RIVM report 601501029/2005

Environmental Risk Limits for Nine Trace Elements

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This investigation has been performed for the account of the Directorate-General for Environmental Protection, Directorate for Chemicals, Waste and Radiation, in the context of the project 'International and National Environmental Quality Standards for Substances in the Netherlands', RIVM-project no. 601501.

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Rapport in het kort

Milieurisicogrenzen voor negen sporenelementen

In dit rapport wordt een herziening van milieurisicogrenzen gepresenteerd voor de sporenelementen beryllium, vanadium, cobalt, selenium, molybdeen, tin, antimoon, barium en thallium. Er werd literatuuronderzoek uitgevoerd om de gegevenssets die in 1992 voor de normafleiding zijn gebruikt, aan te vullen. Er zijn milieurisicogrenzen afgeleid voor zoet water, grondwater, bodem en sediment. De herziene milieurisicogrenzen voor water en grondwater zijn in de meeste gevallen lager dan de bestaande waarden. Dit wordt veroorzaakt door het vinden van nieuwe informatie op het gebied van toxiciteit en door veranderingen in de methodologie die bij de afleiding van normen gebruikt wordt. De nieuw afgeleide risicogrenzen voor bodem zijn nu gebaseerd op toxiciteitsgegevens voor bodemorganismen, terwijl de bestaande waarden alle zijn berekend uit de risicogrenzen voor water, middels evenwichtspartitie. De risicogrenzen voor sediment zijn wel berekend met behulp van evenwichtspartitie bij gebrek aan toxiciteitsgegevens. In het algemeen zijn de nieuw afgeleide milieurisicogrenzen voor sediment weinig veranderd ten opzichte van de bestaande. Het gemiddelde van gemeten concentraties van beryllium, vanadium, cobalt en barium in zoet oppervlaktewater overschrijdt het maximaal toelaatbaar risiconiveau (MTR). Voor selenium en antimoon was dit niet het geval. Voor grondwater laat een kwalitatieve vergelijking zien dat het MTR wordt overschreden voor beryllium, vanadium, cobalt, selenium en barium, maar niet voor molybdeen, tin, antimoon en thallium. Voor de compartimenten bodem, sediment en zeewater werden geen meetgegevens gevonden.

Trefwoorden: milieurisicogrenzen; metalen; sporenelementen; maximaal toelaatbaar risiconiveau; verwaarloosbaar risiconiveau

Abstract

Environmental Risk Limits for Nine Trace Elements

In this report, we present an update of environmental risk limits (ERLs), based on the literature, for nine trace elements, namely, beryllium (Be), vanadium (V), cobalt (Co), selenium (Se), molybdenum (Mo), tin (Sn), antimony (Sb), barium (Ba) and thallium (Tl). The updated ERLs, established for these elements in freshwater, groundwater, soil and sediment, are to supplement 1992 datasets for risk limit derivation. The updated ERLs for water and groundwater have turned out to be generally lower than existing limits as a result of both new information on toxicity and changes in the methodology used to derive risk limits. Risk limits derived for soil are now based on soil toxicity data for the elements investigated, whereas the existing values for soil were all based on ERLs for water using equilibrium partitioning (EqP). Due to lack of data, ERLs for sediment are still based on EqP and generally show minor changes when compared to existing limits. The maximum permissible concentration (MPC) in rivers and lakes in the Netherlands was found to be exceeded by average measured concentrations of Be, V, Co and Ba, but not of Se and Sb. A qualitative comparison shows that the MPC in groundwater is exceeded for Be, V, Co, Se and Ba concentrations but not for Mo, Sn, Sb and Tl concentrations, although some data on deeper groundwater are missing. No measurement data could be found for the soil, sediment and marine water compartments.

Keywords: environmental risk limits; metals; trace elements; maximum permissible concentration; negligible concentration

Contents

Samenvatting

In dit rapport zijn maximaal toelaatbare risiconiveaus (MTRs), verwaarloosbaar risiconiveaus (VRs) en 'Serious Risk Concentrations' voor ecosystemen (SRC_{ECO}s) afgeleid voor negen elementen die in lage concentraties in het milieu voorkomen (sporenelementen), te weten: beryllium (Be), vanadium (V), cobalt (Co), selenium (Se), molybdeen (Mo), tin (Sn), antimoon (Sb), barium (Ba) en thallium (Tl). Het MTR representeert het potentiële risico van een stof voor een ecosysteem en deze norm wordt afgeleid met gebruik van ecotoxicologische en milieuchemische data. MTRs vormen de wetenschappelijke basis voor milieukwaliteitsnormen die worden vastgesteld door de stuurgroep stoffen. De meeste van de negen onderzochte elementen worden beschouwd als metalen en/of ze gedragen zich als metalen in het milieu. De bestaande gegevensset met ecotoxicologische gegevens dateert uit 1992. In het huidige onderzoek werd literatuuronderzoek uitgevoerd om nieuwe ecotoxicologische gegevens over deze elementen te verzamelen. De gegevensset uit 1992 werd aangevuld met de nieuwe gegevens. Er werd ook gezocht naar gegevens omtrent adsorptiegedrag van de negen elementen en naar gegevens omtrent het voorkomen in verscheidene milieucompartimenten (oppervlaktewater, zeewater, grondwater, bodem) in Nederland. Voor de volledigheid moet worden opgemerkt dat voor antimoon geen VR en MTR zijn afgeleid omdat momenteel een Europese risicobeoordeling wordt opgesteld voor diantimoon trioxide.

De stuurgroep van het project INS heeft besloten voor het afleiden van nationale milieukwaliteitsnormen per 1-1-2004 de Europese richtlijnen voor de risicobeoordeling van nieuwe en bestaande stoffen en biociden (TGD) te gebruiken. Dit rapport is het eerste waarin deze richtlijnen werden gebruikt voor de afleiding van Nederlandse milieukwaliteitsnormen. De keuze voor het gebruik van een andere richtlijn heeft verschillende gevolgen voor wat betreft afleidingsmethoden en de karakteristieken van de afgeleide normen. De belangrijkste veranderingen worden kort in dit rapport besproken.

Voor de afleiding van de normen is gebruik gemaakt van het toegevoegd risico-concept (achtergrondconcentratie + toevoeging). Als gevolg van een toename van het aantal toxiciteitsstudies met bodemorganismen en een minder belangrijke rol voor evenwichtspartitie (EqP) door de keuze voor de nieuwe richtlijn, zijn alle milieukwaliteitsnormen voor bodem voor de negen elementen nu gebaseerd op toxiciteitsgegevens voor bodemorganismen. Van de nieuw afgeleide MTRs vallen er 7 van de 8 binnen een factor 3 van de oude. Een belangrijk verschil is dat de TGD geen percentage lutum definieert voor standaard-bodem. Daarom zijn de nieuwe normen niet langer uitgedrukt in standaard-bodem. De meeste nieuw afgeleide MTRs voor het aquatisch compartiment zijn lager (d.w.z. strenger) dan de bestaande MTRs. De verschillen worden veroorzaakt door het beschikbaar komen van nieuwe gegevens en/of de verandering van beoordelingsmethodiek (TGD). De MTRs voor grondwater zijn ook iets verlaagd, maar ze vallen in het algemeen binnen een factor 2-3 van de bestaande MTRs. De belangrijkste reden voor de verlaging is dat deze MTRs berekend worden uit het MTR voor water waarvan, zoals gezegd, de meeste verlaagd zijn. Voor sediment werden, evenals in 1992, geen toxiciteitsgegevens gevonden en alle milieunormen werden ook nu berekend met behulp van evenwichtspartitie. Een verandering ten opzichte van de bestaande normen is dat in dit rapport, bij de toepassing van evenwichtspartitie, gebruik werd gemaakt van karakteristieken van zwevend stof (TGD). Voor zeewater werd voor alle negen elementen een maximaal toelaatbare toevoeging (MTT) afgeleid. Omdat achtergrondconcentraties voor zeewater ontbraken konden geen MTR, VR en SRC_{ECO} worden berekend.

