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The Potentially Affected Fraction for Target Species: Additional data and calculations

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ABSTRACT

In studying the possibilities for mapping toxic pressure of contaminants (expressed as Potentially Affected Fraction, PAF) on such target species as butterflies, dragonflies, amphibians, reptiles and plants, the toxicity data available for butterflies, damselflies, dragonflies and reptiles were found to be insufficient. Low PAF values (less than 1%) for copper, zinc and cadmium were found for amphibians at median surface water concentrations. PAF calculations for higher plants indicate a higher toxic pressure for zinc than for cadmium or copper. The highest toxic pressure due to the presence of these metals is found in the 'Brabantse Kempen' area.

SUMMARY

The Nature Policy Plan of 1990 advocates the establishment of a national ecological network. Target species were selected: 657 species from ten taxonomic groups. The toxic pressure of contaminants on target species can be expressed as the Potentially Affected Fraction (PAF). In a previous report, a method was presented to calculate the PAF for avian and mammalian target species[1]. The aim of this report is to assess the potential for including groups of target species other than birds or mammals in the risk assessment: higher plants (408 species), reptiles (5 species), amphibians (7 species), butterflies (47 species) and dragonflies (20 species).

Very little information is available on dragonflies and damselflies and no conclusions can be drawn about systematic sensitivity differences between Odonata and other groups of (benthic) aquatic organisms. A separate risk assessment does not seem feasible.

The existing toxicological knowledge about butterflies mostly consists of LD50s which might allow the calculation of critical leaf concentrations for the caterpillar life stage. Given the little information available, no separate risk assessment for butterflies is considered.

The selected toxicity data for amphibians show that a systematic difference in sensitivity did not exist for cadmium, copper, deltamethrin and methoxychloor, but does exist for zinc with amphibians less sensitive than other organisms. PAF calculations for cadmium, copper and zinc show that amphibians are hardly affected at median concentrations in Dutch surface waters, with PAF values less than 1%. Mapping the PAF for amphibians is feasible if a geographical differentiation of water concentrations is available.

PAF calculations for higher plants are based on the generic PAF method that takes differences in biological availability between laboratory and field into account. Plant toxicity data are usually from experiments with food and staple crops. Preliminary PAF calculations for higher plants indicate a higher toxic pressure for zinc than for cadmium or copper. The highest toxic pressure due to the presence of these metals is found in the 'Brabantse Kempen' area.

[1] Luttik et al., 1997

SAMENVATTING

De Ecologische Hoofdstructuur wordt o.a. gekarakteriseerd door doelsoorten. Hiervoor zijn 657 soorten uit tien taxonomische groepen geselecteerd. De toxische druk van stoffen op soorten kan worden uitgedrukt in de Potentieel Aangetaste Fractie (PAF). In een voorgaand rapport[2] is een methode beschreven om de PAF uit te rekenen voor de doelsoorten behorende tot vogels en zoogdieren. Het doel van dit rapport is de haalbaarheid van uitbreiding met andere groepen doelsoorten te onderzoeken: hogere planten (408 soorten), reptielen (5 soorten), amfibieën (7 soorten), vlinders (47 soorten) en libellen en waterjuffers (20 soorten).

Te weinig ecotoxicologische informatie is beschikbaar over waterjuffers en libellen waardoor geen conclusies kunnen worden getrokken over systematische gevoeligheidsverschillen tussen deze dieren en andere (benthische) organismen. Een aparte risicoanalyse voor deze groep wordt nog niet mogelijk geacht.

Vlinders worden voornamelijk blootgesteld in de larvale levensfase. De beschikbare toxiciteitsgegevens zijn meestal LD50's, maar te weinig gegevens zijn beschikbaar voor een specifieke risicokartering.

De geselecteerde toxiciteitsgegevens voor amfibieën laten zien dat er geen systematisch verschil met andere aquatische organismen kon worden vastgesteld voor cadmium, koper, deltamethrin and methoxychloor. Dit is wel het geval voor zink waarbij amfibieën minder gevoelig zijn dan andere aquatische organismen. De berekende PAF voor cadmium, koper en zink zijn lager dan 1% bij mediane concentraties in Nederlands oppervlaktewater. Het karteren van PAF waarden voor amfibieën is haalbaar als geografisch gedifferentieerde waterconcentraties beschikbaar zijn.

PAF berekeningen voor hogere planten zijn gebaseerd op de generieke PAF methode, waarbij gecorrigeerd wordt voor het verschil in biologische beschikbaarheid tussen laboratorium en veld. De toxiciteitsgegevens zijn voornamelijk afkomstig van experimenten met gecultiveerde planten. Voorlopige berekeningen geven aan dat zink meer toxische druk veroorzaakt voor planten dan cadmium of koper. Voor cadmium en zink is de hoogste toxische druk berekend in de Brabantse Kempen.

[2] Luttik et al., 1997

1. INTRODUCTION

The Nature Policy Plan of 1990 (Dutch Ministry of Agriculture, Nature Management and Fisheries) advocates the establishment of a national ecological network. The network consists of a comprehensive set of nature target types, described in the Handbook of Nature Target Types (Bal et al., 1995). Each of the 132 units in this classification specifies an ecological objective in terms of biotic and abiotic components at a particular scale. In the handbook 657 species from ten taxonomic groups have been selected as target species[3]. The selection is based on an assessment of international significance, knowledge on trends in population size and on national red data lists. The national ecological network is under construction, which means that at specific locations, ecological management must provide the basis for nature development leading to a specific nature target type.

In a previous report, a method was reported for mapping the percentage of birds and mammals of certain nature target types that will be exposed to concentrations higher than the protection level of those species (Luttik et al., 1997). The target species may not be present at a specific location since the ecological network is not completed yet. In addition, the calculated risk for wild life is based on extrapolation of toxicity data for species reared in the laboratory. Hence, *the potential* and not the actual effect of toxic compounds on wildlife is calculated. The term 'Potentially Affected Fraction of Target Species' is used for the calculated risk for birds and mammals (Luttik et al., 1997).

The choice for birds and mammals was based on the following argument:

Food chain transfer of persistent chemicals can lead to bioaccumulation of chemicals (e.g. Romijn et al., 1994; Traas et al., 1996), thereby attaining toxic levels for birds and mammals but not at lower trophic levels. Risk assessment based on direct toxicity of organisms from the soil or water phase, such as used in the general calculations for the Potentially Affected Fraction (Klepper and Van de Meent, 1997) does not cover this phenomenon.

Scope of this study

The aim of this report is to asssess to potential for including groups of target species other than birds or mammals in the risk assessment for target species. In addition, a comparison is made between toxicity data for different taxa to assess the sensitivity differences between groups. Based on these results, recommendations are made whether or not to include other groups of

[3] In this report, the term 'target species' refers to the species listed in the handbook by Bal et al. (1995).

target species besides birds and mammals: higher plants (408 species), reptiles (5 species), amphibians (7 species), butterflies (47 species), dragonflies (20 species), fish (56 species), crustaceans (24 species), echinoderms (10 species). The possible inclusion of fish, crustaceans and echinoderms was not yet studied, but may be a subject of further study in cooperation with the responsible research institutions (RIZA, RIKZ and RIVO).

Calculation of the potentially affected fraction of plant target species will be considered in depth in a separate study in 1998. A pilot study on the effect of metals on plants is included in this report, in line with the present PAF methods (Klepper and Van de Meent, 1997; Luttik et al., 1997).

2. METHODS

2.1 Exposure assessment of target species

Many target species are exposed to the contaminant directly by way of soil, soil pore water or surface water. Toxicants uptake proceeds over exchange surfaces: roots and leaves for plants, body surface (skin) and gills for animals. Additional exposure may be ingestion of contaminated food. The relative contribution of each exposure route to total toxicant uptake depends on the type of organism and the properties of the toxicant. In aquatic ecosystems for instance, food uptake becomes important for hydrophobic toxicants with a log K_{ow} of over 5 (Thomann, 1989). For many target species, several exposure routes are possible; e.g. some butterflies are either exposed to a toxicant through contact with contaminated vegetation or by way of ingesting honey (Table 1). Risk calculations for birds and mammals are based on exposure to toxicants mainly by consumption of contaminated food. This may be important for other species too.

Table 1: species groups as used in the handbook of nature target types in the Netherlands (Bal et al. 1995).

Species groups	Exposure routes	routes modelled
higher plants (408 species)	pore water, air	pore water [1]
mammals (16 species)	food, soil, air, water	food [2]
birds (64 species)	food, soil, air, water	food [2]
reptiles (5 species)	food, soil, air, water	food [1]
amphibians (7 species)	food, soil, air, water	water [1]
butterflies (47 species)	food, air, water	food [1]
dragonflies (20 species)	food, air, water	water [1]
fish (56 species)	food, water	[3]
crustaceans (24 species)	food, water	[3]
echinoderms (10 species)	food, water	[3]

[1]: This study

[2]: Luttik et al. 1997

[3]: Not in this study

Exposure modeling of target species for the purpose of mapping risks, is only possible if geographically explicit information on environmental concentrations is available, such as soil maps of cadmium, copper, zinc and lead (see Klepper and Van de Meent, 1997). However,

concentrations in regional water bodies were not made geographically explicit. This severely limits the possibilities of differentation of risks for organisms mainly exposed by the waterphase. This also holds true for aquatic organisms exposed to contaminants with a high log K_{ow}. Food exposure becomes the dominant route, but then sediment and/or food concentrations must be available for exposure assessment. These data are not yet available in a geographically explicit form for the Netherlands as a whole.

2.2 Toxicity data for target species

Butterflies and dragonflies. A literature search was performed for toxicity data on butterflies and dragonflies in BIOSIS and TOXLINE Plus (Appendices I and II). All target species are listed in the Handbook of Nature Target Types (Bal et al., 1995).

Amphibians and reptiles. For amphibians and reptiles, separate searches were performed for heavy metals on the one hand and organic hydrocarbons and pesticides on the other hand.

Plants. For plants, a non-exhaustive literature search was performed on several metals, in combination with keywords for 'uptake, accumulation or bioaccumulation'. Additional research on agro-chemicals and organic hydrocarbons is planned for 1998.

