1994): Guidelines for the decommissioning and clean-up of sites in Ontario. PIBS 141E, Ontario Ministry of Environment.

Ontario MOEE (1996): Guidelines for use at contaminated sites in Ontario, PIBS 3161E01, Ontario Ministry of Environment and Energy.

SCB (1995): Statistisk Årsbok, Statistical yearbook of Sweden, Statistiska Centralbyrån, Stockholm.

Shell (1994): The concepts of HESP, Reference Manual, Human exposure to soil pollutants, Version 2.10a, Shell Internationale Petroleum, The Hague.

Skare I and Engqvist A (1992): Amalgamfyllningar en beaktansvärd källa till tungmetallexponering, Läkartidningen, Vol 89, No 15.

SLV (1993): Livsmedelsverkets kungörelse om dricksvatten. SLV FS 1993:35 (In Swedish)

SLV (1995): Gravida, ammande och storkonsumenter bör undvika vissa fiskar. Vår föda 2/95, Livsmedelsverket (In Swedish).

UBA (1993): Basisdaten toxikologie fur umweltrelevante stoffe zur gefahrenbeurteilung bei altlasten. Umwelt Bundes Amt 4-93. Erich Schmidt Verlag, Berlin.

USEPA (1980 - 1993): Ambient water quality criteria.

USEPA (1996): Soil Screening Guidance: Technical Background document. EPA/540/R-95/128. PB96-963502, US EPA, Washington, VA.

van den Berg R (1991); Blootstelling van de mens aan bodemverontreiniging. Een kwalitatieve en kwantitatieveanalyse, leidend tot voorstellen voor humaan toxicologische C-toetsingswaarden. Report no 725201006. RIVM (National Institute of Public Health and Environmental Protection), Netherlands.

van den Berg R, Bockting G J M, Crommentuijn G H and Janssen P J C M (1994): Proposal for intervention values for soil clean-up: Second series of chemicals, Report no 715810004, RIVM (National Institute of Public Health and Environmental Protection), Netherlands.

van den Berg R (1995); Blootstelling van de mens aan bodemverontreiniging. Een kwalitatieve en kwantitatieveanalyse, leidend tot voorstellen voor humaan toxicologische C-toetsingswaarden. Rapportnr 725201006. Modified version of original report from 1991. RIVM (National Institute of Public Health and Environmental Protection), Netherlands.

WHO (1987): Air Quality Guidelines for Europe. WHO Regional Publications, European Series No. 23. WHO Regional Office for Europe, Copenhagen.

WHO (1993): Guidelines for drinking water quality. Volume 1. Recommendations. Second Edition. WHO, Geneva.

Appendix 1. Generic guideline values for contaminated soils in Sweden

Table A1.1 Generic guideline values for contaminated soils in Sweden

KM = land with sensitive use
MKM GV = land with less sensitive use and groundwater extraction
MKM = land with less sensitive use

SUBSTANCE/SUBSTANCE GROUP	KM mg/kg dw	MKM GV mg/kg dw	MKM mg/kg dw
METALS			
Arsenic	15	15	40
Lead	80	300	300
Cadmium	0.4	1	12
Cobolt	30	60	250
Copper	100	200	200
Chromium total (Valid only if Cr VI is not present)	120	250	250
Chromium VI	5	15	20
Mercury	1	5	7
Nickel	35	150	200
Vanadium	120	200	200
Zinc	350	700	700
OTHER INORGANIC SUBSTANCES			
Cyanide total (Only valid if accessible cyanide is not present)	30	80	1000
Cyanide, accessible	1	2	20
PHENOLS AND CHLOROPHENOLS			
Phenol + Cresol	4 [1)]	10 [1)]	40
Sum of chlorophenols except pentachlorophenol	2 [1)]	10 [1)]	10
Pentachlorophenol	0.1	3	5
CHLOROBENZENES			
Sum of mono- and dichlorobenzenes	15 [1)]	30 [1)]	30
Sum of tri-, tetra- and pentachlorobenzenes	1 [1)]	20 [1)]	30
Hexachlorobenzene	0.05	20	30

Continuation Table A1.1 SUBSTANCE/SUBSTANCE GROUP	KM mg/kg dw	MKM GV mg/kg dw	MKM mg/kg dw
OTHER CHLORINATED SUBSTANCES			
PCB total, according to Naturvårdsverket 1990	0.02	4	7
Dioxins, furanes and planar PCBs (given in NORD 1992 and Ahlborg et al 1992) (as TCDD-equivivalents)	10 ng/kg dw	250 ng/kg dw	250 ng/kg dw
Dibromochloromethane	2	4	100
Bromodichloromethane	0.5	2	8
Carbon tetrachloride	0.1	0.2	3
Trichloromethane	2	8	50
Trichloroethylene	5	30	60
Tetrachloroethylene	3	20	60
1,1,1-trichloroethane	40	90	90
Dichloromethane	0.1	0.3	60
NITRO COMPOUNDS			
2,4-dinitrotoluene	0.5	2	20
SIMPLE AROMATIC HYDROCARBONS (BTEX)			
Benzene	0.06	0.2	0.4
Toluene	10	35	35
Ethylbenzene	12	50	60
Xylene	15	60	70
POLYCYCLIC AROMATIC HYDROCARBONS (PAH)			
Sum of carcinogenic PAH (benzo(a)anthracene, chrysene, benzo(b)fluoranthene, benzo(k)fluoranthene, benzo(a)pyrene, indeno(1,2,3-cd)pyrene and dibenzo(a,h)anthracene).	0.3	7	7
Sum of other PAH (naphthalene, acenaphthylene, acenaphthene, fluorene, phenanthrene, anthracene, fluoranthene, pyrene and benzo(ghi)perylene).	20	40	40

1) Taste problems in groundwater can occur at lower levels.

Table A1.2 Values for human toxicity with dominating exposure pathway, adjusted human toxicity values and ecotoxicity values.

KM = land with sensitive use
MKM GV = land with less sensitive use and groundwater extraction
MKM = land with less sensitive use

Letters besides values indicate the dominating exposure pathwyas according to:
So = ingestion of soil
De = dermal contact with soil
Du = inhalation of dust
Va = inhalation of vapors
Gw = ingestion of groundwater as drinkingwater
Ve = ingestion of vegetables

Values in bold in shadowed cells are the chosen generic guideline values.

