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EVALUATION OF THE SWEDISH GUIDELINE VALUES FOR CONTAMINATED SITES - CADMIUM AND POLYCYCLIC AROMATIC HYDROCARBONS -

SUMMARY REPORT

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LIST OF ABBREVIATIONS AND SYMBOLS

BCF	bioconcentration factor for stem or root crops
bw	body weight [kg]
dw	dry weight
H	Henry's law constant, c.q. the dimensionless Henry coefficient [-]
KM	Känslig Markanvändning; refers to land with sensitive land-use; all types of land use can be permitted
K_{OA}	octanol-air partition coefficient [l/kg]
K_{OC}	partitioning coefficient organic carbon-water [l/kg]
K_{OW}	partitioning coefficient octanol-water [l/kg]
MKM	Mindre Känslig Markanvändning; refers to land with less sensitive land-use but with no groundwater extraction
MKM GV	Mindre Känslig Markanvändning med GrundVattenskydd; refers to land with less sensitive land-use and groundwater extraction
MW	molecular weight [g/mol]
P	vapour pressure [Pa]
PAH	Polycyclic Aromatic Hydrocarbons
RfC	reference concentration [mg/m³]
RfD	reference dose [mg/kg.d]
RIVM	National Institute of Public Health and the Environment (the Netherlands)
ρ_b	dry soil bulk density [kg/dm³]
S-EPA	Swedish Environmental Protection Agency (Naturvårdsverket)
S-RISK	transfer and exposure model to calculate human health effects adapted to specific conditions in a delineated part of South-Sweden and based on the current Swedish methodology to derive generic guideline values for contaminated soil
S-RISK Excel	S-RISK model incorporated in an Excel environment; S-RISK Excel includes the S-EPA and S-RISK models and the S-EPA and S-RISK databases
T	ambient temperature [K]
θ_a	soil air content [dm³ air/dm³ soil]
TCA	Tolerable Concentration in Air [mg/m³]
TDI	Tolerable Daily Intake [mg/kg.d]
TEF	Toxic Equivalence Factor [-]
θ_w	soil water content [dm³ water/dm³ soil]
VITO	Flemish Institute for Technological Research (Flanders, Belgium)
VOLASOIL	risk assessment model based on CSOIL for soils contaminated with volatile compounds (the Netherlands)
WHO	World Health Organization

1 BACKGROUND

Guideline values for soil pollutants are used as a reference to decide if soils are fit for normal use or need special environmental attention or treatment. They try to reflect risk levels for predefined receptors, which can be humans, the ecosystem, or water bodies. With regard to the protection of human health, the guideline values are often based on predicted potential exposure of persons coming into contact with the soil either directly or indirectly. The exposure models are based on the state of scientific knowledge of the transfer processes of pollutants in soil, air, water, food, etc, and of the exposure pathways such as ingestion of soil and food, dermal contact with soil and water, inhalation of vapours and particles. Exposure models may show differences depending on interpretation of scientific information, local characteristics and political decisions.

Swedish Guideline Values for soil quality were developed in 1996, according to the procedure described in "report 4639" of the Swedish Environmental Protection Agency (Naturvårdsverket, 1996b). The guideline values are based on both human health protection and on protection of the environment. International comparisons (e.g EuroRisk study, SETAC 2004) show that the human exposure model used in Sweden to propose these guideline values leads to relatively high exposure estimates for cadmium (Cd) and polycyclic aromatic hydrocarbons (PAHs). Hence, the PAH and Cd guideline values are in the lower range of European soil quality standards. As a consequence, it is often observed that diffuse enrichment of Swedish urban soils with cadmium and PAHs leads to measured concentrations exceeding the guideline values.