Fish. Fish toxicity data were taken from Crommentuijn et al. (1994, 1997) for comparison with toxicity data for other groups of target species.

2.3 PAF calculations

2.3.1 Amphibians

PAF calculations for amphibians were performed by calculating the moments (α and β) of the log-logistic species sensitivity distribution for cadmium, zinc and copper. Basic imput data were LC50s for amphibians, from which NOECs were estimated by dividing LC50s by a factor of 10 (Traas et al. 1997, De Zwart in prep.).

The environmental concentration used is the median available metal concentration in surface water, as provided by RIZA and used by Klepper and Van de Meent (1997, Appendix V).

2.3.2 Plants

Plants are primarily exposed to contaminants via soil pore water. In the generic PAF calculations (Klepper and Van de Meent, 1997), this is accounted for by pore water referencing of the toxicity tests. In the generic PAF method, the following steps are taken:

- subtract a non-exchangeable amount from the total
- calculate the pore water concentration
- correct for the systematic difference in availability between laboratory and field

A different approach was followed in order to compare plant toxicity data based on hydroculture experiments with plant soil toxicity tests.

- Exchangeable metal content of soils was calculated by subtracting background levels of metals from the total metal concentration and field-based partition coefficients were calculated from the data set of Janssen et al. (1997).
- These partition coefficients were related to soil characteristics from the data set of Janssen et al. (1997), using (multiple) linear regression, allowing the calculation of pore water concentrations from known soil characteristics and total metal concentration.
- Plant toxicity tests with Cd, Cu and Zn in water culture (assumed equal to toxicity in pore water) were used to estimate species sensitivity distributions for higher plants.

Both data sets were compared by recalculating the soil toxicity data to pore water concentrations. The following paragraphs describe the steps taken to use the plant toxicity data determined in hydro culture for calculating a plant PAF.

Partition coefficients corrected for non-exchangeable metal

We distinguish a non-exchangeable fraction of metal and a mobile part available for uptake by organisms. Field-based partition coefficients (K_p) Janssen et al. (1996, 1997), were calculated for HNO_3 digested soil, corrected for the non-exchangeable amount. The partition coefficient was defined as

$$K_p = \frac{[Metal]_{solid} - [Metal]_{non\text{-}exch.}}{[Metal]_{pore\ water}} \ [l\ kg^{-1}] \qquad (1)$$

The non-exchangeable amount is calculated according to Lexmond and Edelman (1992) and Van den Hoop (1995), as used by Klepper and Van de Meent (1997, Appendix IV). It was found that for the Lexmond and Edelman (1992) regressions, only the clay-related fraction could be used as a minimum estimate of the non-exchangeable concentration, to prevent background values higher than measured total concentrations (Table 2). Use of the regression for non-exchangeable metal based on data from Van den Hoop (Klepper and Van de Meent, 1997; p. 85) yielded regressions with slightly less explained variance and only marginally different end results (not shown). Therefore, the regressions as listen in Table 2 were used. Calculated K_p's can be found in Appendix III.

*Table 2: coefficient **b** [mg kg^{-1} dw^{-1}] used for estimating the non-exchangeable fraction of metals in the top layer of soil, as determined by lutum content (%).*

model: $M_{non\text{-}exch}$ = b*clay	
cadmium	0.0047
copper	0.58
zinc	2.66

Relation between partition coefficients and soil characteristics

Regression equations were based on easily obtainable soil characteristics, explaining most of the variation in K_p as advocated by Janssen et al. (1997). Since clay content was already used in the regression for background values, it was no longer available for further regression. It was found that for all metals, pH(KCl) was the dominant variable (Table 3) explaining most of the variation in accordance with Janssen et al. (1996). Addition of organic matter did not significantly improve the fit. For copper, introducing dissolved organic (DOC) carbon improved the rather low R^2 of the regression considerably, but since DOC is not a routinely available soil characteristic, it was not used for further PAF calculations.

Table 3: regressions for log Kp [l kg^{-1}] based on exchangeable metal with log transformed soil characteristics.

	nr of soils	model	R^2
cadmium	18	0.41 + 0.47*pH	0.73
copper	19	0.07 + 0.42*pH	0.58
	19	2.53 + 0.36*pH -1.21 * log(DOC)	0.71
zinc	19	-0.639 + 0.596*pH	0.77

Calculation of pore water concentrations

Pore water concentrations were calculated according to

$$M_{\text{pore water}} = \frac{M_{total} - M_{non-exch}}{Kp} \qquad (2)$$

with metal concentrations M_{total} in soil in mg kg^{-1} dw and pore water concentrations in mg l^{-1}.

Plant toxicity data

Various compilations exist of plant toxicity data (e.g. Balsberg-Pahlsson, 1989; Tyler et al., 1989; Wang, 1992). Some compilations of toxicity data are severely biased by the toxicity criterion. Balsberg-Pahlsson (1989) compiled the Lowest Observed Effect Concentration (LOEC) for several vascular plants but the distribution of the data is strongy influenced by the distribution of test concentrations. From the 14 reported LOECs, 9 LOECs were 0.11 mg/l, with remaining concentrations between 0.05 and 0.25 mg/l.

The toxicity tests compiled by Wang (1992) are all hydroculture experiments. The toxicity criterion is a 50% inhibitory concentration (IC50, mg l^{-1}) relative to the control. Toxicity data for aquatic macrophytes were omitted from the data set, and the geometric mean was taken if several IC50 values were reported for the same species. The resulting data sets for cadmium, copper and zinc were used to estimate log-logistic distribution functions using the software ETX 1.3a (Aldenberg 1993). The moment estimates of the log-logistic distribution for Cd, Cu and Zn, as reported by ETX, were used to calculate the PAF for plant species (Appendix IV).

A comparison was made with plant toxicity data in soil (Klepper and Van de Meent, 1997; App. I), recalculated to pore water concentrations using the same regressions (table 2 and 3).

Calculation and mapping of plant PAF

Maps of cadmium, copper and zinc concentrations in soil, as provided by Tiktak et al. (1997) were used to estimate the non-exchangeable amount and the bioavailable metal (Table 2). The final maps were calculated analagous to the procedure described for the generic PAF for terrestrial species, limited to the plant toxicity data using the median parameter values (Klepper and Van de Meent, 1997).

3. RESULTS

3.1 Butterflies, Damselflies and Dragonflies

3.1.1 Toxicity data

Very few toxicity data were found for butterflies (*Lepidoptera*), with only the species *Lymantria dispar* tested for the metals copper, zinc, cadmium and lead (Appendix II). Since the NOEC concentration is given as µg per g of food, a relation with soil concentration can only be found assuming type of food and bioaccumulation in that type of food. Given the virtual absence of toxicity data, this effort is not worthwile.

Toxicity data for several agro-chemicals are available, but for three species at most. These data are given as LD50s in µg per g of bw. Since most LD50s are determined for the larval stage, we may assume that leaves are the main food item. The actual dose in the field should then be calculated from feeding rate (g consumed per g of dw per day) and concentration of the chemical in the leaves. Since foliar concentrations are not known, they should then be estimated based on foliar contamination by spray, atmosperic uptake etc., and or plant uptake from the soil, depending on the type of agro-chemical and spraying pattern. We may therefore expect large uncertainty in environmental concentrations and actual exposure levels, making predictions on toxic effects on butterflies highly uncertain.

For damselflies and dragonflies (*Odonata*) even less information is available (Appendix II). Toxicity data were found for just a few agrochemicals, but not for heavy metals, and never for more than one species. Given the scanty data, and large expected exposure uncertainty, it is therefore not attempted to calculate Potentially Affected Fractions for butterflies, damselflies and dragonflies on a national scale.

3.2 Amphibians and reptiles

3.2.1 Toxicity data

Virtually no information is found on the sensitivity of reptiles towards organic chemicals and metals. For cadmium, one LC50 values was found for *Notophtalmus viridescens* (Appendix II). This does not permit the calculation of PAF for reptiles.

More is known about toxicity of metals and organic chemicals to amphibians.

In Table 4, a comparison is made between the range of LC50 values for amphibians and organisms other than amphibians. In most cases, the geometric mean LC50 for amphibians is higher than for other species, i.e. amphibians are less sensitive.

Table 4: comparison of LC50 data exluding amphibians, with LC50 data for amphibians.

Other species		range	mean	std	n	geomean
Cd	96h mg/l	0.018-15.9	2.10	4.16	14	0.46
Cu	96h mg/l	0.01-8.3	0.75	1.99	17	0.14
Pb	96h mg/l	0.12-50.4	9.81	19.93	6	1.92
Zn	96h mg/l	0.346-20	4.18	5.17	19	2.32
deltamethrin	96h mg/l	0.000036-0.0075	1.85E-03	2.55E-03	7	8.36E-04
carbaryl	96h mg/l	0.0047-46.9	6.26	9.85	39	1.15
fenitrothion	96h mg/l	0.00021-5.8	2.15	1.83	26	0.28
maneb	96h mg/l	0.53-3.7	2.15	1.38	7	1.65
parath.-meth	96h mg/l	0.003-10.4	4.70	3.68	24	1.35
permethrin	mg/l	0.000027-0.014	4.91E-03	4.99E-03	11	1.85E-03
trifluralin	96h mg/l	0.037-2.8	0.74	1.05	9	0.24
Amphibians		range	mean	std	n	geomean
Cd	96h mg/l	0.12-8.2	2.82	3.30	5	1.23
Cu	96h mg/l	0.32-5.21	1.81	2.32	4	0.93
Pb	96h mg/l	0.04-0.75	0.40	0.50	2	0.17
Zn	96h mg/l	19.9-31.3	24.65	5.93	3	24.19
deltamethrin	96h mg/l	0.001-0.02	0.01	0.01	3	4.45E-03
carbaryl	96h mg/l	4.7-7.6	6.15	2.05	2	5.98
fenitrothion	96h mg/l	0.33-2.45	1.39	1.50	2	0.90
maneb	96h mg/l	40-48	44.00	5.66	2	43.82
parathion	96h mg/l	3.7-6.4	5.05	1.91	2	4.87
permethrin	96h mg/l	0.12	0.12		1	0.12

For most compounds shown here, only 1 or 2 amphibian LC50s are available that usually fall within the range of values for other organisms, indicating that no statistically significant difference can be expected. Where more than 2 tests were available, i.e. cadmium, copper, zinc, deltamethrin and methoxychloor, a two tailed t-test for difference between mean LC50 of amphibians and other organisms was employed. For the metals cadmium, copper and zinc, the distribution of LC50 data is shown below (Figures 1-3). The average log LC50 for amphibians, is significantly different ($\alpha = 0.05$) for zinc, nearly significant for copper, but not for cadmium,deltamethrin and methoxychloor.