SUBSTANCE/SUBSTANCE GROUP	HUMAN TOXICOLOGICAL VALUE (mg/kg dry soil)						ECOTOXICOLOGICAL VALUE (mg/kg dry soil)		
	Integrated value			Adjusted values			KM	MKM GV	MKM
	KM	MKM GV	MKM	KM	MKM GV	MKM			
METALS									
Arsenic, As	0.08 Gw	0.18 Gw	**40 So**	**15 (b)**	**15 (b)**		20	40	40
Lead, Pb	80 Gw	290 Gw	8000 So	**80 (c,d)**	**300 (c,d)**	5000 (d)	150	300	**300**
Cadmium, Cd	0.4 Gw	0.9 Gw	250 Du	**0.4 (c,d)**	**1 (c,d)**	200 (d)	6	12	**12**
Cobalt, Co	20 Gw	**60 Gw**	3000 So	**30 (b)**			120	250	**250**
Copper, Cu	5000 Ve	30000 Gw	no limit	8000 (c)			**100**	**200**	**200**
Chromium total, Cr	1500 Gw	3000 Gw	no limit				**120**	**250**	**250**
Chromium VI, Cr^{6+}	**5 Du**	**15 Du**	**20 Du**				x	x	x
Mercury, Hg	2 Gw	5 Gw	25 Va	**1 (c,d)**	**5 (c,d)**	**7 (c,d)**	5	10	10
Nickel, Ni	40 Gw	130 Gw	900 De	**35 (c,d)**	**150 (c,d)**	450 (d)	100	200	**200**
Vanadium, V	**120 Gw**	300 Gw	13000 So				*100*	***200***	***200***
Zinc, Zn	5000 Ve	42000 Gw	no limit				**350**	**700**	**700**
OTHER INORGANIC SUBSTANCES									
Cyanide (total)	**30 Gw**	**80 Gw**	2500			**1000 (e)**	x	x	x
Cyanide (accessible)	0.8 Gw	**2 Gw**	700	**1**		**20 (e)**	x	x	x

Continuation Table A1.2 SUBSTANCE/SUBSTANCE GROUP	HUMAN TOXICOLOGICAL VALUE (mg/kg dry soil)						ECOTOXICOLOGICAL VALUE (mg/kg dry soil)		
	Integrated value			Adjusted values			KM	MKM GV	MKM
	KM	MKM GV	MKM	KM	MKM GV	MKM			
PHENOLS AND CHLOROPHENOLS									
Phenol + cresol	**4** *) **Gw, Ve**	**10** *) **Gw**	17000 De				20	40	**40**
Sum of chlorophenols except pentachlorophenol	**2** *) **Ve**	15 *) Gw	900				5	**10**	**10**
Pentachlorophenol	**0.1 Ve**	**3 Gw**	2800 De				2,5	5	**5**
CHLOROBENZENES									
Sum of mono- and dichlorobenzenes	10 *) Gw,Va	35 *) Gw,Va	100	20 (a,c)	40 (a,c)		**15**	**30**	**30**
Sum of tri-, tetra- and pentachlorobenzenes	**1 Gw, Ve**	**20 Gw**	250 De				15	30	**30**
Hexachlorobenzene	**0.05 Ve**	**20 Gw**	70 Va				15	30	**30**
OTHER CHLORINATED SUBSTANCES									
PCB total	**0.02 Ve**	**4 Gw**	**7 So,De**				35	70	70
Dioxins, furans and planar PCBs (asTCDD-equivivalents) **NOTE! ng/kg dry soil**	20 Ve	2500 De	2500 De	**10 (b,d)**	**250 (d)**	**250 (d)**	25000	50000	50000
Dibromochloromethane	1.5 Gw	4 Gw	**100 Va**	**2 (c)**	**4 (c)**		x	x	x
Bromodichloromethane	**0.5 Ve, Gw, Va**	**2 Gw**	**8 Va**				x	x	x
Carbontetrachloride	0.1 Gw	0.2 Gw	**3 Va**	**0.1 (c)**	**0.2 (c)**		30	60	60
Trichloromethane	2 Gw	7 Gw	**50 Va**	**2 (c)**	**8 (c)**		30	60	60
Trichloroethylene	**5 Ve**	**30 Gw**	250 Va				30	60	**60**
Tetrachloroethylene	**3 Ve**	**20 Gw**	200 Va				30	60	**60**
1,1,1-trichloroethane	30 Va	80 Gw	150 Va	**40 (c)**	150 (c)		45	**90**	**90**
Dichloromethane	**0.1 Gw**	**0.3 Gw**	100 Va				30	60	**60**
NITRO COMPOUNDS									
2,4-dinitrotoluene	**0.5 Ve**	**2 Gw**	1500 De				*10*	*20*	***20***

Continuation Table A1.2	HUMAN TOXICOLOGICAL VALUE (mg/kg dry soil)						ECOTOXICOLOGICAL VALUE (mg/kg dry soil)		
SUBSTANCE/SUBSTANCE GROUP	Integrated value			Adjusted values			KM	MKM GV	MKM
	KM	MKM GV	MKM	KM	MKM GV	MKM			
SIMPLE AROMATIC HYRDOCARBONS									
Benzene	**0.06** Va,Gw Ve	**0.2** Va, Gw	**0.4** Va				12	24	24
Toluene	8 Va	25 Va	**35** Va	**10** (c)	**35** (c)		60	120	120
Ethylbenzene	9 Va	30 Va	**60** Va	**12** (c)	**50** (c)		*60*	*120*	*120*
Xylene	14 Va	40 Va	**70** Va	**15** (c)	**60** (c)		*60*	*120*	*120*
POLYCYCLIC AROMATIC HYDROCARBONS (PAH)									
Sum of carcinogenic PAH	**0.3** Ve	**7** Du	**7** Du				20	40	40
Sum of other PAH	25	250	3000				**20**	**40**	**40**

x = ecotoxicological values not available
value in italics = ecotoxicological values estimated from literature data
*) =Taste problems in groundwater can occur at lower levels.