Voor bodem, zeewater en sediment zijn geen meetgegevens beschikbaar. Er werden meetgegevens gevonden voor Be, V, Co, Se, Sb en Ba in Nederlands oppervlaktewater (meest grote rivieren en enkele meren) in de periode 1972-2000. Op sommige locaties overschrijden jaargemiddelde of langjarig gemiddelde concentraties van Be, V, Co en Ba het MTR, terwijl de gemiddelden voor Se en Sb onder het MTR blijven. In grondwater zijn voor de meeste gevallen uitgebreide meetseries voorhanden, gemeten in jaren uit de periode 1982-1999. In ondiep grondwater overschrijden Be, V, Co en Se concentraties het MTR op veel van de bemonsterde locaties, terwijl in dieper grondwater het MTR regelmatig wordt overschreden door Be, Co, Se en Ba concentraties.

De afgeleide milieurisiconiveaus voor oppervlaktewater zijn weergegeven in Tabel 1 (opgeloste fractie) en in Tabel 2 (totale waterfase). Voor grondwater zijn alleen risiconiveaus voor de opgeloste fractie berekend (Tabel 3) en de toegevoegd risiconiveaus voor zeewater zijn weergegeven in Tabel 4. De afgeleide milieurisiconiveaus voor bodem en sediment zijn weergegeven in Tabel 5 en Tabel 6.
N.B. De waarden voor bodem en sediment zijn uitgedrukt in $\mu g.kg^{-1}$ bodem en $\mu g.kg^{-1}$ sediment, *niet* in standaard-bodem of standaard-sediment.

Tabel 1. Achtergrondconcentraties, toevoegingen en milieurisiconiveaus voor negen sporenelementen in water (opgeloste fractie).

		Opgelost	Opgelost		Opgelost		Opgelost	
Element	Symbool	C_b [$\mu g.l^{-1}$]	VT [$\mu g.l^{-1}$]	VR [$\mu g.l^{-1}$]	MTT [$\mu g.l^{-1}$]	MTR [$\mu g.l^{-1}$]	SRA_{ECO} [$\mu g.l^{-1}$]	SRC_{ECO} [$\mu g.l^{-1}$]
beryllium	Be	0,017	0,00080	0,018	0,080	0,097	49	49
vanadium	V	0,82	0,041	0,86	4,1	4,9	98	99
cobalt	Co	0,19	0,0050	0,20	0,50	0,69	750	750
selenium	Se	0,041	0,021	0,062	2,1	2,1	220	220
molybdeen	Mo	1,3	0,29	1,6	29	30	54000	54000
tin	Sn	0,0082	0,03	0,038	3,0	3,0	400	400
antimoon	Sb	0,29	–[a]	–[a]	–[a]	–[a]	11000	11000
barium	Ba	73	0,58	74	58	130	15000	15000
thallium	Tl	0,038	0,0016	0,040	0,16	0,20	6,5	6,5

[a]geen VT, VR, MTT en MTR afgeleid (zie paragraaf 1.2.1).

Tabel 2. Milieurisiconiveaus voor negen sporenelementen in water (totale water fase).

		Totaal		
Element	Symbool	VR [$\mu g.l^{-1}$]	MTR [$\mu g.l^{-1}$]	SRC_{ECO} [$\mu g.l^{-1}$]
beryllium	Be	0,018	0,10	51
vanadium	V	1,0	5,8	120
cobalt	Co	0,23	0,81	880
selenium	Se	0,063	2,2	230
molybdeen	Mo	1,7	31	56000
tin	Sn	0,46	37	4900
antimoon	Sb	–[a]	–[a]	12000
barium	Ba	77	140	16000
thallium	Tl	0,041	0,21	6,8

[a]geen VR en MTR afgeleid (zie paragraaf 1.2.1).

Tabel 3. Achtergrondconcentraties, toevoegingen en milieurisiconiveaus voor negen sporenelementen in grondwater (opgeloste fractie).

Element	Symbool	Opgelost C_b [µg.l^{-1}]	Opgelost VT [µg.l^{-1}]	Opgelost VR [µg.l^{-1}]	Opgelost MTT [µg.l^{-1}]	Opgelost MTR [µg.l^{-1}]	Opgelost SRA_{ECO} [µg.l^{-1}]	Opgelost SRC_{ECO} [µg.l^{-1}]
beryllium	Be	0,05	0,00080	0,051	0,080	0,13	49	49
vanadium	V	1,2	0,041	1,2	4,1	5,3	98	99
cobalt	Co	0,63	0,0050	0,64	0,50	1,1	750	750
selenium	Se	0,024	0,021	0,045	2,1	2,1	220	220
molybdeen	Mo	0,69	0,29	1,0	29	30	54000	54000
tin	Sn	2	0,030	2,0	3,0	5,0	400	400
antimoon	Sb	0,091	–[a]	–[a]	–[a]	–[a]	11000	11000
barium	Ba	197	0,58	200	58	260	15000	15000
thallium	Tl	2	0,0016	2,0	0,16	2,2	6,5	8,5

[a]geen VT, VR, MTT en MTR afgeleid (zie paragraaf 1.2.1).

Tabel 4. Achtergrondconcentraties, toevoegingen en milieurisiconiveaus voor negen sporenelementen in zeewater (opgeloste fractie).

Element	Symbool	Opgelost C_b [µg.l^{-1}]	Opgelost VT [µg.l^{-1}]	Opgelost VR [µg.l^{-1}]	Opgelost MTT [µg.l^{-1}]	Opgelost MTR [µg.l^{-1}]	Opgelost SRA_{ECO} [µg.l^{-1}]	Opgelost SRC_{ECO} [µg.l^{-1}]
beryllium	Be	-	0,000080	–	0,0080	–	49	–
vanadium	V	-	0,0041	–	0,41	–	98	–
cobalt	Co	-	0,0010	–	0,10	–	750	–
selenium	Se	-	0,021	–	2,1	–	220	–
molybdeen	Mo	-	0,029	–	2,9	–	54000	–
tin	Sn	-	0,0030	–	0,30	–	400	–
antimoon	Sb	-	–[a]	–	–[a]	–	11000	–
barium	Ba	-	0,058	–	5,8	–	15000	–
thallium	Tl	-	0,00016	–	0,016	–	6,5	–

- betekent: geen waarde beschikbaar.
[a]geen VT en MTT afgeleid (zie paragraaf 1.2.1).

Tabel 5. Achtergrondconcentraties, toevoegingen en milieurisiconiveaus voor negen sporenelementen in bodem.