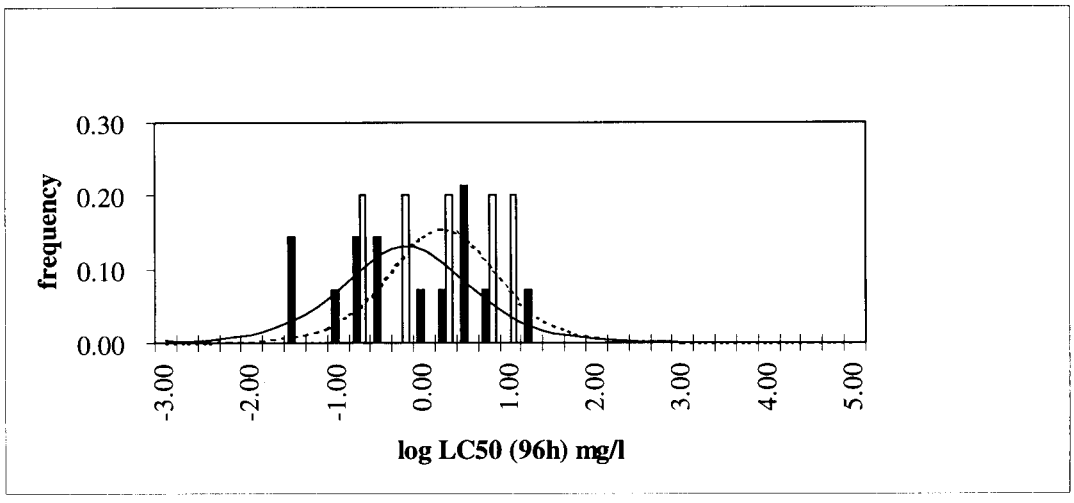

Figure 1: Comparison of cadmium LC50 distributions for amphibians (white bars; dotted line; n=5) and organisms other than amphibians (black bars; solid line; n=14).

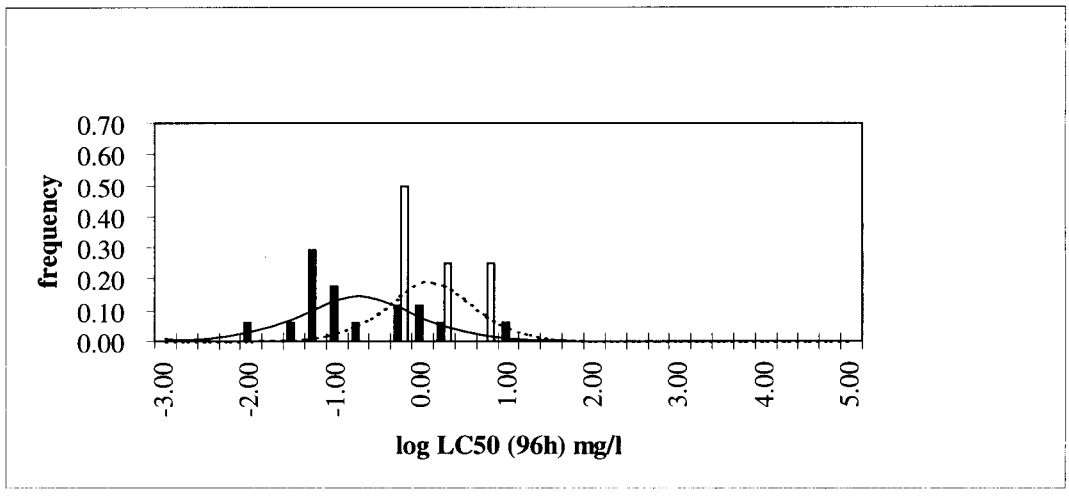

Figure 2: Comparison of copper LC50 distributions for amphibians (white bars; dotted line; n=4) and organisms other than amphibians (black bars; solid line; n=17).

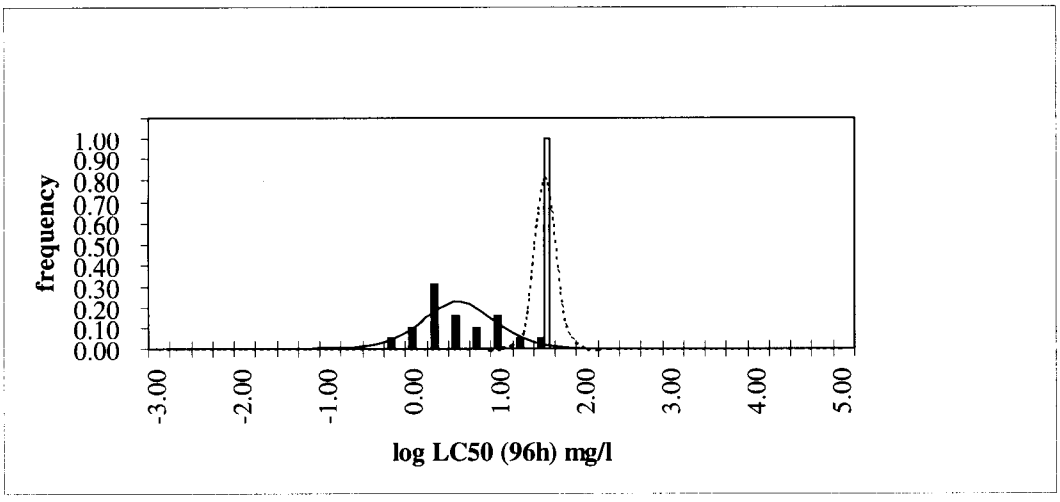

Figure 3: Comparison of zinc LC50 distributions for amphibians (white bars; dotted line; n=3) and organisms other than amphibians (black bars; solid line; n=17). Significant difference in two-tailed t-test at α =0.05

3.2.2 PAF calculations for amphibians

PAFs for amphibians were calculated for median concentrations in Dutch surface water as provided by RIZA (Klepper and Van de Meent, 1997; Appendix V). Table 5 shows that the PAF for amphibian target species is very low for the three metals. Since the median values of dutch surface water are used, higher water concentrations can also be found. Therefore the PAF for amphibians may not be negligible for all surface waters.

Table 5: Potentially Affected Fraction for Amphibians (based on NOECs estimated from LC50s)at median dissolved water concentrations in Dutch regional surface water

	median water concentrations (ug/l)	PAF amphibians
cadmium	0.04	0.01 %
copper	2.3	0.7 %
zinc	7.1	< 0.01%

3.3 Terrestrial higher plants

3.3.1 comparison of plant toxicity data

Interpretation of plant toxicity studies in soil are hampered by differences in bio-availability due to soil characteristics that influence sorption of metals such as clay, organic matter and metal oxides (Janssen et al., 1996). To avoid recalculation of plant toxicity tests to a supposed soil pore water exposure concentration, an attempt was made to use plant toxicity data from hydroculture experiments. The toxicity criterion in the data in Wang (1992) is a 50% inhibitory concentration (IC50, mg l^{-1}) relative to the control, unfortunately without stating the exact inhibition criterion. The cumulative distribution of these data is compared to NOECs from soil toxicity tests, recalculated to soil pore water concentrations. The present data sets for plant IC50s are larger than for NOECs.

A consistent difference between the two data sets indicates that NOECs from soil tests and IC50s from hydroculture can be compared and one can be derived from the other. Based on comparisons of acute and chronic toxicity (Traas et al., 1997, De Zwart pers. comm.), it is expected that NOECs are about two orders of magnitude lower than IC50s: one order to extrapolate from IC50s to NOECs and one order to extrapolate from acute to chronic toxicity.

The comparison in figure 4 shows that for Cd, the average of the NOEC data is three orders of magnitude lower than the IC50 data. The copper toxicity data are not significantly different, but for zinc the NOECs are more than two orders of magnitude lower than IC50s. It can be concluded that differences in speciation and sorption of metals in hydroculture and soil are not consistent with the partition models used as secribed in section 2.3.2. To avoid using arbitrary values to extrapolate from the larger data sets on IC50s to NOECs, the NOEC soil toxicity data are used to calculate a plant PAF according to Klepper and Van de Meent (1997).