Motivations for adjustment:
a) = odor, taste or technical limits for drinkingwater
b) = background levels in natural environments
c) = drinking water guideline values correspond to 10-50% of TDI
d) = background exposure of substance from other sources high
e) = substance with high acute toxicity

Appendix 2. Reference soil concentrations

Table A2.1 Reference soil concentrations for land for sensitive use

Substance	Soil intake mg/kg	Dermal contact mg/kg	Inhalation dust mg/kg	Inhalation vapor mg/kg	Ingestion drinkingw. mg/kg	Ingestion vegetables mg/kg	Ingestion fish mg/kg	Minimum mg/kg	Integrated value mg/kg
arsenic	4,0	67	63	-	0,09	1,1	32	0,09	**0,08**
lead	350	29 167	12 500	-	150	401	*	150	**82**
cadmium	100	357	125	-	0,45	4,4	*	0,45	**0,41**
cobolt	140	3 500	87 500	-	30	124	*	30	**20**
copper	50 000	not limited	not limited	-	15 006	10 619	*	10 619	**5 505**
chromium (III)	100 000	not limited	not limited	-	1 500	164 786	not limited	1 500	**1 463**
chromium (VI)	500	2 778	6,3	-	32	824	*	6,3	**5,1**
mercury	47	470	25 000	8,5	3,0	41	1 754	3,0	**2,0**
nickel	500	714	625	-	75	120	601 200	75	**38**
vanadium	700	17 500	25 000	-	150		*	150	**122**
zinc	100 000	not limited	not limited	-	21 471	7 545	*	7 545	**5 276**
cyanides free	1 200	2 000	750 000	443	0,90	5,7	*	0,90	**0,78**
cyanides complex	2 000	3 333	not limited	-	44	81	*	44	**28**
phenol	4 000	7 692	not limited	76 172	6,7	10	*	6,7	**4,0**
monochlorophenol (2-)	500	962	312 500	100	8,5	7,5	*	7,5	**3,8**
dichlorophenol (2,4-)	300	375	187 500	2 898	2,0	0,56	582 159	0,56	**0,44**
trichlorophenol (2,4,5-)	10 000	19 231	not limited	723 596	690	58	*	58	**53**
trichlorophenol (2,4,6-)	4 467	2 233	670 000	10 950	23	2,6	1 689	2,6	**2,3**
tetrachlorophenol (2,3,4,6-)	3 000	5 769	not limited	69600	37	2,3	*	2,3	**2,2**
pentachlorophenol	300	1 364	187 500	not limited	1,6	0,09	*	0,09	**0,09**
cresol (2-)	5 000	9 615	not limited	82 277	22	22	*	22	**11**
monochlorobenzene	9 000	45 000	not limited	79	21	33	*	21	**11**
dichlorobenzene (1,2)	43 000	215 000	not limited	838	188	196	2,0E+06	188	**86**
dichlorobenzene (1,4)	11 000	55 000	375 000	38	56	51	2,0E+06	38	**16**
trichlorobenzene (1,2,4)	770	4 813	225 000	111	11	4,2	*	4,2	**2,9**
tetrachlorobenzene (1,2,4,5)	30	150	18 750	353	26	0,62	not limited	0,62	**0,59**
pentachlorobenzene	80	400	50 000	657	208	2,2	not limited	2,2	**2,1**
hexachlorobenzene	22	11	3 300	45	17	0,05	49	0,05	**0,05**
PCB	0,53	4,0	331	2 041	3,7	0,02	1,6	0,02	**0,02**
dioxins (TCDD)	5,0E-04	1,3E-03	3,1E-01	2,7E+01	1,2E-02	2,3E-05	*	2,3E-05	**2,2E-05**
dibromochloromethane	1 790	8 950	not limited	33	2,2	4,9	1 381	2,2	**1,4**
bromodichloromethane	1 333	667	200 000	2,7	1,2	1,0	1 233	1,0	**0,46**
carbon tetrachloride	714	3 570	350 000	0,86	0,12	2,6	1 602	0,12	**0,10**
trichloromethane	1 300	6 500	425 000	16	4,1	4,5	1 381	4,1	**1,9**
trichloroethylene	2 380	11 900	not limited	92	18	8,3	17 316	8,3	**5,4**
tetrachloroethylene	1 400	7 000	not limited	61	10	4,9	1 806	4,9	**3,1**
trichloroethane (1,1,1)	58 000	290 000	not limited	57	75	189	*	57	**28**
dichloromethane	600	3 000	not limited	35	0,13	1,0	420	0,13	**0,12**
dinitrotoluene (2,4)	200	769	125 000	44 421	0,90	0,92	1 152	0,90	**0,45**
benzo(a)pyrene	15	7,7	2,8	969	214	0,41	38 067	0,41	**0,33**
naphthalene	4 000	20 000	2 500 000	3 249	345	64	*	64	**53**
acenaphthylene	-	-	-	-	-	-	-	-	-
fluorene	4 000	10 000	not limited	169 318	2 367	123	515	123	**92**
phenanthrene	-	-	-	-	-	-	-	-	-
fluoranthene	4 000	10 000	not limited	not limited	18 345	211	not limited	211	**194**
pyrene	3 000	7 500	not limited	not limited	13 501	158	3 919	158	**140**
benzo(a)anthracene	-	-	-	-	-	-	-	-	-
chrysene	-	-	-	-	-	-	-	-	-
benzo(b)fluoranthene	-	-	-	-	-	-	-	-	-
benzo(k)fluoranthene	-	-	-	-	-	-	-	-	-
indeno(1,2,3-cd)pyrene	-	-	-	-	-	-	-	-	-
dibenzo(a,h)anthracene	-	-	-	-	-	-	-	-	-
benzo(ghi)perylene	-	-	-	-	-	-	-	-	-
carcinogenic PAH	15	7,7	2,8	969	214	0,41	38 067	0,41	**0,33**
other PAH	3 000	7 500	1,9E+06	1,7E+05	2 367	123	515	123	**92**
benzene	220	110	32 500	0,14	0,21	0,18	3 380	0,14	**0,06**
toluene	22 300	92 917	not limited	11	41	80	not limited	11	**8,0**
ethylbenzene	9 700	24 250	not limited	19	34	40	not limited	19	**9,2**
xylene	17 900	74 583	not limited	23	60	75	*	23	**14**