Element	Symbool	C_b [mg.kg^{-1}]	VT [mg.kg^{-1}]	VR [mg.kg^{-1}]	MTT [mg.kg^{-1}]	MTR [mg.kg^{-1}]	SRA_{ECO} [mg.kg^{-1}]	SRC_{ECO} [mg.kg^{-1}]
beryllium	Be	1,1	0,0043	1,1	0,43	1,5	1,9	3,0
vanadium	V	42	0,00032	42	0,032	42	25	67
cobalt	Co	9	0,0023	9,0	0,23	9,2	15	24
selenium	Se	0,7	0,000058	0,70	0,0058	0,71	1,2	1,9
molybdeen	Mo	0,5	0,0076	0,51	0,76	1,3	270	270
tin	Sn	19	0,00068	19	0,068	19	250	270
antimoon	Sb	3,0	–[a]	–[a]	–[a]	–[a]	51	54
barium	Ba	155	0,082	160	8,2	160	210	360
thallium	Tl	1,0	0,001	1,0	0,10	1,1	1,0	2,0

De waarden in deze tabel zijn uitgedrukt mg.kg^{-1} bodem (geen karakteristieken), *niet* in standaard-bodem.
[a]geen VT, VR, MTT en MTR afgeleid (zie paragraaf 1.2.1).

Tabel 6. Achtergrondconcentraties, toevoegingen en milieurisiconiveaus voor negen sporenelementen in sediment.

Element	Symbool	C_b [mg.kg^{-1}]	VT [mg.kg^{-1}]	VR [mg.kg^{-1}]	MTT [mg.kg^{-1}]	MTR [mg.kg^{-1}]	SRA_{ECO} [mg.kg^{-1}]	SRC_{ECO} [mg.kg^{-1}]
beryllium	Be	1,1	0,00068	1,1	0,078	1,2	42	43
vanadium	V	42	0,24	42	24	66	560	610
cobalt	Co	9	0,030	9,0	3,0	12	4500	4500
selenium	Se	0,7	0,013	0,71	1,3	2,0	140	140
molybdeen	Mo	0,5	0,37	0,87	37	38	70000	70000
tin	Sn	19	56	75	5600	5600	150000	150000
antimoon	Sb	3,0	–[a]	–[a]	–[a]	–[a]	43000	43000
barium	Ba	155	0,88	160	88	240	23000	23000
thallium	Tl	1,0	0,0024	1,0	0,24	1,2	10	11

De waarden in deze tabel zijn uitgedrukt mg.kg^{-1} sediment (geen karakteristieken), *niet* in standaard-sediment.
[a]geen VT, VR, MTT en MTR afgeleid (zie paragraaf 1.2.1).

Summary

In this report maximum permissible concentrations (MPCs), negligible concentrations (NCs) and Serious Risk Concentrations for the ecosystem (SRC_{ECO}s) are derived for nine elements that occur in low concentrations in the environment (trace elements): beryllium (Be), vanadium (V), cobalt (Co), selenium (Se), molybdenum (Mo), tin (Sn), antimony (Sb), barium (Ba) and thallium (Tl). The MPC represents the potential risk of substances to the ecosystem and it is derived using data on (eco)toxicology and environmental chemistry. MPCs are the scientific basis for Environmental Quality Standards (EQSs) set by the Steering Committee for Substances. Most of the elements are considered to be metals and/or behave like metals in the environment. The existing dataset on ecotoxicological information dates from 1992. In the present project, literature research was performed to collect new ecotoxicological data on these elements. The 1992 dataset was supplemented with newly found data. A data search was also performed for data on sorption properties of the nine elements and on occurrence of the nine elements in several environmental compartments (surface water, sea water, groundwater, soil). It should be noted that no NC and MPC were derived for antimony since a European risk assessment is currently being drafted for diantimony trioxide.

The steering committee of the project 'International and National environmental quality standards for Substances in the Netherlands' (INS) has recently decided to use the guidance given in the Technical Guidance Document (TGD) of the European Commission for the derivation of ERLs in the Netherlands. This report is the first in which this guidance was applied to the derivation of Dutch national environmental risk limits. The choice for the use of a different guideline has had several consequences with respect to methods of derivation and characteristics of the standards derived. The most important changes are highlighted in this report.

The added risk approach was used for derivation of the standards. Due to an increase in the number of available soil toxicity studies and a less important role for equilibrium partitioning (EqP) as a consequence of new guidance, all ERLs for soil for all nine elements are now based on soil toxicity data. Of the derived MPCs, 7 out of 8 are a within factor of 3 of the old MPCs. One important difference that should be kept in mind, is that ERLs are no longer expressed in standard soil since the TGD does not define a fixed percentage lutum for standard soil. Most of the newly derived MPCs for the aquatic compartment decrease (i.e. are more conservative) compared to existing MPC values. The retrieval of new toxicity data or the change in guidance (or a combination of both) has caused most of these changes. The MPCs for groundwater have generally decreased within a factor of 2-3 of the existing MPCs. The main reason here, is that these values are based on the MPCs for water, most of which have decreased. For sediment, no toxicity data were found (as in 1992), and all ERLs are calculated using EqP. A difference with respect to the existing standards is that in this report, in the application of EqP, suspended matter characteristics are used (following TGD). For seawater, only a maximum permissible addition (MPA) was derived for all nine elements. Since background concentrations were absent, we could not calculate MPCs, NCs and SRC_{ECO}s.

Measurement data were found for Be, V, Co, Se, Sb and Ba in freshwater bodies in the Netherlands (mostly major rivers and some lakes) within the period 1972-2000. At some locations, long-term average values of concentrations of Be, V, Co and Ba exceed the MPC,

while these averages for Se and Sb are below the MPC. In groundwater extended measurement series are available in most cases, measured in years from the period 1982-1999. In shallow groundwater Be, V, Co and Se concentrations exceed the MPC at many of the locations, while in deeper groundwater regular MPC exceedance for Be, Co, Se and Ba is observed. Monitoring data of these compounds in several compartments are missing: data for soil, seawater and sediment are lacking and for some elements no data in surface water are available.

The derived enironmental risk limits for surface water are shown in Table 1 (dissolved fraction) and Table 2 (total water phase). Risk limits for groundwater were calculated for the dissolved fraction only (Table 3) and the added risk limits for seawater are presented in Table 4. Environmental risk limits for soil and sediment are shown in Table 5 and Table 6. N.B. The values for soil and sediment are expressed in $\mu g.kg^{-1}$ soil and $\mu g.kg^{-1}$ sediment, *not* in standard soil or standard sediment.

Table 1. Background concentrations, additions and environmental risk limits for nine trace elements for surface water (dissolved fraction).

