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Ecotoxicological effect factors for the terrestrial environment in the frame of LCA

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Content

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1. Introduction

In LCA, an assessment of potential fate and effects on humans, terrestrial ecosystems and aquatic ecosystems of toxic substances is needed in the derivation of toxicity potentials. These potentials - existing of a fate and effect factor - are used to describe the relative contribution of emissions to toxicity related environmental problems. Recently, RIZA (1999) derived ecotoxicological effect factors pertaining to the aquatic environment for 259 substances. Although these effect factors are derived with help of risk assessment methods, these factors are primarily meant to be used for LCA purposes. This report aims to perform an equivalent exercise for ecotoxicological effect factors pertaining to the terrestrial environment for 181 substances as selected by Huijbregts (1999). The terrestrial ecosystem consists of an above-ground community, a soil community and a groundwater community. Only effects on soil organisms exposed directly via pore water and/or soil are addressed in this assessment.

2. Material & Methods

This section mentions the literature search and data sources (Section 2.1), methods to derive toxicity end points from literature (Section 2.2), data selection procedures for extrapolation (Section 2.3), and the extrapolation methods used (Section 2.4).

2.1 Literature search and data sources

For many compounds extensive toxicological reviewing and experimental research has been carried out by the RIVM. Criteria to judge toxicity studies have been developed at the Centre for Substances and Risk assessment of the RIVM. These criteria can be found in CSR (1996). In the review reports a distinction has already been made between toxicity data which can be used in the calculation of terrestrial effect factors and data that can not be used. These data are used in this report to derive the terrestrial PNECs. Furthermore, toxicological data for lead, nickel and zinc from Doelman & Haanstra (1986, 1989) and Haanstra & Doelman (1991) are used in this assessment. No further literature research was carried out in this assessment. The following literature sources are used:

- *Metals*: Crommentuijn et al. (1997a), Van de Plassche et al. (1992), Cleven et al. (1993), Janus (1993), Janus et al. (1996), Janus et al. (1999), Van de Meent et al. (1990a, b), Slooff et al. (1995), Doelman & Haanstra (1986, 1989), Haanstra & Doelman (1991);
- *Pesticides*: Crommentuijn et al. (1997b, c), Van de Plassche (1994), Van de Plassche et al. (1994), Van de Meent et al. (1990a, b);
- *Aromatics*: Denneman & Van Gestel (1990a, b)**,** Van de Plassche et al. (1993), Hulzebos et al. (1993);
- *Polycyclic Aromatic Hydrocarbons*: Kalf et al. (1995);
- *Halogenated non-aromatics*: Van de Plassche et al. (1993);
- *Halogenated aromatics*: Reuther et al. (1998), Hesse et al. (1991); Janus et al. (1991), Slooff et al. (1991a, b), Liem et al. (1993), Hulzebos et al. (1993); Van Gestel et al. (1991, 1996).

All raw data are given in Appendix A to F. The result of the toxicity test in $mg.kg_{dwt}^{-1}$ is shown together with some experimental conditions: species used or process studied, soil type, pH, duration of the experiment, % organic matter, % clay and the effect considered.

2.2 Methods to derive toxicity endpoints from the literature

2.2.1 Criteria for derivation of NOECs and L(E)C50

Only toxicological data that show effects at the population level of species are taken into account. These are survival, growth and reproduction and are commonly expressed as an L(E)C50 (short term tests, duration 4 days or less) or NOEC (long term tests, duration more than four day). An exception is made for micro-organisms and algae for which a NOEC may be derived from experiments during less than four days. If a Lowest Observed Effect Concentration (LOEC) for species or an Effect Concentration (EC) for terrestrial processes is given, the following conversion procedures to a NOEC are applied:
- (LO)EC 11% to 19% effect: NOEC = LOEC/2;
- (LO)EC 20 to 49% effect: NOEC = LOEC/3;
- (LO)EC > 50% effect: NOEC = LOEC/10.

2.2.2 Conversion to standard soil

The data for terrestrial species and for microbial processes are normalised to standard soil, containing 3.4% organic matter (H) and 25% clay (L) (EC, 1996). For organic chemicals the following equation is used to extrapolate to the standard soil:

$$NOEC;L(E)C50_{ssoil} = NOEC;L(E)C50_{\exp soil} \times \frac{H_{ssoil}}{H_{\exp soil}} \times CONV_{soil} \quad (1)$$

$NOEC;L(E)C50_{ssoil}$ = normalised NOEC or L(E)C50 for standard soil ($kg_c.kg_{wwt}^{-1}$)
$NOEC;L(E)C50_{expsoil}$ = NOEC or L(E)C50 for soil as used in the experiment ($kg_c.kg_{dwt}^{-1}$);
H_{ssoil} = organic matter content of standard soil (3.4%);
$H_{expsoil}$ = organic matter content of soil used in experiment (%);
$CONV_{soil}$ = conversion factor for soil concentrations: dwt to wwt ($kg_{dwt}.kg_{wwt}^{-1}$)

$$CONV_{soil} = \frac{Fsolid_{soil} \times RHOsolid}{RHO_{soil}} \quad (2)$$

$CONV_{soil}$ = conversion factor for soil concentrations: dwt to wwt ($kg_{dwt}.kg_{wwt}^{-1}$)
$Fsolid_{soil}$ = fraction of solids in soil ($m^3.m^{-3}$)
RHOsolid = density of solid phase ($kg.m^{-3}$)
RHO_{soil} = bulk density of soil ($kg_{wwt}.m^{-3}$)

If H is smaller than 2% in the original tests of organic chemicals, the percentage is set to 2%; if H is larger than 30%, the percentage is set to 30%.

For metals a slightly different equation is used for normalisation to the standard soil:

$$NOEC;L(E)C50_{ssoil} = NOEC;L(E)C50_{\exp soil} \times \frac{RL_{ssoil}}{RL_{\exp soil}} \times CONV_{soil} \quad (3)$$

$NOEC;L(E)C50_{ssoil}$ = normalised NOEC or L(E)C50 for standard soil ($kg_c.kg_{wwt}^{-1}$)
$NOEC;L(E)C50_{expsoil}$ = NOEC or L(E)C50 for soil as used in the experiment ($kg_c.kg_{dwt}^{-1}$);
RL_{ssoil} = reference value for standard soil ($kg_c.kg_{dwt}^{-1}$);
$RL_{expsoil}$ = value for soil used in experiment ($kg_c.kg_{dwt}^{-1}$);
$CONV_{soil}$ = conversion factor for soil concentrations: dwt to wwt ($kg_{dwt}.kg_{wwt}^{-1}$)

The RLs are metal-specific and can be calculated with formulas given in *Table 1*.