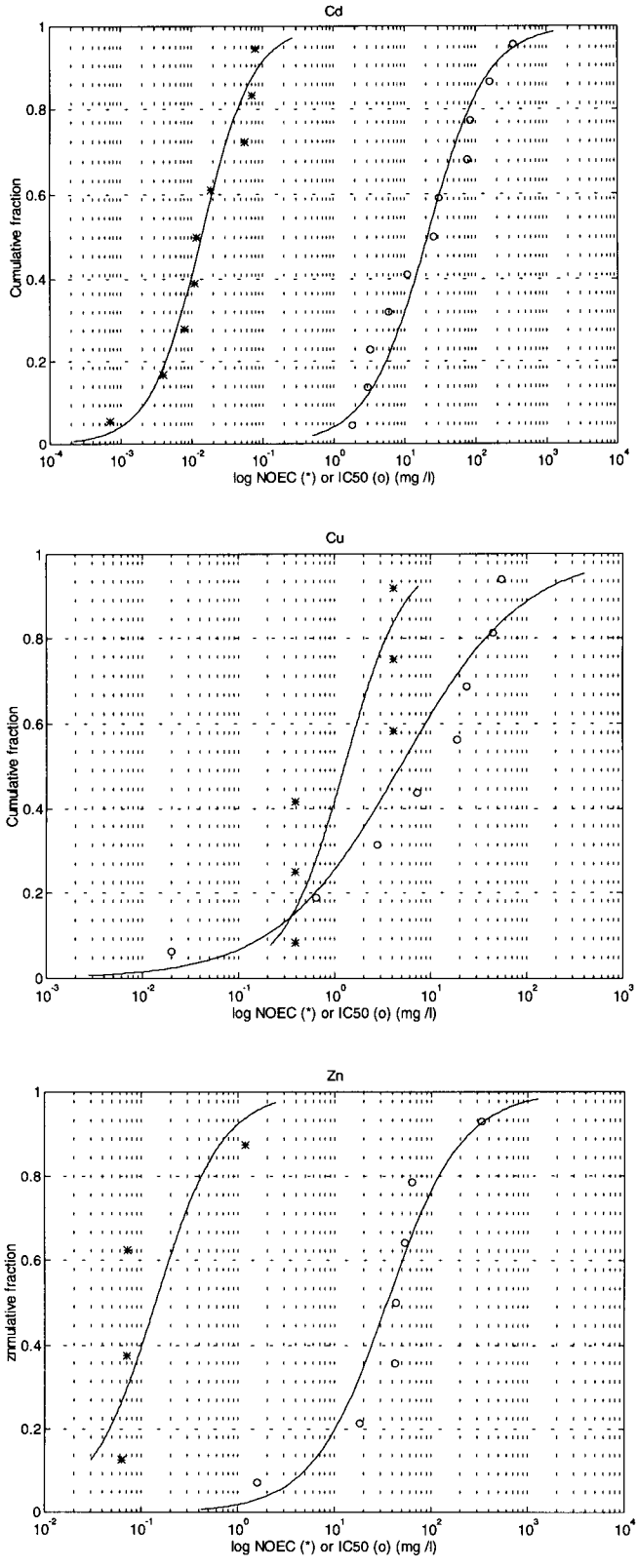

Figure 4: Plant toxicity data (plotted as cumulative sensitivity distributions) for cadmium, copper and zinc (mg/l), recalculated from NOECs from soil toxicity studies (*) and IC50s from tests in hydro culture (o).

3.3.2 Exceedance of selected PAF levels

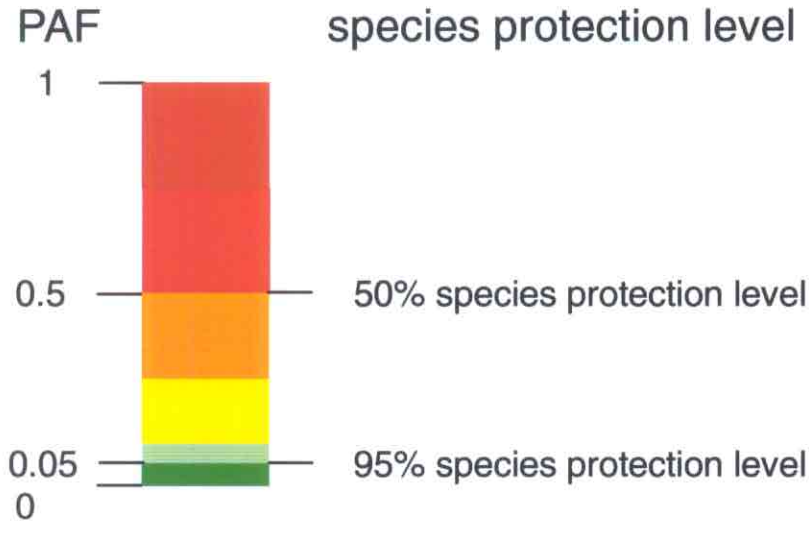

Figure 5: Ecotoxicological risk limits and the relation to PAF (redrawn after Beek and Knoben, 1997). Colours are the same as used for mapping PAF levels in following figures.

A tentative estimate of the magnitude of metal toxicity to plants is calculated from the percentage of grid cells where specific PAF levels are exceeded. For this, several levels of PAF were selected (Luttik et al., 1997). The low risk limit is the PAF level used for setting the Maximum Permissible Concentration, (MPC; e.g. Van de Plassche, 1994) according to Aldenberg and Slob (1993). The MPC is the hazardous concentration for 5 % of the species (equal to a 95% species protection level). Therefore, the low risk limit used here is a PAF of 0.05, i.e. the 5th percentile of the species sensitivity distribution used for calculating the PAF for plants.

The ecotoxicological criterion for serious soil contamination is defined as the Hazardous concentration for 50 % of the species, involving a stepwise approach for different groups of species (Crommentuijn et al. 1994). Therefore, the serious risk limit used here is a PAF of 0.5, i.e. the 50th percentile of the species sensitivity distribution used for calculating the PAF for plants.

Table 5 shows that the toxic effects on plants decrease in the order zinc, cadmium, copper. For zinc, the toxic pressure is substantial and for copper very small. The low risk limit for zinc is exceeded in 28.5 % of the area for wich a plant PAF could be calculated.

For cadmium, the model predicts a small exceedance of the low risk limit at 4.3% of the calculated area. Copper toxicity to plants is predicted to be negligable, with only a 0.1% area with a PAF higher than 0.05. The high risk limit (PAF=0.5) is exceeded in only a very small percentage of the area, 0.08% for cadmium, not for copper and a 3.2 % area for zinc.

Table 6: Exceedance of PAF risk limits as a percentage of the area for which a PAF plants could be calculated.

	Low risk limit PAF=0.05	Serious risk limit PAF=0.5
cadmium	4.3	0.08
copper	0.1	0
zinc	28.5	3.2

3.3.3 Mapping metal PAFs for plants

The predicted PAF values are presented as maps for copper, cadmium, zinc. The PAF for plants due to cadmium in Dutch soils is generally very low with an average PAF of 1% (Figure 6a). In an area with known high cadmium concentrations as the Kempen, PAF values up to 40% are reached, meaning that NOECs are exceeded for 40% of the plant species.

Copper toxicity is almost absent (Figure 6b) with an average PAF values of 0.3%. Slightly higher values are found on peat soils in the western and south-eastern part of the Netherlands. (Figure 6b). PAF values for zinc are higher (Figure 7) with an average PAF value of 7%. Values up to 40% are found at 'De Utrechtse Heuvelrug' and in the south-eastern part of the Netherlands. The high PAF level at 'De Utrechtse Heuvelrug' is mainly due to the correction for low pH in the field, leading to a 5 to 10 times higher availability in the field as compared to the laboratory toxicity data (Klepper and Van de Meent, 1997; Chapter 4). High PAF values in the south-eastern part are mainly caused by elevated zinc concentrations due to the metal industry in that area. PAF values on clay soils are generally very low, due to high pH and correction for natural background levels of zinc.

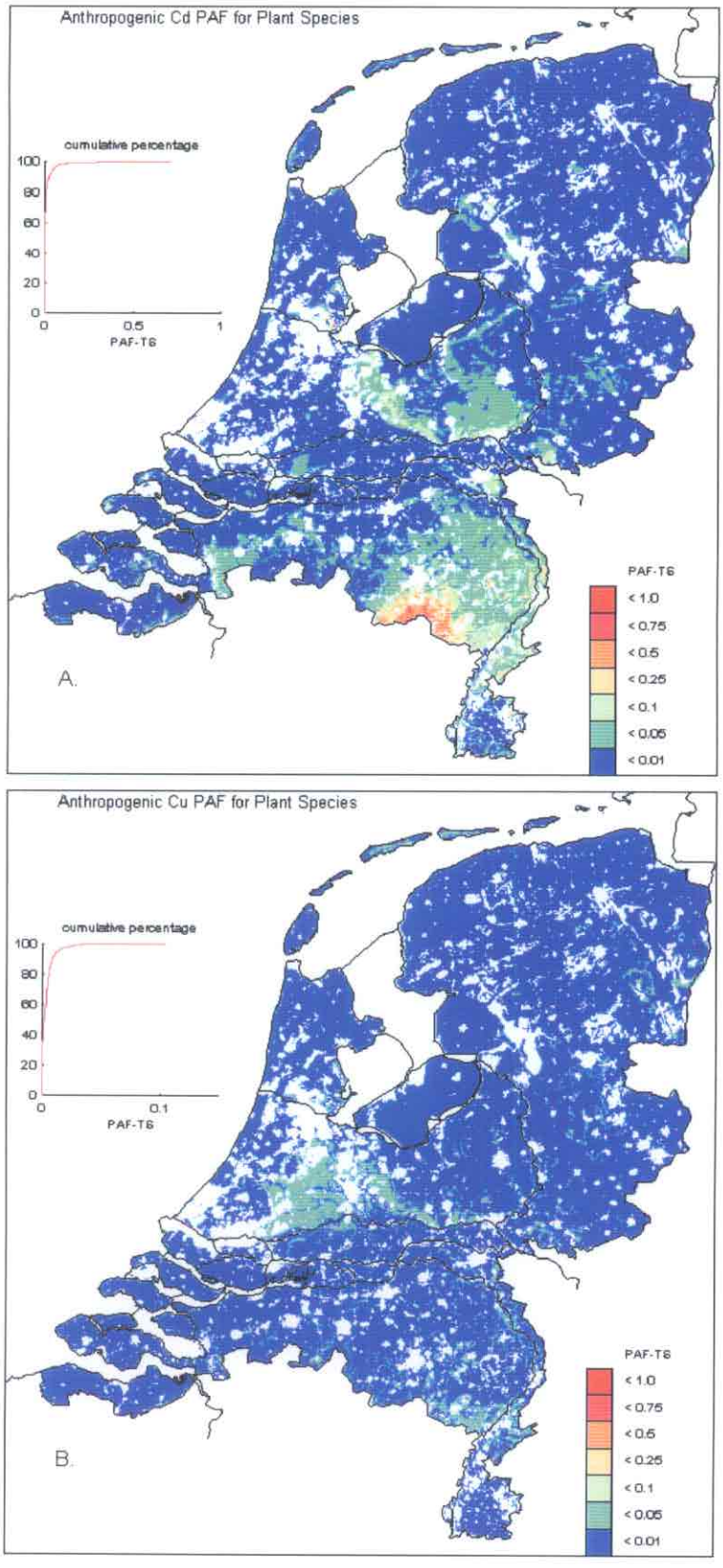

Figure 6: Maps of Plant PAFs for cadmium (A) and copper (B), together with the cumulative distribution of calculated PAFs.