		Dissolved	Dissolved		Dissolved		Dissolved	
Element	Symbol	C_b [$\mu g.l^{-1}$]	NA [$\mu g.l^{-1}$]	NC [$\mu g.l^{-1}$]	MPA [$\mu g.l^{-1}$]	MPC [$\mu g.l^{-1}$]	SRA_{ECO} [$\mu g.l^{-1}$]	SRC_{ECO} [$\mu g.l^{-1}$]
beryllium	Be	0.017	0.00080	0.018	0.080	0.097	49	49
vanadium	V	0.82	0.041	0.86	4.1	4.9	98	99
cobalt	Co	0.19	0.0050	0.20	0.50	0.69	750	750
selenium	Se	0.041	0.021	0.062	2.1	2.1	220	220
molybdenum	Mo	1.3	0.29	1.6	29	30	54000	54000
tin	Sn	0.0082	0.03	0.038	3.0	3.0	400	400
antimony	Sb	0.29	–[a]	–[a]	–[a]	–[a]	11000	11000
barium	Ba	73	0.58	74	58	130	15000	15000
thallium	Tl	0.038	0.0016	0.040	0.16	0.20	6.5	6.5

[a]no NA, NC, MPA and MPC derived (see section 1.2.1).

Table 2. Environmental risk limits for nine trace elements for surface water (total water phase).

		Total		
Element	Symbol	NC [$\mu g.l^{-1}$]	MPC [$\mu g.l^{-1}$]	SRC_{ECO} [$\mu g.l^{-1}$]
beryllium	Be	0.018	0.10	51
vanadium	V	1.0	5.8	120
cobalt	Co	0.23	0.81	880
selenium	Se	0.063	2.2	230
molybdenum	Mo	1.7	31	56000
tin	Sn	0.46	37	4900
antimony	Sb	–[a]	–[a]	12000
barium	Ba	77	140	16000
thallium	Tl	0.041	0.21	6.8

[a]no NC and MPC derived (see section 1.2.1).

Table 3. Background concentrations, additions and environmental risk limits for nine trace elements for ground water (dissolved fraction).

Element	Symbol	Dissolved C_b [µg.l^{-1}]	Dissolved NA [µg.l^{-1}]	Dissolved NC [µg.l^{-1}]	Dissolved MPA [µg.l^{-1}]	Dissolved MPC [µg.l^{-1}]	Dissolved SRA_{ECO} [µg.l^{-1}]	Dissolved SRC_{ECO} [µg.l^{-1}]
beryllium	Be	0.05	0.00080	0.051	0.080	0.13	49	49
vanadium	V	1.2	0.041	1.2	4.1	5.3	98	99
cobalt	Co	0.63	0.0050	0.64	0.50	1.1	750	750
selenium	Se	0.024	0.021	0.045	2.1	2.1	220	220
molybdenum	Mo	0.69	0.29	1.0	29	30	54000	54000
tin	Sn	2	0.030	2.0	3.0	5.0	400	400
antimony	Sb	0.091	–[a]	–[a]	–[a]	–[a]	11000	11000
barium	Ba	197	0.58	200	58	260	15000	15000
thallium	Tl	2	0.0016	2.0	0.16	2.2	6.5	8.5

[a]no NA, NC, MPA and MPC derived (see section 1.2.1).

Table 4. Background concentrations, additions and environmental risk limits for nine trace elements for sea water (dissolved fraction).

Element	Symbol	C_b [µg.l^{-1}]	Dissolved NA [µg.l^{-1}]	NC [µg.l^{-1}]	Dissolved MPA [µg.l^{-1}]	MPC [µg.l^{-1}]	Dissolved SRA_{ECO} [µg.l^{-1}]	SRC_{ECO} [µg.l^{-1}]
beryllium	Be	–	0.000080	–	0.0080	–	49	–
vanadium	V	–	0.0041	–	0.41	–	98	–
cobalt	Co	–	0.0010	–	0.10	–	750	–
selenium	Se	–	0.021	–	2.1	–	220	–
molybdenum	Mo	–	0.029	–	2.9	–	54000	–
tin	Sn	–	0.0030	–	0.30	–	400	–
antimony	Sb	–	–[a]	–	–[a]	–	11000	–
barium	Ba	–	0.058	–	5.8	–	15000	–
thallium	Tl	–	0.00016	–	0.016	–	6.5	–

- means: no data available.
[a]no NA and MPA derived (see section 1.2.1).

Table 5. Background concentrations, additions and environmental risk limits for nine trace elements for soil.

Element	Symbol	C_b [mg.kg^{-1}]	NA [mg.kg^{-1}]	NC [mg.kg^{-1}]	MPA [mg.kg^{-1}]	MPC [mg.kg^{-1}]	SRA_{ECO} [mg.kg^{-1}]	SRC_{ECO} [mg.kg^{-1}]
beryllium	Be	1.1	0.0043	1.1	0.43	1.5	1.9	3.0
vanadium	V	42	0.00032	42	0.032	42	25	67
cobalt	Co	9	0.0023	9.0	0.23	9.2	15	24
selenium	Se	0.7	0.000058	0.70	0.0058	0.71	1.2	1.9
molybdeen	Mo	0.5	0.0076	0.51	0.76	1.3	270	270
tin	Sn	19	0.00068	19	0.068	19	250	270
antimoon	Sb	3	–[a]	–[a]	–[a]	–[a]	51	54
barium	Ba	155	0.082	160	8.2	160	210	360
thallium	Tl	1.0	0.001	1.0	0.10	1.1	1.0	2.0

The values in this table are expressed in mg.kg^{-1} soil (no characteristics), *not* in standard soil.
[a]no NA, NC, MPA and MPC derived (see section 1.2.1).

Table 6. Background concentrations, additions and environmental risk limits for nine trace elements for sediment.

Element	Symbol	C_b [mg.kg^{-1}]	NA [mg.kg^{-1}]	NC [mg.kg^{-1}]	MPA [mg.kg^{-1}]	MPC [mg.kg^{-1}]	SRA_{ECO} [mg.kg^{-1}]	SRC_{ECO} [mg.kg^{-1}]
beryllium	Be	1.1	0.00068	1.1	0.078	1.2	42	43
vanadium	V	42	0.24	42	24	66	560	610
cobalt	Co	9	0.030	9.0	3.0	12	4500	4500
selenium	Se	0.7	0.013	0.71	1.3	2.0	140	140
molybdenum	Mo	0.5	0.37	0.87	37	38	70000	70000
tin	Sn	19	56	75	5600	5600	150000	150000
antimony	Sb	3	–[a]	–[a]	–[a]	–[a]	43000	43000
barium	Ba	155	0.88	160	88	240	23000	23000
thallium	Tl	1.0	0.0024	1.0	0.24	1.2	10	11

The values in this table are expressed in mg.kg^{-1} sediment (no characteristics), *not* in standard sediment.
[a]no NA, NC, MPA and MPC derived (see section 1.2.1).