* = no data available

Table A2.2 Reference soil concentrations for land for less sensitive use

Substance	Soil intake mg/kg	Dermal contact mg/kg	Inhalation dust mg/kg	Inhalation vapor mg/kg	Ingestion drinkingw. mg/kg	Groundwater use minimum mg/kg	Groundwater use integrated mg/kg	No groundwater use minimum mg/kg	No groundwater use integrated mg/kg
arsenic	60	200	188	-	0,18	0,18	**0,18**	60	**37**
lead	11 667	83 333	37 538	-	300	300	**289**	11 667	**8 042**
cadmium	3 333	1 020	375	-	0,91	0,91	**0,90**	375	**254**
cobolt	4 667	10 000	262 763	-	60	60	**59**	4 667	**3 144**
copper	not limited	not limited	not limited	-	30 012	30 012	**29 231**	not limited	**not limited**
chromium (III)	not limited	not limited	not limited	-	3 000	3 000	**2 995**	not limited	**not limited**
chromium (VI)	16 667	7 937	19	-	65	19	**15**	19	**19**
mercury	1 567	1 343	75 075	26	6,0	6,0	**4,8**	26	**25**
nickel	16 667	2 041	1 877	-	150	150	**129**	1 877	**924**
vanadium	23 333	50 000	75 075	-	301	301	**294**	23 333	**13 127**
zinc	not limited	not limited	not limited	-	42 943	42 943	**42 137**	not limited	**not limited**
cyanides free	40 000	1 714	not limited	1 331	1,8	1,8	**1,8**	1 331	**735**
cyanides complex	66 667	2 857	not limited	-	87	87	**85**	2 857	**2 738**
phenol	133 333	21 978	not limited	228 745	13	13	**13**	21 978	**17 390**
monochlorophenol (2-)	16 667	2 747	938 438	299	17	17	**16**	299	**265**
dichlorophenol (2,4-)	10 000	1 071	563 063	8 704	4,0	4,0	**4,0**	1 071	**870**
trichlorophenol (2,4,5-)	333 333	54 945	not limited	not limited	1 380	1 380	**1 340**	54 945	**46 054**
trichlorophenol (2,4,6-)	67 000	25 769	not limited	32 882	47	47	**47**	25 769	**11 815**
tetrachlorophenol (2,3,4,6-)	100 000	16 484	not limited	209 009	75	75	**74**	16 484	**13 222**
pentachlorophenol	10 000	3 896	563 063	not limited	3,3	3,3	**3,2**	3 896	**2 788**
cresol (2-)	166 667	27 473	not limited	247 077	43	43	**43**	27 473	**21 480**
monochlorobenzene	300 000	128 571	not limited	236	41	41	**35**	236	**236**
dichlorobenzene (1,2)	not limited	614 286	not limited	2 516	377	377	**327**	2 516	**2 501**
dichlorobenzene (1,4)	366 667	157 143	not limited	114	113	113	**57**	114	**113**
trichlorobenzene (1,2,4)	25 667	13 750	675 676	333	21	21	**20**	333	**321**
tetrachlorobenzene (1,2,4,5)	1 000	429	56 306	1 061	53	53	**43**	429	**233**
pentachlorobenzene	2 667	1 143	150 150	1 974	417	417	**240**	1 143	**567**
hexachlorobenzene	330	254	9 910	134	33	33	**22**	134	**69**
PCB	18	11	995	6 128	7,4	7,4	**3,6**	11	**6,8**
dioxins (TCDD)	1,7E-02	3,6E-03	9,4E-01	8,0E+01	2,5E-02	3,6E-03	**2,6E-03**	3,6E-03	**2,9E-03**
dibromochloromethane	59 667	25 571	not limited	98	4,4	4,4	**4,2**	98	**98**
bromodichloromethane	20 000	20 000	600 601	8,0	2,4	2,4	**1,8**	8,0	**8,0**
carbon tetrachloride	23 800	10 200	not limited	2,6	0,23	0,23	**0,21**	2,6	**2,6**
trichloromethane	43 333	18 571	not limited	47	8,2	8,2	**6,9**	47	**46**
trichloroethylene	79 333	34 000	not limited	275	36	36	**32**	275	**272**
tetrachloroethylene	46 667	20 000	not limited	184	20	20	**18**	184	**182**
trichloroethane (1,1,1)	not limited	828 571	not limited	170	150	150	**80**	170	**170**
dichloromethane	20 000	8 571	not limited	104	0,27	0,27	**0,27**	104	**103**
dinitrotoluene (2,4)	6 667	2 198	375 375	133 397	1,8	1,8	**1,8**	2 198	**1 626**
benzo(a)pyrene	230	115	8,3	2 911	428	8,3	**7,3**	8,3	**7,4**
naphthalene	100 000	42 857	not limited	7 317	517	517	**475**	7 317	**5 876**
acenaphthylene	-	-	-	-	-	-	-	-	-
fluorene	133 333	28 571	not limited	508 463	4 735	4 735	**3 909**	28 571	**22 422**
phenanthrene	-	-	-	-	-	-	-	-	-
fluoranthene	133 333	28 571	not limited	not limited	36 689	28 571	**14 295**	28 571	**23 421**
pyrene	100 000	21 429	not limited	not limited	27 003	21 429	**10 645**	21 429	**17 574**
benzo(a)anthracene	-	-	-	-	-	-	-	-	-
chrysene	-	-	-	-	-	-	-	-	-
benzo(b)fluoranthene	-	-	-	-	-	-	-	-	-
benzo(k)fluoranthene	-	-	-	-	-	-	-	-	-
indeno(1,2,3-cd)pyrene	-	-	-	-	-	-	-	-	-
dibenzo(a,h)anthracene	-	-	-	-	-	-	-	-	-
benzo(ghi)perylene	-	-	-	-	-	-	-	-	-
carcinogenic PAH	230	115	8,3	2 911	428	8,3	**7,3**	8,3	**7,4**
other PAH	100 000	21 429	not limited	not limited	27 003	21 429	**10 645**	21 429	**17 574**
benzene	3 300	330	97 598	0,41	0,42	0,41	**0,21**	0,41	**0,41**
toluene	743 333	31 857	not limited	34	81	34	**24**	34	**34**
ethylbenzene	323 333	13 857	not limited	56	68	56	**30**	56	**56**
xylene	596 667	25 571	not limited	69	119	69	**44**	69	**69**