Table 1: Metal-specific formulas for calculation of $RL_{expsoil}$ and values for RL_{ssoil} (Crommentuijn et al., 1997a)

Metal	$RL_{expsoil}$	RL_{ssoil}
arsenic	15 + 0.4 (L + H)	26
barium	30 + 5L	155
beryllium	0.3 + 0.033L	1.1
cadmium	0.4 + 0.007 (L + 3H)	0.65
chromium	50 + 2L	100
cobalt	2 + 0.28L	9
copper	15 + 0.6 (L + H)	32
lead	50 + L + H	78
mercury	0.2 + 0.0017 (2L + H)	0.3
molybdenum	0.5	0.5
nickel	10 + L	35
selenium	0.7	0.7
tin	4 + 0.6L	19
vanadium	12 + 1.2L	42
zinc	50 + 1.5 (2L + H)	130

L = % clay; H = % organic matter

For metals no upper or lower limits are applied for the percentages of organic matter and clay, except for tests performed in food, litter, manure or spar-mor, containing > 90% organic matter. In such cases 30% organic matter was used in the conversion to standard soil (Crommentuijn et al., 1997a).

2.3 Data selection procedures for extrapolation

In the extrapolation methods only one value per species is used as input. For derivation of effect factors long term as well as short term ecotoxicological data are selected and/or calculated as follows:

- Test results indicating that the effect concentration for a species or process is larger or smaller than a certain value are only used in the derivation of the height of the assessment factor. The effect concentration itself is not taken into account in the extrapolation procedure;
- If a test result is indicated as a value between a lowest and a highest value, the highest value is taken in the extrapolation procedure;
- If for a single species several L(E)C50 or NOEC values are derived for different effect parameters the lowest is selected;
- If for a single species several L(E)C50 or NOEC values are derived for the same effect parameter a geometric mean value is calculated. According to Slooff (1992), the geometric mean is considered as the most representative value, although EC (1996) advises to calculate the arithmetic mean.
- In some cases data for effects of different life stages are available. If a certain life stage is more sensitive, this result is used in the extrapolation.
- For the data on fungi, bacteriophyta, microbial processes and enzymatic activities, more than one value per species or process is included in the extrapolation method. Different soils will have a substantially different population of fungi, bacteria or microbes performing the process under consideration. Thus, these values should be treated separately. Only if the same soil is used in several tests, a selection is made.
- For chronic toxicity tests on species and toxicity tests on terrestrial processes, priority is given to the result of the test with the longest exposure.

Appendix G lists the selected toxicity data for terrestrial species, used in the extrapolation. *Appendix H* lists the selected toxicity data for terrestrial processes.

2.4 Extrapolation methods for terrestrial species

RIZA (1999) proposed the use of the Technical Guidance Documents (TGD: EC, 1996) for the derivation of aquatic effect factors within the frame of LCA. The TGD is developed for performing risk assessment for new notified- and existing substances (EC, 1996). Because of consistency reasons, the TGD method for deriving terrestrial effect factors is also used in this document. In the TGD the derived risk limits are called Predicted No Effect Concentrations (PNECs). The effect factors derived here are synonym to the PNEC of the TGD. PNECs can be derived using three approaches from the TGD: statistical extrapolation (Section 2.4.1), assessment factors (Section 2.4.2), or the equilibrium partition method (Section 2.4.3).

2.4.1 Statistical extrapolation

If NOECs for individual species of four or more taxonomic groups are available, statistical extrapolation may be used in the calculation of the $PNEC_{soil}$ (Slooff, 1992). The statistical extrapolation method used here is the Aldenberg & Slob method (Aldenberg & Slob, 1993), which is used in the Netherlands in the frame of the project 'Setting of Integrated Environmental Quality Criteria'. In the Aldenberg & Slob method the $PNEC_{soil}$ is defined as the 50% confidence limit of the concentration that protects 95% of the species in the terrestrial ecosystem. The calculation can be performed with the following formulas:

$$AVGterr = mean(\log NOECterr_i) \quad (4)$$

$$STDterr = standard\ deviation(\log NOECterr_i) \quad (5)$$

$$PNEC_{soil} = 10^{AVGterr - Eterr \times STDterr} \quad (6)$$

$NOECterr_i$ = NOEC for terrestrial organisms, trophic level i ($kg_c.kg_{wwt}^{-1}$)
AVGterr = average of all log-transformed terrestrial NOECs (dimensionless)
STDterr = standard deviation of all log-transformed terrestrial NOECs (dimensionless)
Eterr = extrapolation constant, dependent on sample size (dimensionless)

Table 2 shows the extrapolation constants, taken from Aldenberg & Slob (1993).

Table 2: Extrapolation constants 'Eterr' (Aldenberg & Slob, 1993)

m	E	m	E	m	E
4	1.92	10	1.73	20	1.68
5	1.85	11	1.72	30	1.66
6	1.81	12	1.72	50	1.65
7	1.78	13	1.71	100	1.64
8	1.76	14	1.70	200	1.63
9	1.75	15	1.70	∞	1.62

m = number of species; Eterr = extrapolation constant

The method of Aldenberg & Slob (1993) assumes that the NOECs used for calculation fit the log-logistic distribution. This assumption can be tested statistically with the Kolmogorov-Smirnov D*sqrt(n) test. If the NOECs are not log-logistically distributed at a significance level of 1% it is unlikely that the species sensitivities are log-logistically distributed (Slooff, 1992). There could, however, be a misfitting resulting from outliers. In that case, outliers are identified and eliminated from the input data set. There also could be a rejection due to the fact that the distribution is bi- or multimodal. In that case the most sensitive groups of species of which the sensitivities do follow a log-logistic distribution are identified and used in the statistical extrapolation. If the species sensitivities are not log-logistically distributed and there are no reasons for leaving out outliers, assessment factors are applied to the toxicity data to obtain the $PNEC_{species}$ (→ Section 2.4.2).

2.4.2 Assessment factors

Assessment factors (→ *Table 3*) are used when the criterion is not met that NOECs are available for 4 or more taxonomic groups. The height of the assessment factors depends on the number and type of trophic levels and taxonomic groups for which toxicological data are available. Three trophic levels and eleven taxonomic groups are distinguished in this assessment:

- primary producers (algae, cyanophyta, macrophyta);
- consumers (acari, insecta, isopoda, mollusca, nematoda, oligochaeta);
- decomposers (fungi, bacteriophyta).