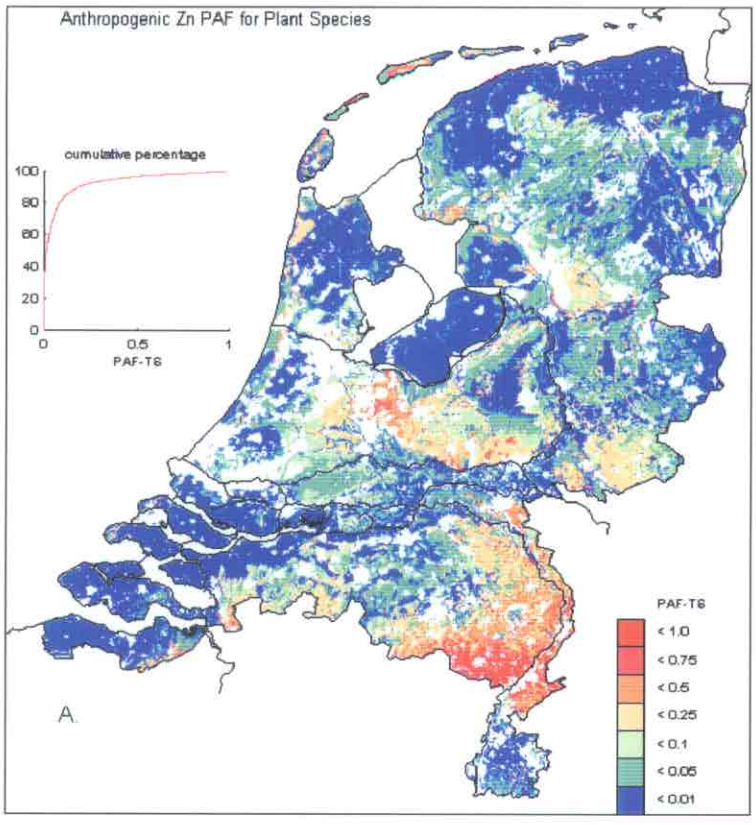

Figure 7: Maps of Plant PAF for zinc, together with the cumulative distribution of calculated PAFs.

4. DISCUSSION AND CONCLUSIONS

Very few toxicity studies are available for dragonflies, damselflies and butterflies. Limited information is available for dragonflies and damselflies and no conclusions can be drawn about systematic sensitivity differences between Odonata (dragonflies) and other groups of (benthic) aquatic organisms. The larval stage of dragonflies and damselflies dominates the life span and exposure of the larvae is probably mainly by way of water or sediment pore water. Contaminated prey may contribute to total toxicant exposure, but could not be studied in detail. Given the few data, no separate risk assessment seems feasible. It is possible to include the toxicity data on Odonata in the overall assessment of the generic toxicity with the PAF method (Klepper and Van de Meent, 1997).

For Lepidoptera, ingestion of contaminated leaves by the caterpillar stage seem to be the most relevant exposure pathway. The existing toxicological knowledge, mostly LD50s might allow the calculation of critical leaf concentrations. Since the contamination of leaves is usually not known, separate plant accumulation or spray drift models must be used to calculate the concentration in leaves. Uncertainty in these calculations is too high, given the little available information.

Amphibians are mainly exposed through the waterphase although food uptake most likely contributes for compounds with a log K_{ow} larger than 5. The selected toxicity data show that a systematic difference in sensitivity did not exist for cadmium, copper, deltamethrin and methoxychloor, but only exists for zinc with amphibians less sensitive than other organisms. Based on the results for these 5 toxicants, it seems that amphibians are protected sufficiently when protection is based on toxicity data for all aquatic organisms. PAF calculations for cadmium, copper and zinc show that amphibians are not expected to be affected at median concentrations in Dutch surface waters. Some caution is in place: relatively few compounds are taken into account, and recent accounts of malformations of amphibians in the United States (Schmidt, 1997; Pelley, 1997) could point to an as yet unknown specific sensitivity of amphibians for other compounds.

PAF calculations for vascular plants suggest that toxic pressure for zinc is highest of the three metals studied. Affected fractions up to 40 % are predicted. It is clear that these preliminary PAF calculations based on a small set of toxicity data only indicate the toxic pressure on plants; some aspects of metal partitioning, metal uptake and metal toxicity have been simplified or ignored. Most necessary is the collection of additional toxicity data.

Plants can influence the uptake of minerals and metals by secreting acidifying or chelating substances in the root zone (Krishnamurti et al., 1997). By this active mechanism, plants can change the partitioning of metals and probably metal toxicity. This may lead to large differences in plant susceptibility that cannot be accounted for in the present PAF method. Another factor influencing metal uptake is the presence of mycorrhiza. The large hyphal surface does not only enhance nutrient and water uptake but also metal uptake (Rovira et al., 1983, Prof. Ernst, pers. comm).

Plant toxicity data are mainly derived from experiments with food crops. Research with wild plants has mainly focussed on mechanisms of metal toxicity and metal tolerance, or on uptake of metals (e.g. Otte and Wijte, 1993). Additional toxicity data on wild plants is needed to validate the preliminary PAF predictions for plants.

Special attention must be paid to mechanisms of metal regulation since copper and zinc are essential metals. Plants have mechanisms for active uptake, storage and excretion (e.g. by leaves) of metals that show huge differences between species. Some plant species have developed metal-resistant genotypes on contaminated sites. These aspects are subject of further study, as far as applicable in risk assessment for plants.

CONCLUSIONS

Toxicity data for butterflies, damselfies, dragonflies and reptiles do not allow the calculation of PAF for the time being. Since damselflies and dragonflies are mainly exposed in the waterphase during larval development, the generic PAF as calculated for water exposed organisms can be used as a general measure for toxic pressure.

Amphibians do not seem to be more susceptible than other organisms based on LC50 data. At the present median metal concentrations, low levels of PAF (< 1%) are predicted. For zinc, a significantly lower susceptibility was found. For other chemicals, this may not be the case given recent reports in the literature. The comparability with PAF for other aquatic organisms is hampered by the lack of NOEC data for amphibians. Given their importance as indicators of habitat quality, a more in depth study in amphibian toxicity is recommended. Mapping of PAF for amphibians is feasible if a geographical differentiation of water concentrations is available.

Plant toxicity data were used to calculate the PAF for plants, with highest values for zinc (average PAF of 7%), followed by cadmium (average PAF of 1%) and lowest for copper (average PAF of 0.3%). The highest toxic pressure due to these metals is found in 'De Kempen'. Many uncertainties exist, dominated by the small data set on toxicity, that make the present calculations for cadmium, copper and zinc no more than preliminary. However, it is believed that a PAF for plants calculated in this fashion is feasible.

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APPENDIX I. SEARCH PROFILE FOR TARGET SPECIES

1. Search profile for amphibians and reptiles

1a. Database BIOSIS 1983 to 1997

"f frog or toad or ranidae or bufonidae or xenopus or bufo or rana or salamander"

"f tadpole or adder or vipera or lizard or lacerta or snake or blindworm"

"f frogs or toads or salamanders or ringsnakes or bullfrogs or tadpoles or adders"

"f lizards or snakes or slowworms or axolotls or reptiles or slowworm"

"f ringsnake or bullfrog or spadefoot or scaphiopus or acris or amphibians"

"f ambystoma or axolotl or hyla or microhyla or pseudacris or pleurodeles"

"f gastrophryne or ambystomatidae or pelobat? or pipidae or hylidae or reptile"

"f microhylidae or salamandridae or fetax or amphibian or triturus or coronella"

"f anguis or natrix or alytes or lacertidae"

"f 1 to 9"

"f 10 not (poison or snake bite or venom or toxin or venoms or toxins or snake bites)"

"f (effect or effects or reproduct? or lethal or lethality or mortality or embryotoxic?)/ti"

"f (inhibit? or survival or growth or mortalities or sensitivity or impact)/ti"

"f (suscept? or sensitivities or tolerance or alteration or alterations)/ti"

"f (response or responses or change or changes or influence or intoxication)/ti"

"f toxic?/(ti;ut) or lc50 or lc 50 or ec50 or ec 50 or noec or loec or noel or nel or match"

"f 12 to 16"

"f 11 and 17"

"f 18 not la=(ru or ch or cz or bu or it or sp or po or ja or hu)"

1b: For effects of metals on amphibians and reptiles:

Database BIOSIS 1970- 1997

Combination of:

metals: cadmium, copper, zinc or lead

Reptiles: Vipera, Coronella, Anguis, Natrix, Lacerta

Amphibians: Triturus, Hyla, Pelobatus, Bufo, Alytes, Xenopus, Ambystoma

2. Search profile for butterflies , damselflies and dragonflies

- Database BIOSIS 1983 to 1997
- CDROM TOXLINE PLUS 1985 to 1997

"f bc=(75330 or 75338) or zygoptera or anisoptera or ophiogomphus or lestes or ischnura"

"f anax or boyeria or tarnetrum or sympetrum or onychogomphus or aeschna or pantala"

"f cordulegaster calopteryx or ceriagrion or enallagma or cercion or copera"

"f butterfly or butterflies or dragonfly or dragonflies or damselfly or damselflies"

"f 1 to 4"

"f (effect or effects or reproduct? or lethal or lethality or mortality or embryotoxic?)/ti"

"f (inhibit? or survival or growth or mortalities or sensitivity or impact)/ti"

"f (suscept? or sensitivities or tolerance or alteration or alterations)/ti"

"f (response or responses or change or changes or influence or intoxication)/ti"

"f toxic?/(ti;ut) or lc50 or lc 50 or ec50 or ec 50 or noec or loec or noel or nel or match"

"f 6 to 10"

"f 5 and 11"

"f 12 not la=(ch or ja or ru or cz or bu or it or sp or hu or po)"

"f 13 not (synergis? or resistan? or toleran? or metabolis? or behavio?)(ti;ut)"

3: For toxicity of metals to plants:

Database BIOSIS 1985-1997

Combination of:

Metals: copper, zinc, cadmium, mercury, nickel, chromium, arsene

Keywords: uptake, accumulation of bioaccumulation

APPENDIX II: TOXICITY DATA FOR DAMSELFLIES, DRAGONFLIES AND BUTTERFLIES

Table II.1: Toxicity data for damselflies and dragonflies

Species	chemical	tox. criterion	ug/l	reference
Ophiogomphus rup.	Diazinon	NOEC	1.29	Crommentuijn et al. 1997
Ophiogomphus rup.	malathion	NOEC	0.28	Crommentuijn et al. 1997
Boyeria vinosa	malathion	NOEC	1.7	Crommentuijn et al. 1997
Ischnura verticalis	DDD	LC50 96h	34	Mayer and Ellersieck 1986
Ischnura verticalis	dieldrin	LC50 96h	12	Mayer and Ellersieck 1986
Ischnura verticalis	endrin	LC50 96h	2.4	Mayer and Ellersieck 1986
Ischnura verticalis	endrin	LC50 96h	2.1	Mayer and Ellersieck 1986
Ischnura verticalis	Meth.parathion	LC50 96h	33	Mayer and Ellersieck 1986
Ischnura verticalis	parathion	LC50 96h	0.6	Mayer and Ellersieck 1986
Ischnura verticalis	aroclor 1242	LC50 96h	400	Mayer and Ellersieck 1986
Ischnura verticalis	aroclor 1254	LC50 96h	200	Mayer and Ellersieck 1986
Lestes congener	malathion	LC50 96h	10	Mayer and Ellersieck 1986
Ophiogomphus spec.	DDT	LC50 96h	32	Mayer and Ellersieck 1986
Macromia spec.	aroclor 1242	LC50 96h	800	Mayer and Ellersieck 1986
Macromia spec.	aroclor 1254	LC50 96h	800	Mayer and Ellersieck 1986

Toxicity data for selected metals and organic compounds found for different species of amphibia, reptilia, lepidoptera and odonata. (values in mg/l)

species (age)	cadmium	copper	lead	zinc	org. compound	reference
Amphibia (A) and Reptilia (R)						
Ambystoma gracile (larvae) (R)	10 d NOAEL=0.11 (b)					Nebeker et al., 1995
Ambystoma gracile (larvae) (R)	24 d NOAEL=0.05 (c)					Nebeker et al., 1995
Ambystoma gracile (larvae) (R)	96 h LC50=0.47					Nebeker et al., 1995
Ambystoma jeffersonianum (embr)(R)		96 h LC50=0.32				Horne & Dunson, 1994
Bufo arenarum (stage 26) (20°C)	24 h LC50=3.41					Ferrari et al., 1993
Bufo arenarum (stage 26) (25°C)	24 h LC50=4.05					Ferrari et al., 1993
Bufo arenarum (stage 28-29) (20°C)	24 h LC50=4.76					Ferrari et al., 1993
Bufo arenarum (stage 28-29) (25°C)	24 h LC50=9.92					Ferrari et al., 1993
Bufo arenarum (tadpoles)	96 h LC50=2.08					Muino et al., 1990
Bufo arenarum (blastulae stage) (A)	LC50=2					Herkovits & Perez-Coll, 1993
Bufo arenarum (late gastrulae	LC50=1					Herkovits & Perez-Coll, 1993
Bufo arenarum (neural tube)	LC50=0.12					Herkovits & Perez-Coll, 1993
Bufo arenarum (gill circulation)	LC50=0.15					Herkovits & Perez-Coll, 1993
Bufo arenarum (operculum folds)	LC50=0.25					Herkovits & Perez-Coll, 1993
Bufo arenarum (complete operculum)	LC50=0.5					Herkovits & Perez-Coll, 1993
Bufo arenarum (neuromusculara act)			48 h LC50=1			Perez-Coll & Herkovits, 1990
Bufo arenarum (embryos)			48 h LC50=0.47-0.90			Perez-Coll et al., 1988
Bufo arenarum (tadpoles)				deltamethrin	96 h LC50=0.0044*	Crommentuijn et al., 1997
Bufo bufo				deltamethrin	72 h LC50=0.001	Crommentuijn et al., 1997
Bufo bufo (30 d)				maneb	48 h LC50=40*	Crommentuijn et al., 1997
Bufo woodhousii fowleri (tadpoles)				trifluralin	96 h LC50=0.11	Crommentuijn et al., 1997
Gastrophyrne carolinensis (A)			96 h LC50=0.04			Stansley et al., 1997
Microhyla ornata (1-week) (A)	96 h LC50=1.58	96 h LC50=5.04		96 h LC50=22.41		Rao & Madhyastha, 1987
Microhyla ornata (4-week) (A)	96 h LC50=1.81	96 h LC50=5.38		96 h LC50=23.08		Rao & Madhyastha, 1987
Microhyla ornata (embryos)				ETU	96 h LC50=43	Crommentuijn et al., 1997
Microhyla ornata (2 d prehatch eggs)				fenitrothion	96 h LC50=3.2; 4.2	Crommentuijn et al., 1997
Microhyla ornata (8 d tadpoles)				fenitrothion	96 h LC50= 1.1	Crommentuijn et al., 1997

Notophthalmus viridescens (R)	21 d LC50=6.75					Manson & O'Flaherty, 1978
Notophthalmus viridescens (R)	66 d LC50=4.5					Manson & O'Flaherty, 1978
Pseudacris triseriata (tadpoles)				paration-methyl	96 h LC50=3.7	Crommentuijn et al., 1997
Rana catesbeiana (eggs) (A)			10 w NOEC >=0.06			Stansley et al., 1997
Rana catesbeiana (tadpoles)				parathion-methyl	96 h LC50=6.4	Crommentuijn et al., 1997
Rana catesbeiana (2-5 g)				permethrin	96 h LC50=0.12	Crommentuijn et al., 1997
Rana palustris (eggs) (A)			14 w NOEC=0.031			Stansley et al., 1997
Rana temporaria (tadpoles)				deltamethrin	48 h LC50=0.02	Crommentuijn et al., 1997
Rana temporaria (frogs,males)				fenitrothion	acute LD50=2400 mg/kg bw	Gromysz-Kalkowska & Szubartowska, 1993
Rana temporaria (frogs,females)				fenitrothion	acute LD50=2220 mg/kg bw	Gromysz-Kalkowska & Szubartowska, 1993
Rana tigrina (tadpoles)				carbaryl	96 h LC50=7.6	Crommentuijn et al., 1997
Tiliqua rugosus (R)					LD50=590 mg/kg (d)	Freeman et al., 1996
Triturus cristatus (male, 8 g)				maneb	96 h LC50=42*	Crommentuijn et al., 1997
Triturus cristatus (female, 12 g)				maneb	96 h LC50=55*	Crommentuijn et al., 1997
Triturus cristatus carnifex (male)				2,4-D	102 h LC50=75	Zaffaroni et al., 1986
Triturus cristatus carnifex (female)				2,4-D	132 h LC50=75	Zaffaroni et al., 1986
Triturus cristatus carnifex (male)				2,4-D	14 h LC50=150	Zaffaroni et al., 1986
Triturus cristatus carnifex (female)				2,4-D	52 h LC50=125	Zaffaroni et al., 1986
Triturus cristatus carnifex (male)				MCPA	17 h LC50=3200	Zaffaroni et al., 1986a
Triturus cristatus carnifex (female)				MCPA	21 h LC50=3200	Zaffaroni et al., 1986a
Triturus cristatus carnifex (male)				MCPA	35 h LC50=1600	Zaffaroni et al., 1986a
Triturus cristatus carnifex (female)				MCPA	46 h LC50=1600	Zaffaroni et al., 1986a
Varanus gouldii (R)					LD50=27.5 mg/kg (d)	Freeman et al., 1996
Xenopus laevis (embryos) (A)				EC50=3.6 (a)		Dawson et al., 1988
Xenopus laevis (embryos) (A)				LC50=34.5		Dawson et al., 1988
Xenopus laevis (embryos) (A)	96 h EC50=0.4 (a)					Plowman et al., 1994
Xenopus laevis (tadpoles) (A)	90 h LC50=80-100			90 h LC50=20-25		Woodall et al., 1988
Xenopus laevis (blastulae) (A)	96 h LC50=3.6					Sunderman et al., 1991
Xenopus laevis (blastulae) (A)	96 h NOEC=0.2 (b)					Sunderman et al., 1991
Xenopus laevis (embryos)				guthion	96 h LC50=6.1-6.3	Schuytema et al., 1994
Xenopus laevis (embryos)				guthion 2S	96 h LC50=1.6 (j)	Schuytema et al., 1994
Xenopus laevis (embryos)(A)	24, 72 h NOEC < 0.1					Herkovits et al., 1997