The Flemish Institute for Technological Research (VITO) and the National Institute of Public Health and the Environment (RIVM) were asked by JM AB to evaluate the Swedish Guideline Values for cadmium and polycyclic aromatic hydrocarbons with regard to the human health part. Therefore, the human exposure models, their parameter values and the toxicological reference values were evaluated to see whether they are still in line with the current state-of-the-art of contaminated sites risk assessment. This evaluation has resulted in the proposal of alternative soil quality guidelines for Cd and PAHs for the Swedish situation. Because these alternative values are based on the properties of specific filling material JM uses and on climatological conditions of the land south of the line going from Göteborg at the West Coast to Gävle at the East Coast, they are valid for building sites in that geographical region (where most of the JM projects are situated) but may not be so for other Swedish sites. The alternative values are not to be considered generic Swedish values.

The present document is a summary document. A detailed description of the assessment and the results can be found in the accompanying technical report.

2 ELEMENTS OF REVISION

2.1 General aspects

In analogy with S-EPA the same three different types of land-use have been considered: land with sensitive land-use (KM), land with less sensitive land-use and groundwater extraction (MKM GV), and land with less sensitive land-use without groundwater extraction (MKM).

The following elements of the Swedish Guideline Values have been evaluated:

- evaluation of model equations and parameter values for transfer from contaminants to the contact media (indoor air, groundwater, plants, ambient air);
- evaluation of model equations and parameter values for exposure calculations;
- evaluation of contaminant-properties for cadmium and PAHs;
- slight modification of the risk calculations, i.e. the comparison of calculated dose with toxicological reference dose;
- toxicological criteria.

A new spreadsheet model was developed. In this report, the model is referred to as S-RISK, while the spreadsheet is called S-RISK Excel. S-RISK Excel includes both the S-EPA and S-RISK models. Compound specific properties can be selected from either the S-EPA or S-RISK databases.

2.2 Contact media

The S-EPA model used one single soil type with associated soil parameters. The S-RISK model used three different soil types, but retained the soil type silty sand which corresponds most to filling material used by JM in construction projects. Comparison of S-EPA and S-RISK values are given in Table 1.

Table 1: Basic soil parameters used in S-EPA (Naturvårdsverket, 1996) and S-RISK

	S-EPA	S-RISK	units
f_{OM} (organic matter)	0.02	0.02	%
ρ_b (bulk density)	1.5	1.56	kg/dm³
θ_w (water content)	0.3	0.11	dm³/dm³
θ_a (air content)	0.2	0.28	dm³/dm³

Soil-to-indoor-air dilution factors have been calculated, based on the most volatile PAH considered, i.e. naphthalene, using a probabilistic approach. This was done for three soil types frequently used by JM as filling material and two building types most frequently built by JM, i.e. a concrete floor directly on the soil (slab-on-grade) and a concrete basement. The models used were the Johnson & Ettinger model (concrete floor, single dilution factor) and a combination of the Johnson & Ettinger and the Volasoil model (basement, two dilution factors: soil to basement, basement to indoor air). The latter approach explicitly tried to implement the effect of building practices that limit the infiltration of radon and

consequently also of volatile chemicals into buildings. The lower 5th percentile dilution factor was then used for the calculation of the guideline value. The resulting dilution factors for silty sand (most representative soil type) were 1/16,000 (concrete floor) and 1/3,000,000 (basement). The dilution factor in the S-EPA model is 1/20,000.

A similar procedure was used to calculate a dilution factor for groundwater to a groundwater well for a 'typical' building site near the waterfront. The same equations of S-EPA were used, although it was noted that for MKM GV the approach could result in pollution of the groundwater body between the source and the receptor at 500 m (which could result in conflicts with the EU Groundwater Directive). The lower 5th percentile value for the dilution factor was chosen. Because the values were relatively close to the values in the original approach, and accounting for the uncertainty involved, the values from the S-EPA approach were adopted in S-RISK (1/DF equals 15 for KM and 30 for MKM GV).

The equations for transfer of contaminants to surface water were not revised.