Abbreviations and variables

Ba	barium
Be	beryllium
CAS	chemical abstract service
CEC	cation exchange capacity
Co	cobalt
dw	dry weight
EC10, EC50	effect concentration causing 10% or 50% effect, respectively
EPA	Environmental Protection Agency
EqP	equilibrium partitioning
ERL	environmental risk limit
EQS	environmental quality standard
EU	European Union
EU-RAR	European Union-risk assessment report
TGD	technical guidance document (for the risk assessment of new and existing chemicals and biocides within the European Union)
HC	hazardous concentration
INS	the project 'International and National environmental quality standards for Substances in the Netherlands'
K_d	sorption coefficient soil/water or sediment/water
K_{oc}	organic carbon normalised sorption coefficient
K_p	partition coefficient soil/water or sediment/water
K_{ppm}	partition coefficient standard suspended (particulate) matter/water
$K_{p,\ susp}$	partition coefficient suspended matter/water (nomenclature as used in EU-RAR)
LC10, LC50	lethal concentration (causing 10% or 50% lethality, respectively)
LOEC	lowest observed effect concentration
MATC	maximum acceptable toxicant concentration
Mo	molybdenum
MPA	maximum permissible addition
MPC	maximum permissible concentration
NA	negligible addition
NC	negligible concentration
NOEC	no observed effect concentration
o.m.	organic matter
PNEC	predicted no effect concentration
RIKZ	National Institute for Coastal and Marine Management
RIVM	National Institute for Public Health and the Environment
RIZA	Institute for Inland Water Management and Waste Water Treatment
RQ	risk quotient
SRA_{ECO}	ecotoxicological serious risk addition
SRC_{ECO}	ecotoxicological serious risk concentration
Sb	antimony (stibium)
Se	selenium
Sn	tin (stannum)
SSD	species sensitivity distribution
S_w	water solubility
TGD	Technical Guidance Document

Tl	thallium
V	vanadium
VROM	Dutch Ministry of Housing, Spatial Planning and the Environment
V&W	Dutch Ministry of Transport, Public Works and Water Management
ww	wet weight

1. Introduction

1.1 Project Framework

This report is a result in the project 'International and National environmental quality standards for Substances in the Netherlands', abbreviated with INS. Until 1-1-2004 this project was called 'Setting Integrated Environmental Quality Standards'. The guidance for this project was laid down in Traas (2001). From 1-1-2004, the context of the project has changed, which has resulted in a different name: 'International and National Environmental Quality Standards for Substances in the Netherlands'. The abbreviation INS is still used as acronym for the project. The most important change with respect to content is that the *guidance* used to derive environmental risk limits is now the Technical Guidance Document (TGD), issued by the European Commission and developed in support of the risk assessment of new notified chemical substances, existing substances and biocides (ECB, 2003).

The aim of the project is to derive environmental risk limits (ERLs) for substances in the environment for the compartments air, (ground)water, sediment and soil. Environmental risk limits (ERLs) serve as advisory values to set environmental quality standards (EQS) by the Ministry of VROM for various policy purposes. The term EQS is used to designate all legally and non-legally binding standards that are used in Dutch environmental policy and Table 7 shows the correspondence between ERLs and EQSs. The various ERLs are:

- the negligible concentration (NC) for water, soil, groundwater, sediment and air;
- the maximum permissible concentration (MPC) for water, soil, groundwater, sediment and air;
- the ecotoxicological serious risk concentration (SRC_{ECO}) for water, soil, groundwater and sediment.

Table 7. Environmental risk limits (ERLs) and related environmental quality standards (EQS) that are set by the Dutch government in the Netherlands for the protection of ecosystems.

Description	ERL	EQS
The NC represents a value causing negligible effects to ecosystems. The NC is derived from the MPC by dividing it by 100. This factor is applied to take possible combined effects into account.	NC (for air, water, soil, groundwater and sediment)	Target value (for air, water, soil, groundwater and sediment)
The MPC is the concentration of a substance in air, water, soil or sediment that should protect all species in ecosystems from adverse effects of that substance. Depending on the amount of toxicological data available, the lowest toxicity result is divided by a fixed value (assessment factor). When enough data are available, a cut-off value is used. This is the fifth percentile if a species sensitivity distribution of NOECs is used. This is the hazardous concentration for 5% of the species, the $HC5_{NOEC}$.	MPC (for air, water, soil, groundwater and sediment)	MPC (for air, water, sediment)
The SRC_{ECO} is the concentration of a substance in the soil, sediment or groundwater at which functions in these compartments will be seriously affected or are threatened to be negatively affected. This is assumed to occur when 50% of the species and/or 50% of the microbial and enzymatic processes are possibly affected, the $HC50_{NOEC}$.	SRC_{ECO} (for water, soil, groundwater and sediment)	Intervention value after comparison with SRC_{human} (for soil, sediment and groundwater)

The process of deriving integrated ERLs is shown schematically in Figure 1. ERLs for water are reported for dissolved and total concentrations (including a standard amount of suspended matter) and if found significantly different, differentiated to freshwater and salt water. Each of

the ERLs and its corresponding EQS represents a different level of protection, with increasing numerical values in the order NC < MPC[1] < SRC_{ECO}. Each EQS demands different actions when one of them is exceeded, explained elsewhere (VROM, 2001).

This report is one of a series of RIVM reports that were published in the framework of the project INS in which ERLs and EQSs were derived for approximately 250 substances and groups of substances. For an overview of the EQSs set by the Ministry of VROM, see INS (1999) and VROM (2001). The Expert Centre for Substances of RIVM has recently launched a website at which all EQSs are available. The website can be found at: http://www.stoffen-risico.nl.

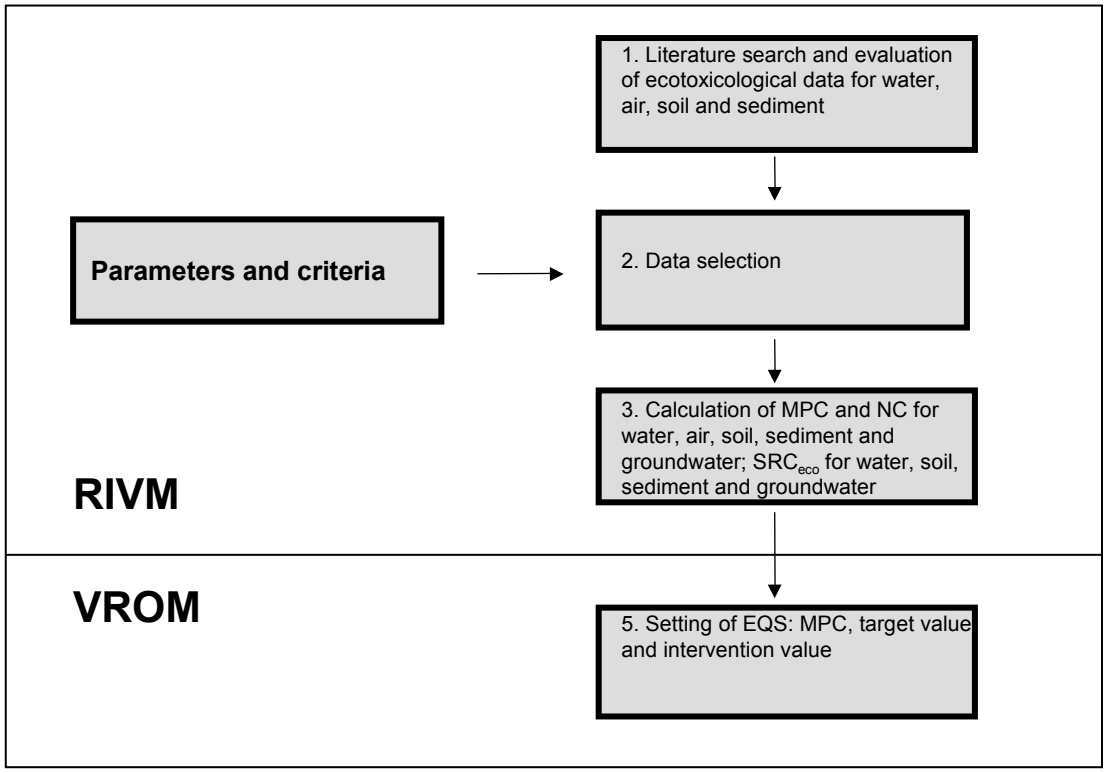

Figure 1. The process of deriving integrated environmental risk limits. Above the line the method to derive ERLs is indicated, i.e. MPC, NC and SRC_{ECO}. Below the line the MPC and target value are indicated, set by the Ministry of Housing, Spatial Planning and the Environment (VROM).