Appendix 3. Physical and chemical data

The various physical and chemical data for substances used in the calculations of the guideline values are presented in Table A3.1. The values given are:

K_{ow}	octanol-water partioning coefficient
K_{oc}	distribution factor between water and organic carbon [l/kg]
K_d	distribution factor between water and soil [l/kg]
S	solubility [mg/l]
H	Henry's constant (dimensionless)

The parameters for estimation of contaminant uptake in plants are given in Table A3.2. The values given are:

For metals:

BCF root	bioconcentration factor for root parts (mg/kg *dry plant*)/(mg/kg *soil*)
BCF stem	bioconcentration factor for stem parts (mg/kg *dry plant*)/(mg /kg *soil*)
Kpl	total bioconcentration factor for plant (mg /kg *fresh plant*)/(mg /kg *soil*)

For other inorganic substances and organics:

BCF root	bioconcentration factor for root parts (mg/kg *fresh plant*)/(mg/l *soil pore water*)
BCF stem	bioconcentration factor for stem parts (mg/kg *fresh plant*)/(mg/l *soil pore water*)
Kpl	total bioconcentration factor for plant (mg/kg *fresh plant*)/(mg/kg *soil*)

Table A3.1 Physical and chemical data for substances

Substance	CAS n:o	Kow l/kg	Koc l/kg	Kd l/kg	S mg/l	enrys cns -	Referens
arsenic	7440-38-2			30			Estimated
lead	7439-92-1			1 000			Estimated
cadmium	7440-43-9			30			Estimated
cobolt	7440-48-7			100			Estimated
copper	7440-50-8			500			Estimated
chromium (III)	7440-47-3			2 000			Estimated
chromium (VI)	7440-47-3			30			Estimated
mercury	7439-97-6			200		0,47	Estimated
nickel	7440-02-0			100			Estimated
vanadium	1314-62-1			100			Estimated
zinc	7440-66-6			100			Estimated
cyanides free	57-12-5			1		0,0013	Estimated
cyanides complex				10			Estimated
phenol	108-95-2	30	29	0,6	8,28E+04	1,6E-05	SSL
monochlorophenol (2-)	95-57-8	141	388	7,8	2,20E+04	1,6E-02	SSL
dichlorophenol (2,4-)	120-83-2	1 200	147	2,9	4 500	1,3E-04	SSL
trichlorophenol (2,4,5-)	95-95-4	7 940	1 600	32	1 200	1,8E-04	SSL
trichlorophenol (2,4,6-)	88-06-2	5 010	381	7,6	800	3,2E-04	SSL
tetrachlorophenol (2,3,4,6-)	58-90-2	12 589	280	6	100	1,0E-04	HSDB*
pentachlorophenol	87-86-5	123 000	592	12	1 950	1,0E-06	CSOIL
cresol (2-)	95-48-7	98	91	2	26 000	4,9E-05	SSL
monochlorobenzene	108-90-7	724	219	4,4	472	0,15	SSL
dichlorobenzene (1,2)	95-50-1	2 690	617	12,3	156	0,08	SSL
dichlorobenzene (1,4)	106-47-7	2 630	617	12	74	0,10	SSL
trichlorobenzene (1,2,4)	120-82-1	10 233	1 780	36	300	0,06	SSL
tetrachlorobenzene (1,2,4,5)	95-94-3	50 119	20 599	412	3,5	0,01	CSOIL
pentachlorobenzene	608-93-5	147 911	60 791	1216	0,24	0,06	SSL
hexachlorobenzene	118-74-1	776 250	55 000	1100	6,2	0,05	SSL
PCB	1336-36-3	398 107	163 622	3272	0,2	3,4E-04	CSOIL
dioxins (TCDD)		1,4E+06	575 400	11508	3,0E-04	8,6E-05	EPRI
dibromochloromethane	124-48-1	148	63	1,3	2 600	0,03	SSL
bromodichloromethane	75-27-4	126	55	1,1	6 740	0,07	SSL
carbon tetrachloride	56-23-5	537	174	3,5	793	1,3	SSL
trichloromethane	67-66-3	83	63	1,3	2 600	0,03	SSL
trichloroethylene	79-01-6	513	166	3,3	1 100	0,42	SSL
tetrachloroethylene	127-18-4	468	155	3,1	200	0,75	SSL
trichloroethane (1,1,1)	71-55-6	302	110	2,2	1 330	0,71	SSL
dichloromethane	75-09-2	74	30	0,6	20 000	0,08	SSL
dinitrotoluene (2,4)	121-14-2	102	96	1,9	270	3,8E-06	SSL
benzo(a)pyrene	50-32-8	1 290 000	1 020 000	20400	1,6E-03	4,6E-05	SSL
naphthalene	91-20-3	2 290	2 000	40	31	2,0E-02	SSL
acenaphthylene	208-96-8	5 500	2 261	45	3,9	6,1E-02	EPRI
fluorene	86-73-7	16 220	13 800	276	2,0	2,6E-03	SSL
phenanthrene	85-01-8	28 800	11 837	237	1,3	6,2E-03	EPRI
fluoranthene	206-44-0	132 000	107 000	2140	0,21	6,60E-04	SSL
pyrene	129-00-0	129 000	105 000	2100	0,14	4,51E-04	SSL
benzo(a)anthracene	56-55-3	501 000	398 000	7960	9,4E-03	1,37E-04	SSL
chrysene	218-01-9	501 000	398 000	7960	1,6E-03	3,88E-03	SSL
benzo(b)fluoranthene	205-99-2	158 000	1 230 000	24600	1,5E-03	4,55E-03	SSL
benzo(k)fluoranthene	207-08-9	1,6E+05	1,2E+06	24600	8,0E-04	3,40E-05	SSL
indeno(1,2,3-cd)pyrene	193-39-5	4,5E+06	3,5E+06	69400	2,2E-05	6,56E-05	SSL
dibenzo(a,h)anthracene	53-70-3	5 000 000	3,8E+06	76000	2,5E-03	6,03E-07	SSL
benzo(ghi)perylene	191-24-2	1,7E+07	7,0E+06	139740	2,6E-04	5,80E-06	EPRI
benzene	71-43-2	135	59	1,2	1 750	0,23	SSL
toluene	108-88-3	562	182	3,6	562	2,72E-01	SSL
ethylbenzene	100-41-4	1 380	363	7,3	169	0,32	SSL
xylene	1330-20-7	1 470	386	7,7	175	0,28	SSL