For the calculation of the cadmium concentration in vegetables a consumption-weighted-average vegetable-soil relation was derived from measured data on soil, crops and the average food consumption pattern. Because of lack of Swedish data the Dutch average consumption pattern is considered a valid basis to calculate a representative consumption weighted concentration in vegetables for the south of Sweden. The model used crop-specific BCF (bioconcentration factor) relationships that relate cadmium in plant to cadmium in soil and a series of soil properties. In addition to the soil properties mentioned in Table 1 a pH of 5.5 and a clay content of 3% was used.
The model for calculating the concentration of PAHs in vegetables was revised into a model that includes uptake from soil as well as gaseous and particle deposition on the plant. However, model calculations could not be supported by measured data. Therefore, measured vegetable-soil relations were used in S-RISK. Resulting BCF values for cadmium and PAHs are given in Table 2.

Table 2: BCF(dry weight basis) values used in S-EPA and S-RISK revised values

	S-EPA		S-RISK	
	root	above-ground	root	above-ground
cadmium	0.7	0.15	0.158	0.483
carcinogenic PAHs				
Acenaphthene[c]	2.32	2.32		modelled
Acenaphthylene[c]	2.32	2.32		
Benzo(a)anthr.[c]	0.015	0.007		
Benzo(a)pyr.[c]	0.012	0.002		
Benzo(b)fluoranthene[c]	0.005	0.014		
Benzo(k)fluoranthene[c]	0.015	0.003		
Chrysene[c]	0.013	0.008		
Dibenzo(a,h)anthracene[c]	0.0005	0.0003		
Fluoranthene[c]	0.023	0.029		
Ind.(1,2,3-cd)pyrene[c]	0.0002	0.0001		
Phenanthrene[c]	0.031	0.041		
Pyrene[c]	0.021	0.011		
noncarcinogenic PAHs				
Anthracene	0.002	0.022		
Benzo(g,h,i)perylene	0.011	0.004		
Fluorene	0.009	0.005		
Naphthalene	2.92	2.92		

The emission and concentration of soil particles in ambient air was calculated on the basis of soil characteristics (soil type, moisture, etc.), site characteristics (vegetation, buildings) and climate (Stockholm, Malmö and Göteborg stations). Particular attention is given to the effect of obstacles in built-up areas (residential areas, industrial sites) on these emissions. To derive an annual average concentration of soil particles in ambient air in the entire region the highest calculated outdoor dust concentration (the Göteborg station) was multiplied with a safety factor of 10 to account for mechanical dust emissions. The resulting value was 5 μg/m³, compared to a value of 41 μg/m³ in S-EPA.

2.3 Exposure

Revised soil ingestion rates for children and adults were derived on the basis of literature reviews. The soil ingestion value for children was lowered from 150 mg/d to 100 mg/d. In the case of land with less sensitive land-use, the adult soil ingestion value from S-EPA was maintained.

The methodology for the calculation of dermal exposure to soil and dust, using absorption factors, was maintained. However, the relative absorption factors were revised, taking into account recommendations of US-EPA (United States- Environmental Protection Agency). They are given in Table 3.

Table 3: Relative absorption factors in S-EPA and S-RISK revision (dimensionless)

Substance	S-EPA	S-RISK
Cadmium	0.14	0.04
carcinogenic PAHs		
Acenaphtene	-	0.13
Acenaphtylene	0.1	0.13
Benzo(a)anthracene	0.2	0.13
Benzo(a)pyrene	0.2	0.13
Benzo(b)fluoranthene	0.2	0.13
Benzo(k)fluoranthene	0.2	0.13
Chrysene	0.2	0.13
Dibenzo(a,h)anthracene	0.09	0.13
Fluoranthene	0.2	0.13
Indeno(1,2,3-cd)pyrene	0.18	0.13
Phenanthrene	0.18	0.13
Pyrene	0.2	0.13
noncarcinogenic PAHs		
Anthracene	-	0.13
Benzo(g,h,i)perylene	0.18	0.13
Fluorene	0.2	0.13
Naphthalene	0.1	0.13