1.2 Adapted methodology for compounds evaluated in EU

At present the Dutch Ministry of Housing, Spatial Planning and the Environment (VROM) has the policy to take over predicted no effect concentrations (PNEC) from a European risk assessment report (EU-RAR) for an existing substance when these PNECs have already been or are being derived at the time the Ministry seeks advice (that is, requests for an MPC to be derived) for that substance. During the course of this project a first draft of a European risk assessment report (EU-RAR) became available for antimony tri-oxide (Sb_2O_3). The environmental risk assessment section of this EU-RAR does include effect studies with antimony salts other than antimony tri-oxide. The derived PNEC values will therefore be valid for antimony. In the present report, we will present our collected effect data on

[1] A complicating factor is that the term MPC is used both as an ERL and as an EQS. For historical reasons, however, the same abbreviation is used.

antimony, but we will not derive environmental risk limits for the reason outlined above. The following section very briefly introduces the European existing substances framwork.

In 1993 the Council of the European Communities adopted Council Regulation (EEC) 793/93 or the Existing Substances Regulation (ESR), thereby introducing a comprehensive framework for the evaluation and control of existing chemical substances. This is a legal instrument that was proposed by the European Commission upon approval of the Fourth Community Action Programme on the Environment (1987-1992) by the Council. The Commission, in consultation with member states, drew up four priority lists for substances that are to be evaluated for both human and environmental risks. For a given prioritised compound, this process will result in a EU-RAR at step 3 of the regulation. In the environmental section of a RAR, environmental risk limits are derived for each environmental compartment, which are called predicted no effect concentrations (PNEC). A PNEC is comparable to the maximum permissible concentration (MPC), which is the environmental risk limit (ERL) used as an advisory value within the Dutch national framework of setting environmental quality standards (EQS).

1.2.1 EU-risk assessment reports

During the course of this project a project, a draft version of an EU RAR for antimony tri-oxide (Sb_2O_3) became available. Since this RAR has a draft status, no data may be used for publication, until the final report is issued. MPCs and NCs will not be derived for antimony in this report for reasons outlined in the following section.

To derive an MPC at the national level while a PNEC derivation at the European level is in progress is not preferable because new data (e.g. toxicity studies) may be added to the data set that may alter the outcome of the ERL derivation. In compliance with the present viewpoint of the Ministry of VROM (see section 1.2), the PNEC values of antimony will be taken over as MPC values when the finalised version of the draft EU-RAR is issued.

We will, however, derive SRC_{ECO} values for antimony in this report, since the SRC_{ECO} is an ERL derived at the national level, that is not derived in an EU-RAR.

1.3 Major deviations due to change in guidance

This section gives an overview of the major consequences of the change in guidance from INS to TGD. Some of the differences between the TGD methodology (ECB, 2003) and former INS methodology with regard to environmental risk limit derivation are highlighted in Janssen *et al*. (2004).

1.3.1 No harmonisation between compartments

Following TGD guidance, ERLs are no longer harmonised between environmental compartments. This means that preclusion of ERL exceedance in a given environmental compartment by some environmental concentration of a substance below the ERL in another compartment is no longer warranted.

1.3.2 Use of equilibrium partitioning

The difference with the former INS methodology is that the use of EqP for the derivation of soil standards is restricted to very limited datasets. As explained in section 1.3.1, harmonisation is no longer performed, while in the former INS methodology this step was always performed (making use of EqP).

For application of assessment factors to derive a $PNEC_{soil}$, the TGD states in section 3.6, (Effects assessment for the terrestrial compartment): 'when only one test result with soil dwelling organisms is available the risk assessment is performed both on the basis of this result using assessment factors and on the basis of the equilibrium partitioning (EqP) method.' This statement is later refined to 'If only one terrestrial test result is available (earthworms or plants), the risk assessment should be performed both of this test result and on the basis of the outcome of the aquatic toxicity data to provide an indication of risk'.
Our interpretation of this guidance is that when only one test result is available with a soil dwelling organism, the MPCsoil will be derived using both EqP and using assessment factors. The lowest result will be chosen as MPC.

1.3.3 No separate MPC based on microbial processes or enzymatic activities.

In the former INS methodology, two MPC values for the soil compartment were derived (if enough data were available): an MPC for microbial processes and enzymatic activities and an MPC for other soil species (e.g. plants, earthworms, insects). The rationale behind this separation was that an ecotoxicological tests on microbial processes is fundamentally different from a single species test. In a microbial community under toxic stress, the processes carried out can be taken over by less sensitive species. The results of these types of studies can therefore not be averaged.

Following TGD guidance, tests on microbial communities, micro-organisms, enzymatic reactions etc. are considered to represent one trophic level and are treated as such in the scheme of assessment factors. Therefore, only one MPC_{soil} per element will be derived in this report. Note that if enough data are available to calculate a species sensitivity distribution (SSD), data on microbial processes and enzymatic activity and terrestrial species are separated as well.

1.3.4 No normalisation to standard soil and sediment for metals

In this report, concentrations in soil and sediment have not been normalised to a predefined standard soil (or sediment) with fixed characteristics, as was the case in the former INS methodology. For the application of this methodology, a standard lutum (or clay) content should be defined, which was 25% for both soil and sediment in the INS methodology. The TGD does not define a standard lutum content. Further considerations on this topic are elaborated in section 1.3.4.1. The interpretation of ERLs for soil and sediment is now comparable to ERLs for the aquatic environment in that an ERL in soil or sediment should be regarded as 'a' concentration in soil (or sediment), applicable to any soil (or sediment), regardless of its characteristics.

1.3.4.1 No normalisation to standard soil and sediment: considerations

In this section, the considerations are given on the decision not to normalise toxicity data in soil to standard soil. However, the conclusion of this is also applicable to sediment. In parts 1, 3 and 4 of this section, soil can be read as synonym to sediment and terrestrial to benthic.

1. For the effect assessment of the terrestrial compartment, the TGD states that test results should be converted to a standard soil containing 3.4% organic matter. However, for metals, the organic matter fraction in soil does not play a significant role in bioavailability, and if so, it has not been quantified for the elements investigated here. The TGD further states that 'data should be normalised using relationships that describe the bioavailability of chemicals in soils'. In Appendix VIII, the TGD takes notice of the reference lines that have been used in Dutch risk limit derivation for metals in the past. Van de Plassche *et al*. (1992), have also used these reference lines for their ERL

derivation of the nine elements considered here. For these elements, the relationship described by the reference lines is based on the lutum content of the soil only. However, for the EU standard soil, a value for the lutum (or clay) content has not been defined (ECB, 2003). A recalculation to EU standard soil using the reference lines is therefore not possible. Defining a standard lutum value for the EU standard soil within the framework of this report would be an option to overcome this problem. We reject this possibility since the change in direction of the project, taken since 1-1-2004 (see section 1.1), is to follow EU guidance rather than using national guidance and standards. The choice for an EU standard soil with an INS clay content would be in contradiction with this viewpoint.