Table 3: Assessment factors for terrestrial species, according to EC (1996)

Ecotoxicological data		**TOXterr**	**AFterr**
None		$PNEC_{soil,\ ep}$	1
	Additional criteria		
L(E)C50(s) of 1 trophic level	$PNEC_{soil,\ ep} < L(E)C50terr_{min}/1000$ $PNEC_{soil,\ ep} \geq L(E)C50terr_{min}/1000$	$PNEC_{soil,\ ep}$ $L(E)C50terr_{min}$	1 1000
L(E)C50(s) of more than 1 trophic level		$L(E)C50terr_{min}$	1000
NOECs for 1 trophic level; no L(E)C50s	$PNEC_{soil,\ ep} < NOECterr_{min}/100$ $PNEC_{soil,\ ep} \geq NOECerr_{min}/100$	$PNEC_{soil,\ ep}$ $NOECterr_{min}$	1 100
NOECs for 1 trophic level; > 0 L(E)C50s	$L(E)C50terr_{min}/1000 < NOECterr_{min}/100$ $L(E)C50terr_{min}/1000 \geq NOECterr_{min}/100$	$L(E)C50terr_{min}$ $NOECterr_{min}$	1000 100
	Same taxonomic group as $L(E)C50terr_{min}$?		
NOECs for 2 species of 2 trophic levels	yes no	$NOECterr_{min}$ $NOECterr_{min}$	50 100
NOECs for 3 species of 3 trophic levels	yes no	$NOECterr_{min}$ $NOECterr_{min}$	10 50

where,

$$L(E)C50terr_{\min} = \min(L(E)C50terr_i) \quad (7)$$

$$NOECterr_{\min} = \min(NOECterr_i) \quad (8)$$

$$PNEC_{soil,\ ep} = \frac{K_{soil\ -\ water}}{RHO_{soil}} \times PNEC_{water} \quad (9)$$

$$PNEC_{soil} = \frac{TOXterr}{AFterr} \quad (10)$$

$L(E)C50terr_i$ = L(E)C50 for terrestrial organisms, trophic level i ($kg_c.kg_{wwt}^{-1}$);
$NOECterr_i$ = NOEC for terrestrial organisms, trophic level i ($kg_c.kg_{wwt}^{-1}$);
$PNEC_{soil,\ ep}$ = PNEC for terrestrial organisms derived by equilibrium partition ($kg_c.kg_{wwt}^{-1}$);
$K_{soil\text{-}water}$ = soil-water partition coefficient ($m^3.m^{-3}$);
RHO_{soil} = bulk density of soil ($kg_{wwt}.m^{-3}$);
$PNEC_{water}$ = PNEC for aquatic organisms ($kg_c.m^{-3}$);
TOXterr = toxicological data used for extrapolation of PNEC ($kg_c.kg_{wwt}^{-1}$);
AFterr = assessment factor applied in extrapolation of PNEC (dimensionless);
$PNEC_{soil}$ = PNEC for terrestrial organisms ($kg_c.kg_{wwt}^{-1}$).

2.4.3 Equilibrium partition method

If no L(E)C50(s) or NOEC(s) from terrestrial ecotoxicological tests are available, the terrestrial PNEC is derived from the aquatic PNEC by applying equilibrium partition. If a L(E)C50(s) or NOEC(s) for only one trophic level is available, the terrestrial PNEC based on toxicity data on soil organisms should be compared with the terrestrial PNEC derived by the equilibrium partition method (→ *Table 3*). The lowest PNEC is selected. Application of the equilibrium partition method requires, together with the aquatic PNEC, the bulk density of the soil and the soil-water partition coefficient, which can be calculated by

$$RHO_{soil} = Fsolid_{soil} \times RHOsolid + Fwater_{soil} \times RHOwater + Fair_{soil} \times RHO_{air} \quad (11)$$

$$K_{soil-water} = Fsolid_{soil} \times Kp_{soil} \times RHOsolid + Fair_{soil} \times K_{air-water} + Fwater_{soil} \quad (12)$$

$$Kp_{soil} = Foc_{soil} \times Koc \quad (13)$$

$$Koc = \frac{1.26 \times Kow^{0.81}}{1000} \quad (14)$$

$$K_{air-water} = \frac{HENRY_{285K}}{R \times TEMP} \quad (15)$$

$$HENRY_{285K} = \frac{VP_{285K} \times MOLW}{SOL_{285K}} \quad (16)$$

$$VP_{285K} = VP_{298K} \times e^{\frac{H_{0\,vapour}}{R} \times (\frac{1}{298} - \frac{1}{285})} \quad (17)$$

$$SOL_{285K} = SOL_{298K} \times e^{\frac{H_{0\,solution}}{R} \times (\frac{1}{298} - \frac{1}{285})} \quad (18)$$

$K_{soil-water}$ = soil-water partition coefficient ($m^3.m^{-3}$)
Kp_{soil} = solids-water partition coefficient in soil ($m^3.kg^{-1}$)
Foc_{soil} = weight fraction of organic carbon in soil ($kg.kg^{-1}$)
Koc = organic carbon-water partition coefficient ($m^3.kg^{-1}$)
Kow = octanol-water partition coefficient (dimensionless)
$Fair_{soil}$ = fraction of air in soil ($m^3.m^{-3}$)
$Fwater_{soil}$ = fraction of water in soil ($m^3.m^{-3}$)
$Fsolid_{soil}$ = fraction of solids in soil ($m^3.m^{-3}$)
RHO_{soil} = bulk density of soil ($kg_{wwt}.m^{-3}$)
$RHO_{solid,\ water,\ air}$ = density of solid, water and air phase, respectively ($kg.m^{-3}$)
$K_{air-water}$ = air-water partition coefficient ($m^3.m^{-3}$)
$HENRY_{285K}$ = Henry's law constant at temperature 285K ($Pa.m^3.mol^{-1}$)
R = gas constant ($Pa.m^3.mol^{-1}.K^{-1}$)
TEMP = environmental temperature (K)
$VP_{285K/298K}$ = vapour pressure at temperature 285K or 298K (Pa)
MOLW = molecular weight ($kg_c.mol^{-1}$)
$SOL_{285K/298K}$ = water solubility at temperature 285K or 298K ($kg_c.m^{-3}$)
$H_{0\ vapour}$ = enthalpy of vaporisation ($J.mol^{-1}$)
$H_{0\ solution}$ = enthalpy of solution ($J.mol^{-1}$)

Temperature correction of solubility and vapour pressure is preferred in the calculations. Correction rules are taken from RIVM et al. (1998). If an empirical Henry's law constant is known, this value is preferred in the calculations. The following temperature correction is applied to the empirical Henry's law constant:

$$HENRY_{285K} = HENRY_{298K} \times \frac{e^{\frac{H_{0vapour}}{R} \times (\frac{1}{298} - \frac{1}{285})}}{e^{\frac{H_{0solution}}{R} \times (\frac{1}{298} - \frac{1}{285})}} \tag{19}$$

Solubility and the organic carbon-water partition coefficient of dissociating substances are estimated at an environmental pH of 6 and 7 respectively, following the calculation procedure suggested by Shiu et al. (1994):

$$X_{N(x,m)} = \frac{1}{1 + 10^{pH(m) - pKa(x)}} \tag{20}$$

$$SOL_{T(x,m)} = \frac{SOL_{N(x)}}{X_{N(x,m)}} \tag{21}$$

$$Koc_{T(x,m)} = \frac{1.26 \times Kow_{N(x)}^{0.81}}{1000} \times X_{N(x,m)} \tag{22}$$