On the basis of recent consumption rates in both Sweden and the Netherlands, it is concluded that the lifelong averaged consumption rates in both countries are of the same order of magnitude. Because the consumption rates in the Netherlands give more detailed information on specific crops and were evaluated in more detail, while the total rates are similar to the Swedish data, it is proposed to use the consumption data of the Netherlands as basis for S-RISK, for calculating exposure via vegetable consumption.
Although the relatively high total consumption rates of potatoes and aboveground vegetables by kitchen gardeners was calculated, based on Dutch statistics, these values were not used, since the consumption rates for kitchen gardeners were considered to be too conservative.

Table 4: Vegetable consumption values in S-EPA and S-RISK revision for KM

Parameter	S-EPA		S-RISK	
Long-term consumption per unit body weight [kg/kg.d]	0.01 0.004	child adult	0.0079 0.0037	child adult
Integrated lifetime consumption [kg/kg.d]	0.005		0.0041	

The other exposure pathways and their corresponding parameter values were not reviewed.

2.4 Contaminant properties

On the basis of a set of empirical relations between sorption coefficient and soil properties, the sorption coefficient for cadmium was calculated for the South of Sweden. The average value equalled 102 l/kg, compared to the value of 30 l/kg used in S-EPA. All physico-

chemical properties of PAHs were compiled from 5 databases and reviewed. They are given in Table 6.

2.5 Toxicological criteria

There is no evidence of carcinogenicity by oral exposure to cadmium. For chronic oral exposure, the kidney is considered the critical target organ. An oral *TDI* (Tolerable Daily Intake) was derived in analogy with the values from the major international bodies (US-EPA, JECFA). The selected oral TDI of 1 µg/kg bw/d is the same as the TDI used in S-EPA. The WHO-drinking water Guideline Value of 3 µg/l (10 % of the TDI) was adopted for cadmium, which is higher than the S-EPA value of 1 µg/l.
A TCA (Tolerable Concentration in Air) for cadmium of 5 ng/m³ is used in S-RISK. According to the Working Group of the EC this value derived from non-cancer effects provides also an appropriate level of protection from cancer risk due to exposure to cadmium. The value is the same as the TCA used in S-EPA.

Extensive mechanistic studies have shown that many PAH compounds are complete carcinogens, after inhalation exposure and possibly after oral exposure. Although still under debate the TEF (Toxic Equivalency Factor) concept has been applied to PAHs. Application of TEF values provides a relatively simple risk assessment approach, in which for each PAH a TEF is defined, expressed as "order of magnitude" (i.e. 0.001; 0.01; 0.1; or 1.0). Linear additivity of toxic effects (in this case carcinogenesis) of different PAH compounds has been assumed. With the introduction of TEFs, some PAH compounds considered non-carcinogenic in the S-EPA methodology, have to be dealt with as carcinogenic compounds in S-RISK. For oral exposure without carcinogenic effects, the toxicological reference values of the US-EPA have been used, or, when these values are lacking, has been derived from the TPH Criteria Working Group. The classication of the PAHs is given in Table 5.

Table 5: Overview of TEF values and carcinogenic classification in S-RISK compared to carcinogenic classification in S-EPA

PAH	S-EPA	S-RISK	
	carcinogenic classification	carcinogenic classification	Proposed TEF
Acenaphthene	T	NT	0.001
Acenaphthylene	T	NT	0.01
Anthracene	T	T	0
Benzo(a)anthracene	NT	NT	0.1
Benzo(a)pyrene	NT	NT	1.0
Benzo(b)fluoranthene	NT	NT	0.1
Benzo(g,h,i)perylene	T	T	0
Benzo(k)fluoranthene	NT	NT	0.1
Chrysene	NT	NT	0.01
Dibenzo(a,h)anthracene	NT	NT	1.0
Fluoranthene	T	NT	0.01
Fluorene	T	T	0
Indeno(1,2,3-cd)pyrene	NT	NT	0.1
Naphthalene	T	T	0
Phenanthrene	T	NT	0.001
Pyrene	T	NT	0.001

NT: no threshold for effects (genotoxic and carcinogenic compound);
T: threshold for effects;

Table 6: Physico-chemical properties of PAHs (reviewed data at 298K).