2. In two current drafts of EU-risk assessment reports (EU-RARs, cadmium and zinc) normalisation of toxicity data to standard soil is not applied. This indicates that, following EU-guidance, normalisation of soil toxicity data for metals is apparently not the preferential route.
3. For four of the nine elements investigated in this report, no reference line is available. This would mean that for these elements either no ERLs for soil can be derived (based on soil toxicity data) or ERLs should be derived without normalisation. The second option is undesirable because this would lead to two different types of soil standards.
4. In order to perform normalisation using the reference lines, the lutum or clay content of the soil used in the toxicity experiment should be reported. Since this is not the case for all soil toxicity studies, the number of available toxicity data that can be used for risk limit derivation would decrease. This would seriously affect the reliability of the risk limit.
5. The item of normalisation of soil metal concentrations to standard soil was addressed in a Dutch national workshop (September 2001) on bioavailability and its place in environmental policy (Sijm *et al.*, 2002). It was emphasised that the use of the reference lines should be applied as soil type correction for background concentrations rather than as a bioavailability-correction. With respect to normalisation of metal concentrations in soil, it was concluded that the use of reference lines should not be rejected under the condition that improved bioavailability relationships would be developed for ERL derivation in the near future. At present, no improved relationships have been developed for the elements (metals) investigated in this report. The methodology followed in this report is therefore not in accordance with the recommendations of this workshop.

1.4 Strategy for Bioavailability, Deficiency and Background concentrations

1.4.1 Bioavailability

The concentration of an element, added in a toxicity test, generating a certain toxic response in an organism, might differ from the concentration needed in the field to generate the same response. One of the factors that may cause this difference is the availability of the element to the organism.

Departing from the hypothesis that exposure of an organism to an element occurs predominantly via the aqueous phase for both the terrestrial as well as aquatic organisms, the parameters that influence the aqueous concentration are important factors in determining the (bio)availability. Although different between the terrestrial and the aquatic compartment, some of these factors are: pH, concentration of organic matter (e.g. humic acids), clay content, cation concentration, presence of oxides, carbonates and other complex-forming ions or salts. In addition, most elements occur in various valence states in the environment and the speciation in a particular environment is often unknown. For some elements considered in this project it might be possible to calculate the speciation, however, there are several open ends: speciation calculations are often not validated; complexation of metals to dissolved organic

matter is not very well investigated and moreover, properties of organic matter vary considerably between different water types. The latter argument would lead to large uncertainties in concentration estimations when these concentrations are to be used in generic standard setting. With respect to bioavailability in soil, an example of incorporation of bioavailability can be found in the draft EU-RAR for zinc. This report is not yet finalised, but the approach followed here is to use a fixed factor to account for differences in zinc availability. This factor is based on several studies at field locations (with the metal being present for months or years) compared to laboratory experiments. These type of experiments are available for only very few metals.

Although the importance of bioavailability is recognised, it will not be incorporated into the derivation of ERLs in this report. The approach followed in earlier INS reports will be followed here. That means that results from experiments will be based on total added (nominal) or total measured concentrations and differences in bioavailability between laboratory and field situations are not taken into account.

1.4.2 Deficiency/Essentiality

It is difficult to establish whether or not an element *is* essential and moreover, if it is essential to one organism it is not necessarily essential to other organisms. If an element is considered to be essential to organisms, the advised environmental standard for a given compartment should not be lower than the minimum amount needed by the organisms that naturally inhabit that compartment. Striving for that standard (=concentration) would lead to the disappearance or malfunctioning of naturally occurring species due to shortage of the essential element. It should be stressed however, that occurrence of deficiency itself is natural: not all organisms find optimal conditions in all types of habitats.

Following the added risk approach in ERL derivation means that the background concentration is incorporated in the environmental standard. As a consequence, the standard can never be lower than the background. Assuming that, for a given compartment, the local background concentration is the distinguishing factor (seen with respect to this specific element; there are other factors that determine potential occurrence) for the possibility of organisms to occur, standards causing shortage of essential elements will not be derived. The fact that the background concentration (90^{th} percentile values) probably contains anthropogenic influence (see also section 1.4.1) makes it even less probable that there will be species that will be deficient at this level.
An additional remark can be made to the above concept. The ERLs are set generically, meaning that one standard for e.g. the complete (Dutch) terrestrial environment is derived. In reality, the background concentrations will vary from location to location, determined by e.g. soil characteristics. Since the background that is part of the ERL is set at the 90^{th} percentile of measured concentrations, the majority of locations wil have lower background concentrations. The consequence might be that for some locations ERLs are set at a level which is too high.

1.4.3 Background concentrations

Fraters *et al*. (2001) have published an extensive study in which detailed information on groundwater concentrations of 17 metals is gathered from a multitude of sampling locations in the Netherlands over several years and at several depths. Moreover, the authors present an historic overview on the terminology, use and derivation of the topics background concentration (C_b), negligible addition (NA), negligible concentration (NC) and target value (TV). They have also criticised the use of non-natural background concentrations as background concentrations as the basis for calculation of the NC. The current procedure is to use the 90^{th} percentile of all measured or collected background concentrations for a given

element as background concentration, rather than the median. Fraters *et al*. argue that this procedure allows anthropogenic influence in the background concentration, where anthropogenic influence should only be present in the NA. They state that using the added risk approach in this way is incorrect; it suggests the contribution of anthropogenic influence to be lower than it in fact is.

The background concentrations used in the underlying report are taken from Crommentuijn *et al*. (1997). To the opinion of Fraters *et al*. these groundwater background concentrations are neither natural background concentrations, nor are they a good indication of the 90th percentile of the background concentrations for the upper and to a lesser extent for the shallow groundwater. Table 8 shows the background concentrations as used in this report compared to 90th percentile and median values as found under three different soil types reported by Fraters *et al*.. Given are the values at 25 m depth.

Table 8. Background concentrations for groundwater for nine elements under three different soil types. INS values compared to values published by Fraters et al. (2001) for groundwater at 25 m depth.

		90th percentile			median		
Element	C_b INS	Sand	Clay	Peat	Sand	Clay	Peat
Be	0.05	0.9	0.9	0.9	<0.2	<0.2	<0.2
V	1.2	2.7	2.7	2.7	0.86	0.86	0.86
Co	0.63	0.7	0.7	0.7	0.28	0.28	0.28
Se	0.024	0.06	0.06	0.06	<0.005	<0.005	<0.005
Mo	0.69	1.6	1.6	1.6	0.25	0.25	0.25
Sn	<2	<2	<2	<2	<2	<2	<2
Sb	0.091	0.16	0.16	0.16	0.05	0.05	0.05
Ba	197	160	990	990	52	190	190
Tl	<2	<2	<2	<2	<2	<2	<2

The above issue was raised as a question in the interim report on this project (Van Vlaardingen, 2003). The outcome was that the policy with respect to the use of background concentrations has not been changed as a result of the points put forward by Fraters *et al*. (2001). The 90th percentile data should still be used. Since groundwater background concentrations have not been changed within the framework of environmental standard setting policy, we have used the values as reported by Crommentuijn *et al*. (1997).