NOTES

* Henry's constant from 2,3,4,5-tetrachlorophenol

SSL = USEPA Soil screening levels, 1996.

HSDB = Hazardous Substances Database, 1995.

CSOIL = van den Berg, 1991.

EPRI = EPRI, 1988.

Table A3:2 Parameters for estimation of plant concentration

Substance	CAS n:o	BCF root	BCF stem	Kpl
arsenic	7440-38-2	0,030	0,015	0,004
lead	7439-92-1	0,030	0,001	0,003
cadmium	7440-43-9	0,700	0,150	0,076
cobolt	7440-48-7	0,030	0,015	0,004
copper	7440-50-8	0,100	0,100	0,016
chromium (III)	7440-47-3	0,020	0,002	0,002
chromium (VI)	7440-47-3	0,020	0,002	0,002
mercury	7439-97-6	0,030	0,015	0,004
nickel	7440-02-0	0,100	0,070	0,014
vanadium	1314-62-1			
zinc	7440-66-6	0,400	0,100	0,044
cyanides free	57-12-05	0,798	0,883	0,700
cyanides complex		0,798	0,883	0,082
phenol	108-95-2	1,23	0,789	1,30
monochlorophenol (2-)	95-57-8	2,18	1,34	0,221
dichlorophenol (2,4-)	120-83-2	7,92	3,27	1,78
trichlorophenol (2,4,5-)	95-95-4	31,2	5,72	0,574
trichlorophenol (2,4,6-)	88-06-2	22,1	5,20	1,75
tetrachlorophenol (2,3,4,6-	58-90-2	44,2	6,12	4,34
pentachlorophenol	87-86-5	251,6	5,39	10,7
cresol (2-)	95-48-7	1,85	1,16	0,744
monochlorobenzene	108-90-7	5,63	2,66	0,900
dichlorobenzene (1,2)	95-50-1	14,0	4,36	0,733
dichlorobenzene (1,4)	106-47-7	13,8	4,33	0,722
trichlorobenzene (1,2,4)	120-82-1	37,8	5,96	0,611
tetrachlorobenzene (1,2,4,	95-94-3	126,4	6,22	0,161
pentachlorobenzene	608-93-5	289,8	5,15	0,121
hexachlorobenzene	118-74-1	1 036,7	2,72	0,472
PCB	1336-36-3	620,3	3,71	0,095
dioxins (TCDD)		1 632	1,96	0,071
dibromochloromethane	124-48-1	2,24	1,36	1,23
bromodichloromethane	75-27-4	2,07	1,28	1,28
carbon tetrachloride	56-23-5	4,64	2,34	0,907
trichloromethane	67-66-3	1,73	1,10	0,964
trichloroethylene	79-01-06	4,51	2,29	0,951
tetrachloroethylene	127-18-4	4,26	2,20	0,950
trichloroethane (1,1,1)	71-55-6	3,27	1,82	1,02
dichloromethane	75-09-02	1,10	0,672	1,99
dinitrotoluene (2,4)	121-14-2	1,88	1,18	0,727
benzo(a)pyrene	50-32-8	1 532	2,06	0,038
naphthalene	91-20-3	12,5	4,14	0,207
acenaphthylene	208-96-8	23,7	5,31	0,320
fluorene	86-73-7	53,5	6,27	0,108
phenanthrene	85-01-08	82,8	6,40	0,188
fluoranthene	206-44-0	266	5,30	0,063
pyrene	129-00-0	261	5,33	0,063
benzo(a)anthracene	56-55-3	740	3,36	0,047
chrysene	218-01-9	740	3,36	0,047
benzo(b)fluoranthene	205-99-2	305	5,07	0,006
benzo(k)fluoranthene	207-08-9	305	5,07	0,006
indeno(1,2,3-cd)pyrene	193-39-5	3 989	0,877	0,029
dibenzo(a,h)anthracene	53-70-3	4 348	0,803	0,029
benzo(ghi)perylene	191-24-2	11 155	0,269	0,040
benzene	71-43-2	2,14	1,31	1,23
toluene	108-88-3	4,78	2,38	0,924
ethylbenzene	100-41-4	8,72	3,45	0,811
xylene	1330-20-7	9,12	3,54	0,795

Appendix 4. Toxicological data

Toxicological data used in the calculations of the guideline values are presented in Table A4.1. The toxicological data are chosen from information available by the end of 1996. However, toxicological parameters are continuously being revised and updated and therefore revised values may have been published in the literature since then.