Chemical	***MW** [g/mol]**	***S* [mg/l]**		***P** [Pa]**	***H* [-]**		**K_{OW} [l/kg]**		**K_{OC} [l/kg]**	
		S-EPA	**S-RISK**	**S-RISK**	**S-EPA**	**S-RISK**	**S-EPA**	**S-RISK**	**S-EPA**	**S-RISK**
carcinogenic PAHs										
Acenaphthene	154.21 a	*	3.59 g	$4.21x10^{-1}$ g	*	$7.49x10^{-3}$ a	*	$10^{4.05}$ g	*	$10^{3.55}$ g
Acenaphthylene	152.20 a	3.9	6.71 a	$9.45x10^{-1}$ a	$6.1x10^{-2}$	$8.84x10^{-3}$ g	$10^{3.74}$	$10^{3.94}$ a	$10^{3.35}$	$10^{3.23}$ g
Benzo(a)anthracene	228.22 a	$9.4x10^{-3}$	$1.59x10^{-2}$ g	$1.68x10^{-5}$ g	$1.37x10^{-4}$	$1.83x10^{-4}$ g	$10^{5.70}$	$10^{5.83}$ g	$10^{5.60}$	$10^{5.24}$ g
Benzo(a)pyrene	252.56 a	$1.6x10^{-1}$	$3.23x10^{-3}$ g	$1.09x10^{-6}$ g	$4.6x10^{-5}$	$2.60x10^{-4}$ g	$10^{6.11}$	$10^{6.27}$ g	$10^{6.01}$	$10^{5.88}$ c
Benzo(b)fluoranthene	252.24 a	$1.5x10^{-3}$	$2.48x10^{-3}$ g	$8.91x10^{-6}$ g	$4.55x10^{-3}$	$9.66x10^{-4}$ a	$10^{5.20}$	$10^{6.32}$ a	$10^{5.09}$	$10^{5.93}$ c
Benzo(k)fluoranthene	252.24 a	$8.0x10^{-4}$	$1.22x10^{-3}$ g	$3.24x10^{-7}$ g	$3.40x10^{-5}$	$2.30x10^{-3}$ a	$10^{5.20}$	$10^{6.55}$ g	$10^{5.09}$	$10^{5.82}$ g
Chrysene	228.28 a	$1.6x10^{-3}$	$2.78x10^{-3}$ g	$1.96x10^{-6}$ g	$3.88x10^{-3}$	$8.82x10^{-4}$ g	$10^{5.70}$	$10^{5.78}$ g	$10^{5.60}$	$10^{5.12}$ g
Dibenzo(a,h)anthracene	278.36 a	$2.5x10^{-3}$	$7.73x10^{-4}$ g	$1.27x10^{-9}$ g	$6.03x10^{-7}$	$8.72x10^{-6}$ g	$10^{6.70}$	$10^{6.54}$ g	$10^{6.58}$	$10^{5.95}$ g
Fluoranthene	202.20 a	$2.1x10^{-1}$	$1.95x10^{-1}$ g	$4.48x10^{-3}$ g	$6.60x10^{-4}$	$9.30x10^{-4}$ g	$10^{5.12}$	$10^{5.19}$ g	$10^{5.03}$	$10^{4.97}$ g
Indeno(1,2,3-cd)pyrene	276.33 a	$2.2x10^{-5}$	$6.20x10^{-2}$ a	$1.35x10^{-8}$ a	$6.56x10^{-5}$	$8.54x10^{-6}$ a	$10^{6.65}$	$10^{6.28}$ a	$10^{6.54}$	$10^{7.09}$ g
Phenantrene	178.23 a	1.3	$9.03x10^{-1}$ g	$3.99x10^{-2}$ g	$6.2x10^{-3}$	$1.66x10^{-3}$ g	$10^{4.46}$	$10^{4.50}$ g	$10^{4.07}$	$10^{4.15}$ g
Pyrene	202.27 a	$1.4x10^{-1}$	$1.52x10^{-1}$ g	$1.11x10^{-3}$ g	$4.51x10^{-4}$	$9.51x10^{-4}$ g	$10^{5.11}$	$10^{5.05}$ g	$10^{5.02}$	$10^{4.78}$ g
noncarcinogenic PAHs										
Anthracene	178.23 a	*	$6.81x10^{-2}$ g	$2.32x10^{-3}$ g	*	$5.67x10^{-3}$ g	*	$10^{4.44}$ g	*	$10^{4.34}$ g
Benzo(g,h,i)perylene	276.34 a	$2.6x10^{-4}$	$4.00x10^{-4}$ a	$2.99x10^{-8}$ g	$5.80x10^{-6}$	$2.17x10^{-5}$ g	$10^{7.23}$	$10^{6.91}$ g	$10^{6.85}$	$10^{6.52}$ c
Fluorene	166.22 a	2.0	2.03 g	$2.29x10^{-1}$ g	$2.6x10^{-3}$	$4.65x10^{-3}$ a	$10^{4.21}$	$10^{4.19}$ a	$10^{4.14}$	$10^{4.15}$ g
Naphthalene	128.18 a	$3.1x10^{1}$	$3.10x10^{1}$ g	$1.27x10^{1}$ g	$2.0x10^{-2}$	$2.12x10^{-2}$ a	$10^{3.60}$	$10^{3.38}$ g	$10^{3.30}$	$10^{3.17}$ g