$X_{N(x, m)}$ = non-ionic fraction of substance x in compartment m (-)
$pH_{(m)}$ = pH in compartment m (-)
$pKa_{(x)}$ = dissociation constant of substance x (-)
$SOL_{T(x, m)}$ = solubility of the ionic and neutral species of substance x in compartment m ($mg.l^{-1}$)
$SOL_{N(x)}$ = solubility of the neutral species of substance x ($mg.l^{-1}$)
$Koc_{T(x, m)}$ = organic carbon-water partition coefficient of the ionic and neutral species of substance x in compartment m ($m^3.kg^{-1}$)
$Kow_{N(x)}$ = octanol-water partition coefficient of the neutral species of substance x (dimensionless)

The correction of K_{oc}-values for acid dissociation is, however, only appropriate, if the dissociated fraction does not exceed approximately 80%. If the dissociated fraction exceeds the 80%, the adsorption is dominated by characteristics of the dissociated molecule and calculation of pH-dependent K_{oc}-values may lead to an underestimation of 1 to 2 orders of magnitude of adsorption compared to experimental data (Bockting et al., 1993). Therefore, *Formula 22* is only used for estimating the $Koc_{T(x,m)}$ if no experimental data are available and if the non-ionic fraction does not exceed 80% at an environmental pH of 6 and 7.[1]

For metals measured values for soil solids-water partition coefficients (K_p-values) are needed, because *Formulas 13 en 14* are only valid for organic substances.

All substance-independent parameters, needed in the calculation of *Formulas 11 to 22* can be found in *Table 4*. To apply the equilibrium partition method, substance-specific

[1] Equation 16 can be used at an environmental pH of 6, if the pKa-value of the substance is larger than 5.4; at an environmental pH of 7, the pKa value must be larger than 6.4

data are also needed. An extensive research has been carried out by Huijbregts (1999) to obtain these substance-specific data for 181 substances. Furthermore, aquatic PNECs are taken from RIZA (1999). *Appendix I* lists the substance-specific data for the chemicals with toxicity data for terrestrial species of only one taxonomic group and for chemicals with no toxicity data for terrestrial species.

Table 4: Substance independent parameters, following EC (1996) and RIVM et al. (1998)

Parameter	**Symbol**	**Unit**	**Value**
fraction of air in soil	$Fair_{soil}$	$m^3.m^{-3}$	0.2
fraction of water in soil	$Fwater_{soil}$	$m^3.m^{-3}$	0.2
fraction of solids in soil	$Fsolid_{soil}$	$m^3.m^{-3}$	0.6
density of solid phase	RHOsolid	$kg.m^{-3}$	2500
density of water phase	RHOsolid	$kg.m^{-3}$	1000
density of air phase	RHOsolid	$kg.m^{-3}$	1.3
gas constant	R	$Pa.m^3.mol^{-1}.K^{-1}$	8.314
environmental temperature	TEMP	K	285
weight fraction of organic carbon in soil	Foc_{soil}	$kg.kg^{-1}$	0.02
enthalpy of vaporisation	$H_{0\ vapour}$	$kJ.mol^{-1}$	50
enthalpy of solution	$H_{0\ solution}$	$kJ.mol^{-1}$	10

2.4.4 Additional extrapolation rules for metals and pesticides

For two groups of substances additional extrapolation rules to derive PNECs for terrestrial species are needed. For metals background concentrations are not included in the calculation of the terrestrial effect factors. This is decided because in LCA the potential effect caused by an anthropogenic addition of a toxic substance is of primary interest and not the risk related to the total concentration of the toxicant in the environment. The second group of substances with additional extrapolation rules concerns the pesticides. One adaptation of the default extrapolation procedure is that the default assessment factor is lowered with a factor 10, if toxicological data are available for the most sensitive taxonomic group(s). The lowest assessment factor, however, remains 10. This deviation is in accordance with the TGD method. In the TGD (EC, 1996), it is stated that there may be circumstances to vary the assessment factor depending on the evidence available. Furthermore, if for pesticides *acute* toxicity data are available for the most sensitive taxonomic group(s), the PNEC based on these *acute* data is always compared with the PNEC based on chronic data for less sensitive species. The lowest PNEC is selected as the effect factor for terrestrial species.

2.5 Extrapolation method for terrestrial processes

In addition to the use of single species tests, terrestrial toxicity data that are related to the functioning of microbe-mediated processes and/or enzymatic activity can also be used for the derivation of terrestrial PNECs (EC, 1996; Slooff, 1992; Van Beelen & Doelman, 1997). According to TGD method (EC, 1996), data on soil processes may be used together with single species tests in the derivation of terrestrial PNECs. However, Slooff (1992) and Van Beelen & Doelman (1997) recommended to keep the toxicity data for processes separate from data for individual species, because a process test is fundamentally different from a single species test. Here, it is chosen to keep the data for a group of species separate from single species tests. Assessment factors used in the derivation of PNEC for soil processes are given in *Table 5*. The main difference with the assessment factors used in the derivation of the PNEC for soil species (*Table 3*) is that the applied assessment factor is not dependent on L(E)C50 data, that no comparison is made with the terrestrial PNEC derived by equilibrium partition, and that process types are used as a discriminating factor in the height of the assessment factor instead of using trophic levels. Statistical extrapolation is applied, if NOECs for 4 or more different types of terrestrial processes are available.

Table 5: Assessment factors for terrestrial processes

Ecotoxicological data	**TOXterr**	**AFterr**
NOECs for 1 process	$NOECterr_{min}$	100
NOECs for 2 processes	$NOECterr_{min}$	50
NOECs for 3 processes	$NOECterr_{min}$	10

If enough data are available, for both terrestrial species and processes a PNEC is derived. As advised by Slooff (1992), the lowest PNEC is selected as the effect factor for the terrestrial environment.

3. Results

Table 6 lists the terrestrial effect factors for the 181 evaluated substances.