Xenopus laevis		96 h LC50=1.4		96 h LC50=55.6		Luo, et al., 1993
Xenopus laevis		96 h EC50=0.16		96 h EC50=2.6		Luo, et al., 1993
Xenopus laevis (embryos)				carbaryl	24 h LC50=4.7	Crommentuijn et al., 1997
Xenopus laevis (< 2 d)				dimethoate	100 d NOEC=1 (o)	Crommentuijn et al., 1997
Xenopus laevis (< 2 d)				dimethoate	100 d NOEC=32 (b)	Crommentuijn et al., 1991
Xenopus laevis (embryos)				fenitrothion	24 h LC50=0.33	Devillers & Exbrayat, 1992
Xenopus laevis (embryos)				2,4-D	96 h LC50 >270	Morgan et al., 1996
Lepidoptera (L) and Odonata (O)						
Brachythemis contaminata (nymphs)(O)				tannic acid	24 h LC50=306 (f)	Manoharan et al., 1992
Bradinophyga (larvae) (O)				malathion	24 h LC50 >0.4, <0.6 (e)	Saxena & Saxena, 1986
Dragonfly (naids)				dimethoate	96 h LC50=0.28	Sateesh et al., 1996
Galleria mellonella (larvae)	45 d LC50 ~ 50 mg/kg diet					Mathova, 1990
Heliothis armigera (5th instar larvae)(L)				abamectin	96 h LD50=12.1 ng/mg bw (h)	Christie & Wright, 1990
Heliothis armigera (6th instar larvae)(L)				abamectin	96 h LD50=15.8 ng/mg bw (h)	Christie & Wright, 1990
Heliothis armigera (5th instar larvae)(L)				abamectin	96 h LD50=9.4 ng/mg bw (i)	Christie & Wright, 1990
Hemileuca oliviae (3th instar)(L)				cypermethrin	48 h LC50=7.9 (l)	Hagler et al., 1988
Hemileuca oliviae (3th instar)(L)				permethrin	48 h LC50=7.7 (l)	Hagler et al., 1988
Hemileuca oliviae (3th instar)(L)				fenvalerate	48 h LC50=15.1 (l)	Hagler et al., 1988
Ischnura verticalis (late instar)(O)				parthion-methyl	96 h LC50=0.033	Crommentuijn et al., 1997
Lestes congener (late instar) (O)				propoxur	96 h LC50=0.3	Crommentuijn et al., 1997
Lymantria dispar (1st and 4th instars)(L)	NOEC=50 µg/g fd (p)	NOEC=50 µg/g fd (p)	NOEC=100 µg/g fd (p)	NOEC=100 µg/g fd (p)		Gintenreiter et al., 1993
Lymantria dispar (1st and 4th instars)(L)	NOEC=10 µg/g fd (o)	NOEC=10 µg/g fd (o)		NOEC=100 µg/g fd (o)		Gintenreiter et al., 1993
Lymantria dispar (1st instars)(L)	NOEC=2 µg/g fd (q)	NOEC=10 µg/g fd (q)	NOEC=4 µg/g fd (q)	NOEC=100 µg/g fd (q)		Gintenreiter et al., 1993
Neurocordella virginiensis (larvae)(O)				temephos	96 h LC50=2.0	Anadu et al., 1996
Neurocordella virginiensis (larvae)(O)				temephos	96 h NOEC <1.0	Anadu et al., 1996
Pantala flavesens (O)				endosulfan	48 h LC50=15	Yadwad et al., 1990

Pieris brassicae (1st instar larvae)(L)				dimethoate	24 h LD50=2.08 (h1)	Sinha et al., 1990
Pieris brassicae (1st instar larvae)(L)				pirimicarb	24 h LD50=1.58 (h2)	Sinha et al., 1990
Pieris brassicae (1st instar larvae)(L)				phosalone	24 h LD50=1.09 (h3)	Sinha et al., 1990
Pieris brassicae (1st instar larvae)(L)				endosulfan	24 h LD50=6.46 (h4)	Sinha et al., 1990
Pieris brassicae (1st instar larvae)(L)				fenitrothion	24 h LD50=1.18 (h5)	Sinha et al., 1990
Pieris brassicae (1st instar larvae)(L)				pirimiphos-methyl	24 h LD50=1.11 (h6)	Sinha et al., 1990
Pieris brassicae (1st instar larvae)(L)				fenvalerate	24 h LD50=5.39 (h7)	Sinha et al., 1990
Pieris brassicae (1st instar larvae)(L)				diflubenzuron	24 h LD50=2.50 (h8)	Sinha et al., 1990
Pieris brassicae (4th instar larvae)(L)				microcystin-LR	48 h LD50=1.9 mg/kg (I)	Delaney & Wilkins, 1995
Pieris brassicae (4th instar larvae)(L)				carbofuran	48 h LD50=0.3 mg/kg (I)	Delaney & Wilkins, 1995
Pieris brassicae (4th instar larvae)(L)				deltamethrin	72 h LD50=50 ng (h)	Çilgi & Jepson, 1995
Pieris brassicae (4th instar larvae)(L)				deltamethrin	14 d LD50=20 ng (h)	Çilgi & Jepson, 1995
Pieris brassicae (4th instar larvae)(L)				deltamethrin	3-13 d LD50= 0.43-0.004 g/larva	Çilgi & Jepson, 1995
Pieris brassicae (4th instar larvae)(L)				deltamethrin	3-8 d LD50= 0.20-0.03 g/larva	Çilgi & Jepson, 1995
Pieris brassicae (3th instar)(L)				chlordimeform	LD50=130 mg/g (m1)	Blackwell, 1988
Pieris brassicae (3th instar)(L)				chlordimeform	LD50=18.6 µg/g (m2)	Blackwell, 1988
Pieris brassicae (3th instar)(L)				chlordimeform	LD50=4.4 µg/g (m3)	Blackwell, 1988
Pieris brassicae (5th instar)(L)				chlordimeform	LD50=247 µg/g (n1)	Blackwell, 1988
Pieris brassicae (5th instar)(L)				chlordimeform	LD50=299 µg/g (n2)	Blackwell, 1988
Plutella xylostella (4th instar)(L)				tetramethrin	24 h LC50=8.8 (g1)	Chen et al., 1985
Plutella xylostella (4th instar)(L)				phenothrin	24 h LC50=1.3 (g2)	Chen et al., 1985
Plutella xylostella (4th instar)(L)				fenpropathrin	24 h LC50= 0.61(g3)	Chen et al., 1985
Plutella xylostella (4th instar)(L)				permethrin	24 h LC50=0.57(g4)	Chen et al., 1985
Plutella xylostella (4th instar)(L)				cypermethrin	24 h LC50= 0.46(g5)	Chen et al., 1985
Plutella xylostella (4th instar)(L)				deltamethrin	24 h LC50=0.14 (g6)	Chen et al., 1985
Plutella xylostella (4th instar)(L)				fenvalerate	24 h LC50=0.23(g7)	Chen et al., 1985
Plutella xylostella (4th instar)(L)				fluvalinate	24 h LC50= 16.6(g8)	Chen et al., 1985
Plutella xylostella (4th instar)(L)				flucythrinate	24 h LC50=0.34 (g9)	Chen et al., 1985
Plutella xylostella (4th instar)(L)				tralomethrin	24 h LC50=0.28 (g10)	Chen et al., 1985

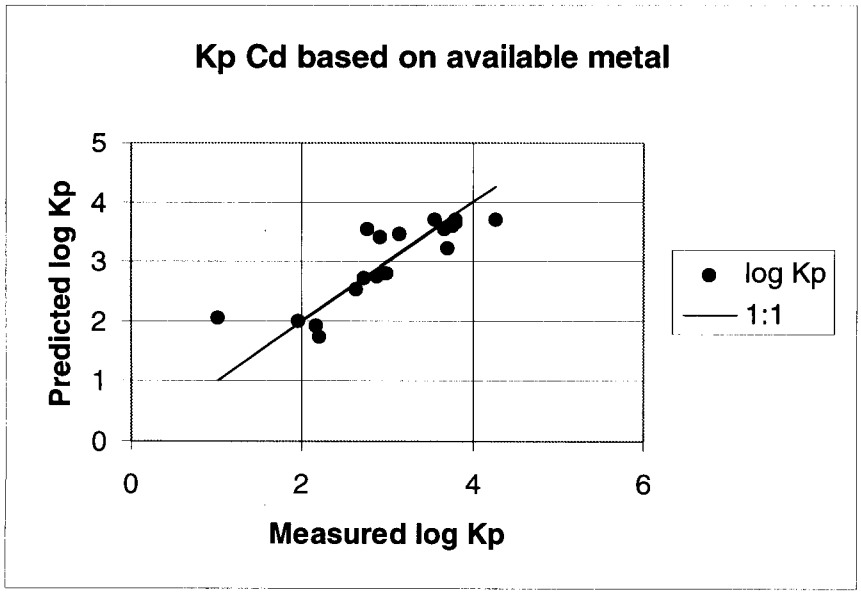
Plutella xylostella (4th instar)(L)					24 h LC50=32.5 (g11)	Chen et al., 1985
Plutella xylostella (3th instar)(L)				microcystin-LR	24 h LD50=1.0 µg/cm2	Delaney & Wilkins, 1995
Plutella xylostella (3th instar)(L)				rotenone	72 h LD50=2.0 µg/cm2	Delaney & Wilkins, 1995
Scotia segetum (caterpillar)	LD50=178 µg/ind					Weisman & rehakova, 1994
Spodoptera littoralis (3th instar larvae)(L)				microcystin-LR	24 h LD50=4.7 mg/kg (I)	Delaney & Wilkins, 1995
Spodoptera littoralis (3th instar larvae)(L)				malathion	24 h LD50=13.1 mg/kg (I)	Delaney & Wilkins, 1995
Spodoptera littoralis (2nd instar larvae)(L)				abamectin	96 h LD50=56.3 ng/mg bw (h)	Christie & Wright, 1990
Spodoptera littoralis (3th instar larvae)(L)				abamectin	96 h LD50=71.7 ng/mg bw (h)	Christie & Wright, 1990
Spodoptera littoralis (4th instar larvae)(L)				abamectin	96 h LD50=471 ng/mg bw (h)	Christie & Wright, 1990
Spodoptera littoralis (5th instar larvae)(L)				abamectin	96 h LD50=223 ng/mg bw (h)	Christie & Wright, 1990
Spodoptera littoralis (6th instar larvae)(L)				abamectin	96 h LD50=0.43 ng/mg bw (h)	Christie & Wright, 1990
Spodoptera littoralis (5th instar larvae)(L)				malathion	96 h LD50=9.5 ng/mg bw (h)	Christie & Wright, 1990
Spodoptera littoralis (6th instar larvae)(L)				malathion	96 h LD50=2.4 ng/mg bw (h)	Christie & Wright, 1990
Spodoptera littoralis (5th instar larvae)(L)				lambda-cyhalothrin	96 h LD50=0.05 ng/mg bw (h)	Christie & Wright, 1990
Spodoptera littoralis (6th instar larvae)(L)				lambda-cyhalothrin	96 h LD50=0.02 ng/mg bw (h)	Christie & Wright, 1990
Spodoptera littoralis (5th instar larvae)(L)				abamectin	96 h LD50=11.2 ng/mg bw (i)	Christie & Wright, 1990
Spodoptera littoralis (6th instar larvae)(L)				abamectin	96 h LD50=0.95 ng/mg bw (i)	Christie & Wright, 1990
Spodoptera littoralis (4th instar) (L)				chlordimeform	LD50=32.7 µg/g (h)	Blackwell, 1988
Trochoplusia ni (3 th instar)(L)				chlordimeform	LD50=750 µg/g (h)	Blackwell, 1988