The values given are:

- TDI, tolerable daily intake
- Cancer risk based daily intake (intake corresponding to a lifetime excess risk of 1/100 000)
- RfC, reference air concentration
- Cancer risk based air concentration
- Dermal absorption factor (absorption for dermal uptake/absorption for oral intake)
- Drinking water guidelines and percentage of TDI committed for drinking water
- Ambient Water Quality Criteria for fish residue values
- Cancer classification according to USEPA and IARC

USEPA:

Group A	Human carcinogen
Group B	probable human carcinogen
B1	limited eveidence from epidemiological studies
B2	"sufficient" evidence from animal studies and "inadeqate" or "no data" from epidemiological studies
Group C	possible human carcinogen
Group D	not classifiable as to health carcinogenicity
Group E	evidence of non-carcinogenicity for humans

IARC:

Group 1	The agent (mixture) is carcinogenic to humans
Group 2A	The agent (mixture) is probably carcinogenic to humans
Group 2B	The agent (mixture) is possibly carcinogenic to humans
Group 3	The agent (mixture) is not classifiable as to its carcinogenicity to humans
Group 4	The agent (mixture) is probably not carcinogenic to humans

In Table A4.2 the exotoxicological data used are presented:

- Dutch intervention values (C-values) based on ecotoxicological effects
- CCME Water Quality Criteria for aquatic life
- Calculated soil concentrations giving concentrations in a nearby surface water corresponding to the CCME Water Quality Criteria [mg/kg]

Table A4.1 Toxicological data

Substance	CAS n:o	ORAL TDI mg/kg/d	ORAL Cancer risk 1E-05 mg/kg/d	INHALATION RfC mg/m3	INHALATION Cancer risk 1E-05 mg/m3	DERMAL Relative absorption factor (h)	DRINKING WATER limit mg/l	DRINKING WATER Fraction of TDI	FISH AWQ (i) Fish microg/l	CANCER CLASS USEPA	CANCER CLASS IARC
arsenic	7440-38-2	1,1E-03 d	6,0E-06 b		2,5E-06 b	3,0E-02	1,0E-02	*100%* c	1,8E-02	A	1
lead	7439-92-1	3,5E-03 b		5,0E-04 b		6,0E-03	1,0E-02	50% c	none	B2	2B
cadmium	7440-43-9	1,0E-03 b		5,0E-06 b	5,6E-06 a	1,4E-01	1,0E-03	10% c	none	B1	2A
cobolt	7440-48-7	1,4E-03 e									
copper	7440-50-8	5,0E-01 b					2,0E+00	10% c		D	
chromium (III)	7440-47-3	1,0E+00 a				4,0E-02	5,0E-02	100% c	3,4E+06		3
chromium (VI)	7440-47-3	1,0E+00 a			2,5E-07 b	9,0E-02			none	A	1
mercury	7439-97-6	4,7E-04 b		1,0E-03 b		5,0E-02	1,0E-03	10% c	1,5E-01	D	3
nickel	7440-02-0	5,0E-03 b		2,5E-05 b		3,5E-01	5,0E-02	10% c	1,0E+02	A (dust	2A/2B
vanadium	1314-62-1	7,0E-03 a		1,0E-03 b							
zinc	7440-66-6	1,0E+00 b				2,0E-02	1,0E+00	c		D	
cyanides free	57-12-5	1,2E-02 b				3,0E-01	5,0E-02	20% c	none	D	
cyanides complex		2,0E-02 a									
phenol	108-95-2	4,0E-02 d				2,6E-01			none	D	3
monochlorophenol (2-)	95-57-8	5,0E-03 a				2,6E-01			none		
dichlorophenol (2,4-)	120-83-2	3,0E-03 a				4,0E-01			3,1E+03		
trichlorophenol (2,4,5-)	95-95-4	1,0E-01 a				2,6E-01			none		3
trichlorophenol (2,4,6-)	88-06-2		6,7E-03 b*			2,6E-01	2,0E-01	*100%* b	3,6E+00	B2	2B
tetrachlorophenol (2,3,4,6-)	58-90-2	3,0E-02 a							none		2B
pentachlorophenol	87-86-5	3,0E-03 b				1,1E-01	9,0E-03	10% b	none	B2	2B
cresol (2-)	95-48-7	5,0E-02 a								C	
monochlorobenzene	108-90-7	9,0E-02 b		1,3E-01 g		0,100	3,0E-01	10% b	none	D	
dichlorobenzene (1,2)	95-50-1	4,3E-01 b		2,6E-01 g		0,100	1,0E+00	10% b	2,6E+03	D	3
dichlorobenzene (1,4)	106-47-7	1,1E-01 b		1,5E-02 g		0,100	3,0E-01	10% b	2,6E+03		2B
trichlorobenzene (1,2,4)	120-82-1	7,7E-03 b		9,0E-03 g		0,080	2,0E-02	10% b		D	
tetrachlorobenzene (1,2,4,5)	95-94-3	3,0E-04 a							4,8E+01		
pentachlorobenzene	608-93-5	8,0E-04 a							8,5E+01	D	
hexachlorobenzene	118-74-1	8,0E-04 a	3,3E-05 b*	3,0E-03 g		1,3E-01	1,0E-03	*100%* b	7,4E-04	B2	2B
PCB	1336-36-3	5,3E-06 **				6,7E-02			7,9E-06	B2	2A
dioxins (TCDD)	1746-01-6	5,0E-09 f				2,0E-01					
dibromochloromethane	124-48-1	1,8E-02 b				1,0E-01	1,0E-01	20% b	1,6E+01	C	3
bromodichloromethane	75-27-4	2,0E-02 a	2,0E-03 b*			1,0E-01	6,0E-02	*100%* b	1,6E+01	B2	2B
carbon tetrachloride	56-23-5	7,1E-03 b		1,4E-02 g			2,0E-03	10% b	6,9E+00	B2	2B
trichloromethane	67-66-3	1,3E-02 b*		1,7E-02 g		1,0E-01	2,0E-01	50% b	1,6E+01	B2	2B
trichloroethylene	79-01-6	2,4E-02 b		5,4E-01 d		1,0E-01			8,1E+01		2A
tetrachloroethylene	127-18-4	1,4E-02 b		6,8E-01 d		1,0E-01			8,9E+00		2A
trichloroethane (1,1,1)	71-55-6	5,8E-01 b		8,0E-01 g		1,0E-01	2,0E+00	10% b		D	3
dichloromethane	75-09-2	6,0E-03 b		3,5E-01 d			2,0E-02	10% b	1,6E+01	B2	2B
dinitrotoluene (2,4)	121-14-2	2,0E-03 a				1,3E-01			9,1E+00		
benzo(a)pyrene	50-32-8	1,0E-03 d	2,3E-05 b		1,1E-07 b	2,0E-01	7,0E-04	*100%* b	3,1E-02	B2	2A
naphthalene	91-20-3	4,0E-02 j				1,0E-01				D	
acenaphthylene	208-96-8					1,8E-01			3,1E-02	D	
fluorene	86-73-7	4,0E-02 a				2,0E-01			3,1E-02	D	3
phenanthrene	85-01-8					1,8E-01			3,1E-02	D	3
fluoranthene	206-44-0	4,0E-02 a				2,0E-01			5,4E+01	D	3
pyrene	129-00-0	3,0E-02 a				2,0E-01			3,1E-02	D	3
benzo(a)anthracene	56-55-3					2,0E-01			3,1E-02	B2	2A
chrysene	218-01-9					2,0E-01			3,1E-02	B2	3
benzo(b)fluoranthene	205-99-2					2,0E-01			3,1E-02	B2	2B
benzo(k)fluoranthene	207-08-9					2,0E-01			3,1E-02	B2	2B
indeno(1,2,3-cd)pyrene	193-39-5					1,8E-01			3,1E-02	B2	2B
dibenzo(a,h)anthracene	53-70-3					9,0E-02			3,1E-02	B2	2A
benzo(ghi)perylene	191-24-2					1,8E-01			3,1E-02	D	3
benzene	71-43-2		3,3E-04 b	1,3E-03 d		8,0E-02	1,0E-02	*100%* b	4,0E+01	A	1
toluene	108-88-3	2,2E-01 b		4,0E-02 d		1,2E-01	7,0E-01	10% b	4,2E+05	D	3
ethylbenzene	100-41-4	9,7E-02 b		4,0E-02 d***		2,0E-01	3,0E-01	10% b	3,3E+03	D	
xylene	1330-20-7	1,8E-01 b		4,0E-02 d		1,2E-01	5,0E-01	10% b		D	3