Table 6: List of substances with derived terrestrial effect factors. AF = Assessment Factor; A&S = Aldenberg & Slob method; EP = Equilibrium partition method; $PNEC_{species}$ = Predicted No Effect Concentration for terrestrial species; $PNEC_{processes}$ = Predicted No Effect Concentration for terrestrial processes;

Substance	$PNEC_{species}$ [$mg_c.kg_{wwt}^{-1}$]	Procedure	$PNEC_{processes}$ [$mg_c.kg_{wwt}^{-1}$]	Procedure	Effect factor [$mg_c.kg_{wwt}^{-1}$]
Pesticides					
Acephate	$9.8 \cdot 10^{-4}$	EP	-	-	$9.8 \cdot 10^{-4}$
Aldicarb	$8.2 \cdot 10^{-6}$	EP	-	-	$8.2 \cdot 10^{-6}$
Aldrin	$2.0 \cdot 10^{-3}$	AF = 100	-	-	$2.0 \cdot 10^{-3}$
Anilazine	$3.6 \cdot 10^{-3}$	EP	$1.9 \cdot 10^{-2}$	AF = 50	$3.6 \cdot 10^{-3}$
Atrazine	$9.0 \cdot 10^{-3}$	AF = 100[a, b]	$7.0 \cdot 10^{-3}$	AF=10	$7.0 \cdot 10^{-3}$
Azinphos-ethyl	$9.3 \cdot 10^{-5}$	EP	-	-	$9.3 \cdot 10^{-5}$
Azinphos-methyl	$2.0 \cdot 10^{-2}$	AF = 100[a]	-	-	$2.0 \cdot 10^{-2}$
Benomyl	$1.5 \cdot 10^{-3}$	AF = 100	$3.4 \cdot 10^{-2}$	AF = 100	$1.5 \cdot 10^{-3}$
Bentazone	$4.5 \cdot 10^{-2}$	EP	-	-	$4.5 \cdot 10^{-2}$
Bifenthrin	$4.3 \cdot 10^{-3}$	EP	-	-	$4.3 \cdot 10^{-3}$
Captafol	$1.5 \cdot 10^{-2}$	AF = 100	$8.5 \cdot 10^{-1}$	AF = 10	$1.5 \cdot 10^{-2}$
Captan	$4.4 \cdot 10^{-3}$	AF=100	$4.0 \cdot 10^{-3}$	AF=10	$4.0 \cdot 10^{-3}$
Carbaryl	$3.7 \cdot 10^{-2}$	AF = 100[a, b]	$3.5 \cdot 10^{-1}$	AF = 100	$3.7 \cdot 10^{-2}$
Carbendazim	$1.8 \cdot 10^{-3}$	AF = 100	-	-	$1.8 \cdot 10^{-3}$
Carbofuran	$1.2 \cdot 10^{-3}$	AF = 100[a, b]	$1.0 \cdot 10^{-2}$	AF = 50	$1.2 \cdot 10^{-3}$
Chlordane	$7.0 \cdot 10^{-3}$	AF = 100[c]	$1.8 \cdot 10^{-1}$	A&S	$7.0 \cdot 10^{-3}$
Chlorfenvinphos	$2.2 \cdot 10^{-2}$	AF = 100[a]	-	-	$2.2 \cdot 10^{-2}$
Chloridazone	$7.8 \cdot 10^{-2}$	AF = 100[a]	$2.3 \cdot 10^{-2}$	AF = 50	$2.3 \cdot 10^{-2}$
Chlorothalonil	$2.5 \cdot 10^{-2}$	EP	-	-	$2.5 \cdot 10^{-2}$
Chlorpropham	$2.4 \cdot 10^{-1}$	EP	-	-	$2.4 \cdot 10^{-1}$
Chlorpyriphos	$1.0 \cdot 10^{-3}$	AF = 100[a, b]	$6.2 \cdot 10^{-2}$	A&S	$1.0 \cdot 10^{-3}$
Coumaphos	$2.7 \cdot 10^{-5}$	EP	-	-	$2.7 \cdot 10^{-5}$
Cyanazine	$1.6 \cdot 10^{-4}$	EP[c]	-	-	$1.6 \cdot 10^{-4}$
Cypermethrin	$9.1 \cdot 10^{-7}$	EP	-	-	$9.1 \cdot 10^{-7}$
Cyromazine	$6.2 \cdot 10^{-5}$	EP	-	-	$6.2 \cdot 10^{-5}$
2,4-D	$2.9 \cdot 10^{-1}$	AF =100	$1.0 \cdot 10^{-2}$	AF=10	$1.0 \cdot 10^{-2}$
DDT	$2.8 \cdot 10^{-2}$	AF = 100[a]	-	-	$2.8 \cdot 10^{-2}$
Deltamethrin	$2.4 \cdot 10^{-3}$	EP	-	-	$2.4 \cdot 10^{-3}$
Demeton	$1.9 \cdot 10^{-4}$	EP	-	-	$1.9 \cdot 10^{-4}$
Desmetryn	$2.5 \cdot 10^{-3}$	AF = 100[a]	-	-	$2.5 \cdot 10^{-3}$
Diazinon	$1.9 \cdot 10^{-3}$	AF = 100[a]	$4.4 \cdot 10^{-2}$	A&S	$1.9 \cdot 10^{-3}$
Dichlorprop	7.1	EP	-	-	7.1
Dichlorvos	$9.2 \cdot 10^{-7}$	EP	-	-	$9.2 \cdot 10^{-7}$
Dieldrin	$3.3 \cdot 10^{-3}$	AF = 100[a]	$1.0 \cdot 10^{-1}$	AF = 10	$3.3 \cdot 10^{-3}$
Dimethoate	$1.7 \cdot 10^{-2}$	AF = 1000	-	-	$1.7 \cdot 10^{-2}$
Dinoseb	$8.9 \cdot 10^{-5}$	EP	$6.0 \cdot 10^{-2}$	AF=10	$8.9 \cdot 10^{-5}$
Dinoterb	$6.2 \cdot 10^{-5}$	EP	-	-	$6.2 \cdot 10^{-5}$
Disulfoton	$5.4 \cdot 10^{-4}$	EP[c]	-	-	$5.4 \cdot 10^{-4}$
Diuron	$2.4 \cdot 10^{-3}$	AF = 100[a]	$1.7 \cdot 10^{-2}$	AF=100	$2.4 \cdot 10^{-3}$
DNOC	$1.9 \cdot 10^{-2}$	AF = 1000	-	-	$1.9 \cdot 10^{-2}$
Endosulfan	$1.5 \cdot 10^{-3}$	AF = 1000	$3.7 \cdot 10^{-1}$	AF =100	$1.5 \cdot 10^{-3}$
Endrin	$1.0 \cdot 10^{-3}$	EP[d]	-	-	$1.0 \cdot 10^{-3}$
Ethoprophos	$8.3 \cdot 10^{-5}$	EP	$1.3 \cdot 10^{-1}$	A&S	$8.3 \cdot 10^{-5}$
Fenitrothion	$2.1 \cdot 10^{-4}$	EP[d]	-	-	$2.1 \cdot 10^{-4}$
Fenthion	$8.3 \cdot 10^{-5}$	EP	-	-	$8.3 \cdot 10^{-5}$
Folpet	$4.0 \cdot 10^{-3}$	EP	-	-	$4.0 \cdot 10^{-3}$
Glyphosate	$1.0 \cdot 10^{-1}$	EP	-	-	$1.0 \cdot 10^{-1}$
Heptachlor	$2.0 \cdot 10^{-3}$	AF = 100	-	-	$2.0 \cdot 10^{-3}$
Heptenophos	$3.6 \cdot 10^{-5}$	EP	-	-	$3.6 \cdot 10^{-5}$