*: No data are given in Naturvårdsverket (1996b).
a: arithmetic mean; g: geometric mean; c: calculated as: $K_{OC} = 0.411 \times K_{OW}$.
$: calculated as: $K_{OA}=K_{OW}/H$.

The oral toxicological reference value for benzo(a)pyrene equals $2.2.10^{-5}$ mg/kg.d, which is the same as the S-EPA value. The basis of the toxicological reference values for carcinogenic effects due to inhalation is the unit risk of $8.7x10^{-5}$ per ng/m³ for benzo(a)pyrene derived by WHO (1987, 2000) and accepted by the EC Working Group on Polycyclic Aromatic Hydrocarbons. The corresponding concentration of benzo(a)pyrene producing an excess lifetime cancer risk of 1/100,000 is 0.12 ng/m³, which is the same as the S-EPA value. The toxicological reference values for the other carcinogenic PAHs can be calculated by multiplying the toxicological reference value of benzo(a)pyrene with the TEF value for the carcinogenic PAH considered.

For non-carcinogenic effects due to inhalation, the toxicological reference concentrations of US-EPA are used. When these values are lacking they are calculated from the (oral) toxicological reference dose, or taken from the TPH Criteria Working Group.

Table 7: Toxicological reference values for noncarcinogenic PAHs

	S-EPA		S-RISK	
	TDI (mg/kg.d)	RfC (mg/m³)	TDI (mg/kg.d)	RfC (mg/m³)
anthracene	-	-	0.3	1.1
benzo(g,h,i)perylene	-	-	0.03	0.11
fluorene	0.04	-	0.04	0.14
naphtalene	0.04	-	0.02	0.003

A reference drinking water concentration can be calculated from a toxicological reference dose for oral exposure, assuming a 2 litre drinking water consumption for a person weighing 60 kg (WHO). For non-carcinogenic effects, 10% of the toxicological reference dose is the basis for the drinking water limit. For carcinogenic effects, the excess lifetime risk of 10^{-5} is completely assigned to drinking water. In case a calculated drinking water limit exceeds the water solubility, an additional adjustment is made. In case the drinking water limit corresponding to carcinogenic effects exceeds the drinking water limit for non-carcinogenic effects, the latter is used in the calculations.