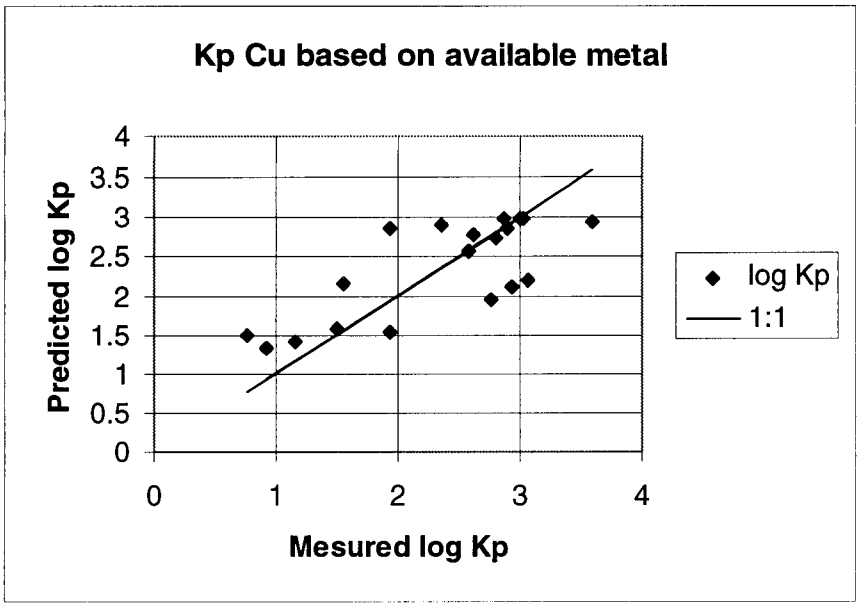
*: above water solubility
a: endpoint is malformations
b: growth
c: survival
d: cereal-based bait impregnated with sodium monofluoroacetate (1080)
e: malation
f: tannic acid
g: 1) tetrametrhin; 2) phenothrin; 3) fenpropathrin; 4) permethrin; 5) cypermethrin; 6) deltamethrin; 7) fenvalerate; 8) fluvalinate; 9) flucythrinate; 10)tralomethrin; 11) DDT.
h: Topical application with 1)dimethoate; 2) pirimicarb; 3) phosalone; 4) endosulfan; 5)fenitrothion; 6) pirimiphos-methyl; 7) fenvalerate; 8) diflubenzuron; valus expressed as µg per insect!
i: exposed by injection
j: result in mg a.i./l
k: larvae were exposed for 72 h to leaf discs with deltamethrin residues, results in g a.i./larva from 1 to 10 days after exposure.
l: filter paper method
m: 3th instar larvae were exposed topically; mortality was evaluated in: 1) 3th instars, 2) 5th instars and 3) pupae
n: 5th instar larvae were exposed topically; mortality was evaluated in 1) 5th instars and 2) pupae
o: reproduction
p: mortlity; first or 4th instar larvae were exposed up to pupae
q: growth, first instar larvae were exposed up to pupae

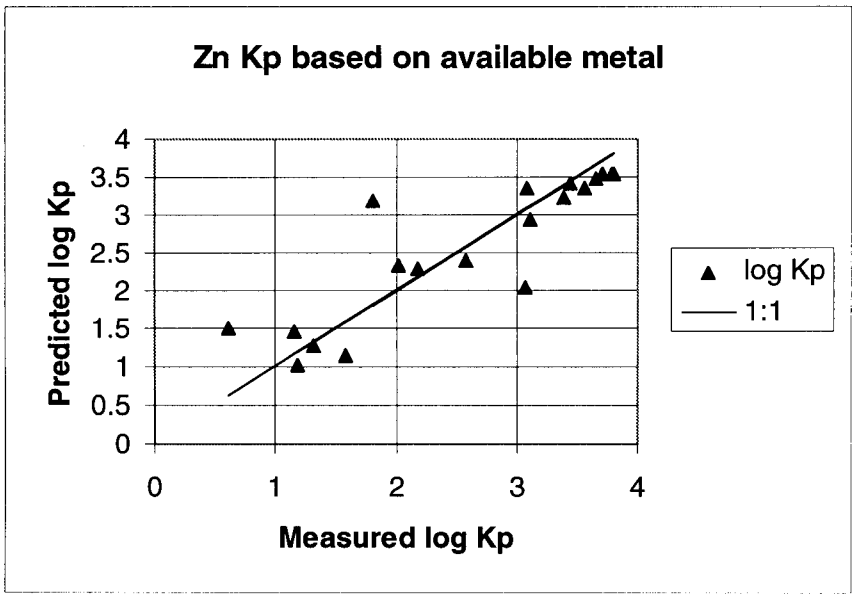
APPENDIX III: KP'S FOR METAL PARTITIONING BASED ON EXCHANGEABLE FRACTION

Table III-1: Kp's based on exchangeable metal fraction calculated for the 'Janssen' soils (1997) calculated with regressions from Table 2.

code	Cd	Cu	Zn
E941018A	neg.	8.4	38.2
E941027B	739.1	35.7	104.8
E941027C	423.3	572.6	1186.4
E941102D	5763.5	227.9	2747.3
E941102E	1371.3	416.3	2422.8
E941102F	5031.7	385.0	1268.0
E941102G	3537.9	994.1	6130.5
E941103H	143.9	14.2	20.8
E941103I	156.5	neg.	15.4
E941103J	531.7	855.2	153.5
E941104K	91.0	5.8	neg.
E941104L	592.8	85.7	1208.7
E941122M	10.2	85.3	14.5
E941122N	n.d.	31.6	4.1
E941125O	971.9	1180.2	377.5
E941128P	4638.1	789.5	3628.7
E941128Q	818.2	635.3	63.4
E941128R	6186.1	3884.9	4559.5
E941129S	6389.7	1076.1	6367.2
E941129T	18207.5	737.1	5116.4




Kp Cu based on available metal
Predicted log Kp
Mesured log Kp
log Kp
1:1
0
0.5
1
1.5
2
2.5
3
3.5
4


Zn Kp based on available metal
Predicted log Kp
Measured log Kp
log Kp
1:1
0
0.5
1
1.5
2
2.5
3
3.5
4

APPENDIX IV: TOXICITY DATA FOR HIGHER PLANTS

IV.1 Cadmium

Table IV-1: 50% inhibitory concentrations of cadmium for plants [mg l^{-1}] (Wang 1992). For species with several toxicity data, the geometric mean was used.

species	IC50	log(IC50)
cucumber	25.99	1.41
lettuce	3.27	0.51
millet	11.00	1.04
ryegrass	1.85	0.27
oats	6.00	0.78
tomato	3.00	0.48
radish	84.91	1.93
red clover	30.20	1.48
wheat	77.92	1.89
corn	160.00	2.20
sunflower	340.00	2.53

Table IV-2:NOECs of cadmium for plants [mg l^{-1}] recalculated acc. to Table 2 and 3 (raw data Klepper & Van de Meent, Table I.1)

species	NOEC	log NOEC
grain	0.011	-1.92
grain	0.007	-2.10
grain	0.071	-1.15
grain	0.011	-1.96
grain	0.056	-1.25
grain	0.019	-1.73
radish	0.079	-1.10
spinach	0.001	-3.15
wheat	0.004	-2.40

IV.2 Copper

Table IV-3: 50% inhibitory concentrations of copper for plants [mg l-1] (Wang 1992). For species with several toxicity data, the average of log transformed data was used.

Species	IC50	log(IC50)
cucumber	0.65	-0.19
lettuce	7.27	0.86
millet	2.80	0.45
ryegrass	0.02	-1.70
radish	55.00	1.74
read clover	45.00	1.65
wheat	24.00	1.38
arabidopsis	19.00	1.28

Table IV-4: NOECs of copper for plants [mg l^{-1}] recalculated acc. to Table 2 and 3 (raw data Klepper & Van de Meent, Table I.1)

Species	NOEC	log(NOEC)
oats	4.14	0.62
cucumber	4.14	0.62
soy bean	4.14	0.62
Banksia eric.	0.39	-0.41
Casuarina ex.	0.39	-0.41
eucalyptus	0.39	-0.41

IV.3: Zinc

Table IV-5: 50% inhibitory concentrations of zinc for plants [mg l-1] (Wang 1992). For species with several toxicity data, the average of log transformed data was used.

Species	IC50	log(IC50)
cucumber	42.78	1.63
lettuce	18.47	1.27
millet	64.00	1.81
ryegrass	1.60	0.20
radish	53.00	1.72
red clover	43.00	1.63
wheat	334.00	2.52

Table IV-6: NOECs of zinc for plants [mg l^{-1}] recalculated acc. to Table 2 and 3 (raw data Klepper & Van de Meent, Table 1.1)

Species	NOEC	log(NOEC)
clover	0.062	-1.20
corn	0.071	-1.15
lettuce	0.070	-1.15
oats	1.188	0.075

Table IV-7: moment estimates of the log-logistic distribution (bias corrected) for Cd, Cu and Zn as calculated by ETX 1.3a (Aldenberg, 1993) for NOECs from soil toxicity tests and IC50s from hydroculture toxicity tests

	NOEC alpha	NOEC beta	IC50 alpha	IC50 beta
cadmium	-1.86	0.37	1.32	0.42
copper	0.10	0.31	0.68	0.64
zinc	-0.86	0.34	1.54	0.39

APPENDIX V: AMPHIBIAN TOXICITY DATA

Table V-I: LC50s for amphibians.

Cd	Cu	Zn
0.12	5.21	22.74
1.69	1.40	31.29
3.60	0.32	19.90
8.20	0.32	
0.47		

Table V-2: moment estimates of the log- logistic distribution (bias corrected) for Cd, Cu and Zn as calculated by ETX 1.3a (Aldenberg, 1993) for NOECs estimated from the LC50s in Table V-1, applying a factor of 10.

	alpha	beta
Cadmium	-0.9101	0.4006
Copper	-1.032	0.322
Zinc	0.3837	0.0557