a = IRIS, 1995.
b = WHO, 1993; WHO (Inhalation), 1987.
c = SLV, 1993.
d = IMM, 1990; IMM (Inhalation), 1991.
e = CSOIL, 1991
f = Nord, 1988.
g = UBA, 1993.
h = MDEP, 1994.
i = AWQ Fish: USEPAs Ambient Water Quality Criteria Fish Residue values. IRIS, 1995.
j = SSL (1996)

NOTES
* Calculated from drinkingwater concentration assuming 2 l/day and 60 kg bodyweight
** Based on 10% of average background exposure SLV, 1995.
*** Assumed to be the same as xylen and toluen

Table A4.2 Ecotoxicological data

Substance	CAS n:o	Dutch C-value ecotox mg/kg	CCME aq life clean up microg/l	Concentration in soil not to exceed CCME value mg/kg
arsenic	7440-38-2	40	50	90000
lead	7439-92-1	290	1 to 7	60000
cadmium	7440-43-9	12	0,01	36
cobolt	7440-48-7	240		
copper	7440-50-8	190	2 to 4	60000
chromium (III)	7440-47-3	230	2 to 20	240000
chromium (VI)	7440-47-3			
mercury	7439-97-6	10	0,1	1200
nickel	7440-02-0	210	25 - 150	150000
vanadium	1314-62-1			
zinc	7440-66-6	720	30	180000
cyanides free	57-12-05		5	360
cyanides complex				
phenol	108-95-2	40	*1	47
monochlorophenol (2-)	95-57-8	10	7	3300
dichlorophenol (2,4-)	120-83-2	10	0,2	38
trichlorophenol (2,4,5-)	95-95-4	10		68000
trichlorophenol (2,4,6-)	88-06-2	10		
tetrachlorophenol (2,3,4,6-)	58-90-2	10		
pentachlorophenol	87-86-5	5	0,5	360
cresol (2-)	95-48-7	50	*1	120
monochlorobenzene	108-90-7	30	15	4100
dichlorobenzene (1,2)	95-50-1	30	2,5	1900
dichlorobenzene (1,4)	106-47-7	30	4	900
trichlorobenzene (1,2,4)	120-82-1	30	0,5	3000
tetrachlorobenzene (1,2,4,5	95-94-3	30	0,15	1100
pentachlorobenzene	608-93-5	30	0,03	2500
hexachlorobenzene	118-74-1	30	0,0065	430
PCB	1336-36-3		0,001	200
dioxins (TCDD)		0,046		
dibromochloromethane	124-48-1			
bromodichloromethane	75-27-4			
carbon tetrachloride	56-23-5	60	13	3000
trichloromethane	67-66-3	60	2	180
trichloroethylene	79-01-06	60	20	4300
tetrachloroethylene	127-18-4	60	110	22000
trichloroethane (1,1,1)	71-55-6	88		
dichloromethane	75-09-02	60		
dinitrotoluene (2,4)			-	
benzo(a)pyrene	50-32-8	40		
naphthalene	91-20-3	40		
acenaphthylene	208-96-8			
fluorene	86-73-7			
phenanthrene	85-01-08	40		
fluoranthene	206-44-0	40		
pyrene	129-00-0			
benzo(a)anthracene	56-55-3	40		
chrysene	218-01-9	40		
benzo(b)fluoranthene	205-99-2			
benzo(k)fluoranthene	207-08-9	40		
indeno(1,2,3-cd)pyrene	193-39-5	40		
dibenzo(a,h)anthracene	53-70-3			
benzo(ghi)perylene	191-24-2	40		
benzene	71-43-2	25	300	25000
toluene	108-88-3	130	2	460
ethylbenzene	100-41-4		90	40000
xylene	1330-20-7			

* = total non-chlorinated phenols, including cresol

References: Swartjes and van den Berg (1993), van den Berg et al (1994), Kreule et al (1995) CCME (1996)

REPORT 4639

Development of generic guideline values

THIS REPORT FORMS the background documentation for the generic guideline values for contaminated soils in Sweden.

The set of guideline values is one of several tools currently being developed for risk assessments of contaminated sites in Sweden. The guideline values are intended to be used in assessments of contaminated sites to indicate contaminant levels which do not pose unacceptable risks to humans or to the environment. They can also be used to indicate the degree of contamination on a site, to develop clean-up goals and to evaluate clean-up results.

This report describes the model and data used to derive these values. The basic assumptions are presented together with the data used to evaluate distribution and transport of contaminants, exposure of humans, toxicological and ecotoxicological effects.

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