Substance	$PNEC_{species}$ [$mg_c.kg_{wwt}^{-1}$]	Procedure	$PNEC_{processes}$ [$mg_c.kg_{wwt}^{-1}$]	Procedure	Effect factor [$mg_c.kg_{wwt}^{-1}$]
Pesticides					
Iprodione	$1.4 \cdot 10^{-2}$	EP	-	-	$1.4 \cdot 10^{-2}$
Isoproturon	$4.5 \cdot 10^{-3}$	EP	$1.5 \cdot 10^{-1}$	AF = 100	$4.5 \cdot 10^{-3}$
Lindane	$2.5 \cdot 10^{-3}$	AF = 100[a]	-	-	$2.5 \cdot 10^{-3}$
Linuron	$2.7 \cdot 10^{-3}$	EP[d]	$1.5 \cdot 10^{-1}$	AF = 10	$2.7 \cdot 10^{-3}$
Malathion	$5.0 \cdot 10^{-2}$	AF = 100	$6.5 \cdot 10^{-2}$	A&S	$5.0 \cdot 10^{-2}$
MCPA	$4.5 \cdot 10^{-2}$	EP	-	-	$4.5 \cdot 10^{-2}$
Mecoprop	$1.0 \cdot 10^{-3}$	EP	-	-	$1.0 \cdot 10^{-3}$
Metamitron	$2.9 \cdot 10^{-1}$	EP	-	-	$2.9 \cdot 10^{-1}$
Metazachlor	$8.1 \cdot 10^{-2}$	EP	-	-	$8.1 \cdot 10^{-2}$
Methabenzthiazuron	$9.5 \cdot 10^{-2}$	EP	-	-	$9.5 \cdot 10^{-2}$
Methomyl	$4.2 \cdot 10^{-5}$	EP[c]	-	-	$4.2 \cdot 10^{-5}$
Methylbromide	$3.7 \cdot 10^{-3}$	EP	-	-	$3.7 \cdot 10^{-3}$
Metobromuron	$1.2 \cdot 10^{-1}$	EP	-	-	$1.2 \cdot 10^{-1}$
Metolachlor	$8.3 \cdot 10^{-2}$	AF = 10[e]	$5.0 \cdot 10^{-1}$	A&S	$8.3 \cdot 10^{-2}$
Mevinfos	$1.8 \cdot 10^{-5}$	EP[c]	-	-	$1.8 \cdot 10^{-5}$
Oxamyl	$5.7 \cdot 10^{-4}$	EP	-	-	$5.7 \cdot 10^{-4}$
Oxydemethon-methyl	$4.3 \cdot 10^{-6}$	EP	-	-	$4.3 \cdot 10^{-6}$
Parathion-ethyl	$1.0 \cdot 10^{-3}$	AF = 100[a, b, f]	$5.0 \cdot 10^{-2}$	A&S[f]	$1.0 \cdot 10^{-3}$
Parathion-methyl	$2.9 \cdot 10^{-4}$	EP[d]	-	-	$2.9 \cdot 10^{-4}$
Permethrin	$1.3 \cdot 10^{-4}$	EP	-	-	$1.3 \cdot 10^{-4}$
Phoxim	$1.0 \cdot 10^{-3}$	EP	-	-	$1.0 \cdot 10^{-3}$
Pirimicarb	$6.7 \cdot 10^{-4}$	EP	-	-	$6.7 \cdot 10^{-4}$
Propachlor	$2.0 \cdot 10^{-3}$	EP	-	-	$2.0 \cdot 10^{-3}$
Propoxur	$5.1 \cdot 10^{-6}$	EP	1.0	AF = 100	$5.1 \cdot 10^{-6}$
Pyrazophos	$1.1 \cdot 10^{-3}$	EP	-	-	$1.1 \cdot 10^{-3}$
Simazine	$1.4 \cdot 10^{-3}$	AF = 100[a]	$5.0 \cdot 10^{-1}$	AF=50	$1.4 \cdot 10^{-3}$
2,4,5-T	$1.5 \cdot 10^{-2}$	AF = 10[g]	1.8	AF = 50	$1.5 \cdot 10^{-2}$
Thiram	$2.8 \cdot 10^{-4}$	EP[d]	$1.6 \cdot 10^{-1}$	A&S	$2.8 \cdot 10^{-4}$
Tolclophos-methyl	$2.8 \cdot 10^{-2}$	EP	-	-	$2.8 \cdot 10^{-2}$
Tri-allate	$4.4 \cdot 10^{-3}$	AF = 10[g]	-	-	$4.4 \cdot 10^{-3}$
Triazophos	$2.0 \cdot 10^{-4}$	EP	-	-	$2.0 \cdot 10^{-4}$
Tributyltin-oxide	$3.1 \cdot 10^{-3}$	EP	$5.6 \cdot 10^{-2}$	AF = 100	$3.1 \cdot 10^{-3}$
Trichlorfon	$7.9 \cdot 10^{-7}$	EP	-	-	$7.9 \cdot 10^{-7}$
Trifluralin	$1.4 \cdot 10^{-3}$	AF =100	$1.0 \cdot 10^{-1}$	AF = 50	$1.4 \cdot 10^{-3}$
Triphenyltin compounds	$1.0 \cdot 10^{-2}$	AF = 100	-	-	$1.0 \cdot 10^{-2}$
Zineb	$1.4 \cdot 10^{-3}$	EP	$3.7 \cdot 10^{-1}$	AF = 100	$1.4 \cdot 10^{-3}$
Non-aromatics					
Acrylonitrile	$1.2 \cdot 10^{-3}$	EP	-	-	$1.2 \cdot 10^{-3}$
Acrolein	$8.8 \cdot 10^{-7}$	EP	-	-	$8.8 \cdot 10^{-7}$
1,3-Butadiene	$6.1 \cdot 10^{-1}$	EP	-	-	$6.1 \cdot 10^{-1}$
Carbon disulfide	$2.1 \cdot 10^{-3}$	EP	-	-	$2.1 \cdot 10^{-3}$
Ethylene	59000	EP	-	-	59000
Formaldehyde	$3.4 \cdot 10^{-4}$	EP	-	-	$3.4 \cdot 10^{-4}$
Propylene oxide	$2.4 \cdot 10^{-2}$	EP	-	-	$2.4 \cdot 10^{-2}$
Polycyclic aromatic hydrocarbons					
Naphtalene	$7.0 \cdot 10^{-3}$	EP	-	-	$7.0 \cdot 10^{-3}$
Anthracene	$1.4 \cdot 10^{-2}$	EP	-	-	$1.4 \cdot 10^{-2}$
Phenanthrene	1.3	EP	-	-	1.3
Fluoranthrene	$1.8 \cdot 10^{-1}$	EP	-	-	$1.8 \cdot 10^{-1}$
Benz(a)anthracene	$7.0 \cdot 10^{-3}$	AF = 100	-	-	$7.0 \cdot 10^{-3}$
Chrysene	$2.2 \cdot 10^{-1}$	EP	-	-	$2.2 \cdot 10^{-1}$
Benzo[k]fluoranthrene	$5.8 \cdot 10^{-3}$	EP	-	-	$5.8 \cdot 10^{-3}$
Benzo[a]pyrene	$8.0 \cdot 10^{-3}$	AF = 100	-	-	$8.0 \cdot 10^{-3}$
Benzo[ghi]perylene	$1.2 \cdot 10^{-1}$	EP	-	-	$1.2 \cdot 10^{-1}$
Indeno[1,2,3-cd]pyrene	$8.6 \cdot 10^{-2}$	EP	-	-	$8.6 \cdot 10^{-2}$