3 PROPOSED SOIL GUIDELINE VALUES

Since the most common soil type used in JM construction is filling material geologically defined as loamy sand, the current Swedish Guideline Values (S-EPA) are compared with the alternative Guideline Values for silty sand (both scenarios buildings with concrete floor and concrete basement).

The comparison is given in the Table 8.

Table 8: Comparison of alternative human health based Soil Guideline Values (S-RISK) for silty soils with current (S-EPA) Swedish Guideline Values (concentrations in [mg/kg dw]).

Substance	S-RISK						S-EPA		
	Concrete floor			Concrete basement					
	KM	MKM GV	MKM	KM	MKM GV	MKM	KM	MKM GV	MKM
Cadmium**	3.0	9.0	905	3.0	9.0	905	0.4	1	200
carcinogenic PAHs***									
Acenaphthene	7.0	24	27	29	185	4,700	$\sum(PAH)_C$: 0.3 *	$\sum(PAH)_C$: 7 *	$\sum(PAH)_C$: 7 *
Acenaphthylene	0.33	1.1	1.1	3	31	205			
Benzo(a)anthracene	27	143	235	32	193	409			
Benzo(a)pyrene	3.8	27	33	4.1	33	41			
Benzo(b)fluoranthene	36	167	227	46	249	409			
Benzo(k)fluoranthene	20	79	118	32	152	406			
Chrysene	41	95	710	48	107	4,000			
Dibenzo(a,h)anthracene	7.4	33	41	7.4	34	41			
Fluoranthene	38	92	507	47	109	3,960			
Indeno(1,2,3-cd)pyrene	83	404	411	83	404	411			
Phenanthrene	70	248	485	122	500	28,700			
Pyrene	304	1,095	3,352	406	1,562	38,900			
noncarcinogenic PAHs									
Anthracene	221	446	165,750	222	446	247,900	$\sum(PAH)_{NC}$: 25 *	$\sum(PAH)_{NC}$: 250 *	$\sum(PAH)_{NC}$: 3,000 *
Benzo(g,h,i)perylene	181	391	23,600	181	391	24,800			
Fluorene	123	500	27,670	123	500	33,000			
Naphthalene	6.0	21	106	7.1	27	9,200			

* Human health based Guideline Values for PAHs are as follows: (i) sum of carcinogenic PAHs: benzo(a)anthracene, chrysene, benzo(b)fluoranthene, benzo(k)fluoranthene, benzo(a)pyrene, indeno(1,2,3-cd)pyrene and dibenzo(a,h)anthracene: KM: 0.3 mg/kg dw, MKM GV and MKM: 7 mg/kg dw; (ii) sum of other PAHs: naphthalene, acenaphthylene, acenaphthene, fluorene, phenanthrene, anthracene, fluoranthene, pyrene and benzo(g,h,i)perylene: KM: 25 mg/kg dw, MKM GV: 250 mg/kg dw, and MKM: 3,000 mg/kg dw (Naturvårdsverket, 1996b).

**: Guideline values for the scenarios buildings with concrete floor and concrete basement are the same since C_a=0 for both scenarios.

***: if $\sum_i \frac{concentration\ PAH_i\ in\ soil}{C_{(M)KM\ (GV)_i}} \leq 1$ then there is no excess lifetime cancer risk of $1/10^5$

Cadmium

For Cd, the alternative human health based Guideline Values for land with sensitive land-use is approximately 8 times higher than the Swedish Guideline Value (3.1 vs. 0.4 mg/kg dw). For land with less sensitive land-use and groundwater extraction the alternative Guideline Value is approximately 9 times higher than the Swedish Guideline Value (9.1 vs. 1 mg/kg dw). The difference in Guideline Values between both methodologies is attributed to the difference in calculated critical concentration in drinking water. The pathway "drinking water consumption" is the dominant pathway for both land-uses, in both S-RISK and S-EPA. The critical concentration in drinking water is to a large extent determined by

the drinking water limit (0.001 mg/l, resp. 0.003 mg/l for S-EPA and S-RISK) and the partition coefficients (30 l/kg and 102 l/kg for S-EPA and S-RISK).