Substance	$PNEC_{species}$ [$mg_c.kg_{wwt}^{-1}$]	Procedure	$PNEC_{processes}$ [$mg_c.kg_{wwt}^{-1}$]	Procedure	Effect factor [$mg_c.kg_{wwt}^{-1}$]
Halogenated non-aromatics					
Dichloromethane	15	EP	-	-	15
Trichloromethane	7.5	EP	-	-	7.5
Tetrachloromethane	$8.7 \cdot 10^{-1}$	EP	-	-	$8.7 \cdot 10^{-1}$
1,2-Dichloromethane	12	EP	-	-	12
1,1,1-Trichloroethane	2.8	EP	-	-	2.8
Trichloroethylene	5.0	EP	-	-	5.0
Tetrachloroethylene	$4.6 \cdot 10^{-2}$	AF = 1000	-	-	$4.6 \cdot 10^{-2}$
Vinylchloride	3.8	EP	-	-	3.8
Hexachlorobutadiene	$7.1 \cdot 10^{-4}$	EP	-	-	$7.1 \cdot 10^{-4}$
Aromatics					
Benzene	3.7	EP	-	-	3.7
Toluene	$1.5 \cdot 10^{-1}$	AF = 100	-	-	$1.5 \cdot 10^{-1}$
Styrene	9.2	EP	-	-	9.2
Phenol	$5.6 \cdot 10^{-2}$	AF=1000	-	-	$5.6 \cdot 10^{-2}$
Ethylbenzene	1.1	EP	-	-	1.1
m-Xylene	1.5	EP	-	-	1.5
o-Xylene	1.4	EP	-	-	1.4
p-Xylene	3.8	EP	-	-	3.8
Butylbenzylphtalate	$2.2 \cdot 10^{-1}$	EP	-	-	$2.2 \cdot 10^{-1}$
Di(2-ethylhexyl)phtalate	12.6	EP	-	-	12.6
Dibutylphtalate	$2.5 \cdot 10^{-1}$	EP	-	-	$2.5 \cdot 10^{-1}$
Diethylphtalate	$5.0 \cdot 10^{-3}$	AF=1000	-	-	$5.0 \cdot 10^{-3}$
Dihexylphtalate	7.8	EP	-	-	7.8
Diisooctylphtalate	81	EP	-	-	81
Diisodecylphtalate	11	EP	-	-	11
Dimethylphtalate	$1.5 \cdot 10^{-3}$	AF=1000	-	-	$1.5 \cdot 10^{-3}$
Dioctylphtalate	481	EP	-	-	481
Phtalic anhydride	$5.9 \cdot 10^{-3}$	EP	-	-	$5.9 \cdot 10^{-3}$
Halogenated aromatics					
Chlorobenzene	$1.8 \cdot 10^{-1}$	AF=1000	-	-	$1.8 \cdot 10^{-1}$
1,2-Dichlorobenzene	1.5	EP	-	-	1.5
1,3-Dichlorobenzene	1.2	EP	-	-	1.2
1,4-Dichlorobenzene	$9.4 \cdot 10^{-2}$	AF=1000	-	-	$9.4 \cdot 10^{-2}$
1,2,3-Trichlorobenzene	$4.3 \cdot 10^{-3}$	AF=1000	-	-	$4.3 \cdot 10^{-3}$
1,2,4-Trichlorobenzene	$3.8 \cdot 10^{-2}$	AF=1000	-	-	$3.8 \cdot 10^{-2}$
1,3,5-Trichlorobenzene	$1.5 \cdot 10^{-1}$	AF=100	-	-	$1.5 \cdot 10^{-1}$
1,2,3,4-Tetrachlorobenzene	$6.9 \cdot 10^{-2}$	AF=1000	-	-	$6.9 \cdot 10^{-2}$
1,2,3,5-Tetrachlorobenzene	$3.5 \cdot 10^{-3}$	AF=1000	-	-	$3.5 \cdot 10^{-3}$
1,2,4,5-Tetrachlorobenzene	$3.0 \cdot 10^{-3}$	AF=1000	-	-	$3.0 \cdot 10^{-3}$
Pentachlorobenzene	$8.3 \cdot 10^{-2}$	AF=1000	-	-	$8.3 \cdot 10^{-2}$
Hexachlorobenzene	$4.7 \cdot 10^{-1}$	EP	-	-	$4.7 \cdot 10^{-1}$
2-Chlorophenol	$7.6 \cdot 10^{-3}$	EP	-	-	$7.6 \cdot 10^{-3}$
2,4-Dichlorophenol	$3.1 \cdot 10^{-2}$	EP	-	-	$3.1 \cdot 10^{-2}$
2,4,5-Trichlorophenol	$2.3 \cdot 10^{-2}$	AF=1000	-	-	$2.3 \cdot 10^{-2}$
2,4,6-Trichlorophenol	$2.6 \cdot 10^{-2}$	AF=1000	-	-	$2.6 \cdot 10^{-2}$
2,3,4,6-Tetrachlorophenol	$5.6 \cdot 10^{-2}$	EP	-	-	$5.6 \cdot 10^{-2}$
Pentachlorophenol (PCP)	$1.1 \cdot 10^{-2}$	AF=50	$5.6 \cdot 10^{-1}$	A&S	$1.1 \cdot 10^{-2}$
Benzylchloride	$2.3 \cdot 10^{-3}$	EP	-	-	$2.3 \cdot 10^{-3}$
3-Chloroaniline	$3.1 \cdot 10^{-2}$	AF=1000	$1.0 \cdot 10^{-1}$	AF=50	$3.1 \cdot 10^{-2}$
4-Chloroaniline	$2.6 \cdot 10^{-3}$	EP	3.1	A&S	$2.6 \cdot 10^{-3}$
3,4-Dichloroaniline	$1.5 \cdot 10^{-2}$	AF=100	2.3	A&S	$1.5 \cdot 10^{-2}$
1-Chloro-4-nitrobenzene	$6.5 \cdot 10^{-3}$	EP	-	-	$6.5 \cdot 10^{-3}$
Pentachloronitrobenzene	$1.2 \cdot 10^{-1}$	EP	-	-	$1.2 \cdot 10^{-1}$
2,3,7,8-TCDD	$3.8 \cdot 10^{-5}$	EP	-	-	$3.8 \cdot 10^{-5}$

Substance	$PNEC_{species}$ [$mg_c.kg_{wwt}^{-1}$]	Procedure	$PNEC_{processes}$ [$mg_c.kg_{wwt}^{-1}$]	Procedure	Effect factor [$mg_c.kg_{wwt}^{-1}$]
Metals					
Antimony	34	EP	-	-	34
Arsenic	$3.6 \cdot 10^{-1}$	AF=100	17	A&S[h]	$3.6 \cdot 10^{-1}$
Barium	3.1	EP	139	A&S	3.1
Beryllium	$5.4 \cdot 10^{-3}$	EP	$4.0 \cdot 10^{-1}$	AF=10	$5.4 \cdot 10^{-3}$
Cadmium	$4.6 \cdot 10^{-1}$	A&S	7.3	A&S	$4.6 \cdot 10^{-1}$
Chrome(III)	$3.3 \cdot 10^{-1}$	AF=100	7.4	A&S	$3.3 \cdot 10^{-1}$
Chrome(VI)[j]	-	-	12	AF=50	$3.3 \cdot 10^{-1}$
Cobalt	$9.2 \cdot 10^{-2}$	EP	18	A&S	$9.2 \cdot 10^{-2}$
Copper	19	A&S	7.7	A&S[i]	7.7
Lead	44	A&S	61	A&S	44
Mercury	$1.5 \cdot 10^{-3}$	AF=100	1.4	A&S	$1.5 \cdot 10^{-3}$
Methyl-mercury	$1.5 \cdot 10^{-3}$	EP	-	-	$1.5 \cdot 10^{-3}$
Molybdenum	22	EP	39	A&S	22
Nickel	$7.4 \cdot 10^{-1}$	AF=100	3.0	A&S	$7.4 \cdot 10^{-1}$
Selenium	$9.4 \cdot 10^{-2}$	EP	$9.9 \cdot 10^{-1}$	AF=10[f]	$9.4 \cdot 10^{-2}$
Thallium	$2.2 \cdot 10^{-1}$	EP	-	-	$2.2 \cdot 10^{-1}$
Tin	30	EP	48	A&S	30
Vanadium	$2.2 \cdot 10^{-1}$	EP	23	A&S	$2.2 \cdot 10^{-1}$
Zinc	27	A&S	6.7	A&S	6.7
Inorganic substances					
Sulphur dioxide	-	-	-	-	-
Nitrogen dioxide	-	-	-	-	-
Ammonia	-	-	-	-	-
Hydrogen sulphide	-	-	-	-	-
Hydrogen chloride	-	-	-	-	-
PM10	-	-	-	-	-

[a] A factor 100 is applied instead of 1000 to the acute toxicological data, because the pesticide is tested on a species of the expected most sensitive taxonomic group;

[b] Although chronic data of 2 or more trophic levels are available, the effect factor is based on acute toxicological data for species of the expected most sensitive taxonomic group;

[c] Because the lowest acute toxicological data concerns sensitive species, a factor 100 is applied instead of a factor 1000. Extrapolation of the chronic toxicological study results in a lower PNEC than the extrapolation from acute data. The lowest value is taken as the $PNEC_{species}$;

[d] Because the lowest acute toxicological data concerns sensitive species, a factor 100 is applied instead of a factor 1000. Calculation of the $PNEC_{species}$ with the equilibrium partition method, however, results in a lower PNEC than the extrapolation from acute data. The lowest value is taken as the $PNEC_{species}$;

[e] A factor 10 is applied instead of 100 to the chronic toxicological data, because the pesticide is tested on a species of the expected most sensitive taxonomic group;

[f] Because toxicity data do not follow a log-logistic distribution, assessment factors are used in the derivation of the PNEC instead of statistical extrapolation;

[g] A factor 10 is applied instead of 50 to the chronic toxicological data, because the pesticide is tested on a species of the expected most sensitive taxonomic group;

[h] Because arsenic toxicity data of soil processes tend to follow a bimodal distribution, the most sensitive group of soil processes are used in the statistical extrapolation;

[i] Because copper toxicity data of the soil process 'ethylene production' does not show a large differentiation for different soil types, the geometrical mean of the 'ethylene production' toxicity data for the different types of soil is used in the statistical extrapolation;

[j] In the soil Cr(III) is the most common stable form. The Cr(VI) present is for the most part directly reduced to Cr(III) (Crommentuijn et al., 1997a). Therefore, the terrestrial effect factor of Cr(III) is also used for Cr(VI).

4. Conclusions

Based upon the experience of applying the extrapolation method and the derived terrestrial effect factors, the following conclusions may be drawn:

- For 110 of the 181 evaluated substances, the equilibrium-partition method (EP) must be applied to obtain the $PNEC_{species}$, indicating that for these substances none or hardly any terrestrial toxicity data are available. Furthermore, due to lack of data the $PNEC_{species}$ of 6 (inorganic) substances and the $PNEC_{processes}$ of 132 substances could not be calculated;
- For 49 evaluated substances it was possible to calculate both the $PNEC_{species}$ and the $PNEC_{processes}$. For 43 of the 49 substances the $PNEC_{species}$ was the lowest value, indicating that terrestrial species are generally more sensitive to pollutants than terrestrial processes;
- No pH-effect of dissociating substances on the $PNEC_{species}$ is found, when applying the EP-method. The main reason is that correction of K_{oc}-values for acid dissociation is not applied, because experimental values were available for almost all of the dissociating substances. For the remaining dissociating substances, the non-dissociated fraction was expected to be smaller than 20%, implying that the dissociation correction of K_{oc}-values can not be applied. Furthermore, the air-water partition coefficient does not have a large influence on the soil-water partition coefficient of the substance;
- Terrestrial PNECs derived by the RIVM may differ from the terrestrial PNECs derived in this report, mainly because a different extrapolation method is applied. Another reason for possible differences is that between RIVM reports differences in data handling are found, because of historical developments, while in this assessment it is attempted to derive toxicity data for the standard soil with the same procedure for all organic substances and the same procedure for all metals;
- Finally, warm-blooded predators (mammals and birds) are considered as a separate impact category, although toxicity potentials were not calculated in this assessment. It is recommended to calculate separate terrestrial effect factors for higher predators. Methods to account for secondary poisoning may be used for this purpose (see Van de Plassche, 1994).

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