The alternative human health based Guideline Value for land with less sensitive land-use and without groundwater extraction is approximately 4.5 times higher than the Swedish guideline (904 versus 200 mg/kg dw). For this land-use, the dominant pathway in S-EPA is "inhalation of dust particles" and in S-RISK "soil ingestion". For the reference soil concentration for the pathway "inhalation of dust particles" the difference between S-EPA and S-RISK is largely due to the difference in parameter value used for the annual average dust concentration in inhaled air (0.041 mg/m³, resp. 0.005 mg/m³ in S-EPA and S-RISK).

PAHs

Contrary to the current Swedish guidelines, a revised soil Guideline Value is derived for each individual PAH compound. There is no excess lifetime cancer risk of $1/10^5$ when the sum of the ratios between concentration and the integrated reference soil concentration for the individual PAHs stays below 1:

$$\sum_i \frac{concentration\ PAH_i\ in\ soil}{C_i} \leq 1$$

As the use of the TEF concept assumes additivity of carcinogenic effects, the measured concentrations of PAHs have to be weighed according to their guideline value and these ratios need to be summed to be able to assess the soil quality. This approach differs from the dioxin approach in which each concentration is translated into an equivalent 2,3,7,8-concentration and the sum of the TEQs is compared to the guideline value for 2,3,7,8-TCDD. In the dioxin approach it is thus assumed that each dioxin exerts the same environmental behaviour as 2,3,7,8-TCDD. In the PAH approach, the differences in environmental behaviour are taken into account resulting in a guideline value per PAH.

For benzo(a)pyrene, the PAH compound on which the generic Guideline Value in S-EPA is based, the the dominant pathways remained the same in the calculation in both S-EPA and S-RISK. This is "consumption of vegetables" for land with sensitive land-use, and "inhalation of dust particles" for land with less sensitive land-use, with and without grondwater extraction. However, the absolute exposure differs. The difference in reference soil concentration for the pathway "vegetable consumption" results from differences in plant-soil ratios used (0.038 (mg/kg fw)/(mg/kg dw), respectively 0.002 (mg/kg fw)/(mg/kg dw) in the S-EPA and S-RISK databases. The difference in reference soil concentration for the pathway "inhalation of dust particles" can be attributed to the difference in parameter value used for the annual average dust concentration in air (0.041 mg/m³ in S-EPA and 0.005 mg/m³ in S-RISK).

The alternative human health based Guideline Value for benzo(a)pyrene for land with sensitive land-use is more than ten times higher than the Swedish Guideline Value. For land with less sensitive land-use the alternative Guideline Value is approximately 4 times higher (when including groundwater extraction), respectively 5 times higher (when excluding groundwater extraction) than the Swedish Guideline Values.

4 POLITICAL BOUNDARY CONDITIONS

The status and possible implementation of the alternative Guideline Values is a political responsibility. Furthermore, the basis for parameter selection (mean or more conservative values) concerns a political boundary condition. Also the position of ecology, for example the need for ecotoxicology based Guideline Values, is a political decision. In the S-EPA framework for developing generic soil Guideline Values, the basic principle is to choose the lowest of the human health based value and the ecotoxicology based value (Naturvårdsverket, 1996b). In this report, only the human health based soil Guideline Values were revised. These alternative Guideline Values were not integrated with their respective ecotoxicology based values. Revision of these latter values would mean a significant improvement in the overall derivation of generic soil Guideline Values.