2. Substance properties, use and occurence

2.1 Physico-chemical properties of the elements[2]

The nine trace elements that are subject of this report will be cited in the order of atomic number, i.e. as they appear the periodic table of elements: beryllium, vanadium, cobalt, selenium, molybdenum, tin, antimony, barium and thallium. Figure 2 shows the periodic table in which the position of the nine elements is indicated by a shaded background.

Table 9 shows some physical and chemical properties of the nine elements discussed in this report, for the elemental state. The elements belong to different groups depending on the properties focussed at. When dividing the elements into the series discerned in the periodic table, the following scheme emerges:

metals	Sn, Tl, Sb*
alkali-earth metals	Be, Ba
transition metals	V, Co, Mo
non-metals	Se

*Sb can also be classified as a metalloid

Metals are cation forming elements when in solution. Oxides of metals are usually hydroxides. Most metals conduct electricity, are crystalline solids, with high reactivity. Most of them are hard and have a high density. The series of the alkali-earth metals, transition metals fall within the group of metals. Alkali-earth metals are elements in the second column (from the left) of the periodic table. They are generally white, and are malleable, extrudable and machinable. Transition metals are generally known for their hardness, high density, and high melting and boiling point. The elements within the groups of the Lanthanides, Actinides and some of the Transactinides fall within the series of transition metals. Non-metals do not display properties of metals: they have low thermal and electrical conductivity and usually high electronegativity. The group comprises halogens, noble gasses and some metalloids. Metalloids is a term that is less commonly used. It refers to elements that exhibit properties of both metals and non-metals. Most metalloids are semiconductors.

[2] Text on subdivision of elements cited from EnvironmentalChemistry.com 2003.

1 IA	2 IIA	3 IIIA	4 IVA	5 VA	6 VIA	7 VIIA	8	9 VIIIA	10	11 IB	12 IIB	13 IIIB	14 IVB	15 VB	16 VIB	17 VIIB	18
1 **H** 1.00794 +1 -1																	2 **He** 4.002602 o
3 **Li** 6.941 +1	4 **Be** 9.012182 +2		23 **V** 50.9415 +2,3,4,5 ← Atomic number, Symbol, Atomic weight, Oxidation states									5 **B** 10.811 +3	6 **C** 12.0107 +2,4 -4	7 **N** 14.00674 +1,2,3,4,5 -1,2,3	8 **O** 15.9994 -2	9 **F** 18.9984032 -1	10 **Ne** 20.1797 0
11 **Na** 22.989770 +1	12 **Mg** 24.3050 +2		Transition elements									13 **Al** 26.981538 +3	14 **Si** 28.0855 +2,4 -4,	15 **P** 30.973761 +3,5 -3	16 **S** 32.066 +4,6 -2	17 **Cl** 35.4527 +1,5,7 -1	18 **Ar** 39.948 0
19 **K** 39.0983 +1	20 **Ca** 40.078 +2	21 **Sc** 44.955910 +3	22 **Ti** 47.867 +2,3,4	23 **V** 50.9415 +2,3,4,5	24 **Cr** 51.9961 +2,3,6	25 **Mn** 54.938049 +2,3,4,7	26 **Fe** 55.845 +2,3	27 **Co** 58.933200 +2,3	28 **Ni** 58.6934 +2,3	29 **Cu** 63.546 +1,2	30 **Zn** 65.39 +2	31 **Ga** 69.723 +3	32 **Ge** 72.61 +2,4	33 **As** 74.92160 +3,5 -3	34 **Se** 78.96 +4,6 -2	35 **Br** 79.904 +1,5 -1	36 **Kr** 83.80 0
37 **Rb** 85.4678 +1	38 **Sr** 87.62 +2	39 **Y** 88.90585 +3	40 **Zr** 91.224 +4	41 **Nb** 92.90638 +3,5	42 **Mo** 95.94 +6	43 **Tc** (98) +4,6,7	44 **Ru** 101.07 +3	45 **Rh** 102.90550 +3	46 **Pd** 106.42 +2,3	47 **Ag** 107.8682 +1	48 **Cd** 112.411 +2	49 **In** 114.818 +3	50 **Sn** 118.710 +2,4	51 **Sb** 121.760 +3,5 -3	52 **Te** 127.60 +4,6 -2	53 **I** 126.90447 +1,5,7 -1	54 **Xe** 131.29 0
55 **Cs** 132.90545 +1	56 **Ba** 137.327 +2	57 **La*** 138.9055 +3	72 **Hf** 178.49 +4	73 **Ta** 180.9479 +5	74 **W** 183.84 +6	75 **Re** 186.207 +4,6,7	76 **Os** 190.23 +3,4	77 **Ir** 192.217 +3,4	78 **Pt** 195.078 +2,4	79 **Au** 196.96655 +1,3	80 **Hg** 200.59 +1,2	81 **Tl** 204.3833 +1,3	82 **Pb** 207.2 +2,4	83 **Bi** 208.98038 +3,5	84 **Po** (209) +2,4	85 **At** (210)	86 **Rn** (222) +0
87 **Fr** (223) +1	88 **Ra** (226) +2	89 **Ac**** (227) +3	104 **Rf** (261) +4	105 **Db** (262)	106 **Sg** (266)	107 **Bh** (264)	108 **Hs** (269)	109 **Mt** (268)	110 **Uun** (271)	111 **Uuu** (272)	112 **Uub**						

*Lanthanides	58 **Ce** 140.116 +3,4	59 **Pr** 140.90765 +3	60 **Nd** 144.24 +3	61 **Pm** (145) +3	62 **Sm** 150.36 +2,3	63 **Eu** 151.964 +2,3	64 **Gd** 157.25 +3	65 **Tb** 158.92534 +3	66 **Dy** 162.50 +3	67 **Ho** 164.93032 +3	68 **Er** 167.26 +3	69 **Tm** 168.93421 +3	70 **Yb** 173.04 +2,3	71 **Lu** 174.967 +3			
**Actinides	90 **Th** 232.0381 +4	91 **Pa** 231.03588 +4,5	92 **U** 238.0289 +3,4,5,6	93 **Np** (237) +3,4,5,6	94 **Pu** (244) +3,4,5,6	95 **Am** (243) +3,4,5,6	96 **Cm** (247) +3	97 **Bk** (247) +3,4	98 **Cf** (251) +3	99 **Es** (252) +3	100 **Fm** (257) +3	101 **Md** (258) +2,3	102 **No** (259) +2,3	103 **Lr** (262) +3			

Figure 2. Periodic table of the elements. Elements that are subject of this study are shaded. All data from Lide (2001).

Table 9. Some physical and chemical properties of the considered elements, valid for the elemental state.

Property	Beryllium	Vanadium	Cobalt	Selenium	Molybdenum	Tin	Antimony	Barium	Thallium
Chemical symbol	Be	V	Co	Se	Mo	Sn	Sb	Ba	Tl
Latin name	Beryllium	Vanadium	Cobalt	Selenium	Molybdenum	Stannum	Stibium	Barium	Thallium
Atomic number	4	23	27	34	42	50	51	56	81
Valence	2	2,3,4,5	2,3	-2,+4,+6	2,3,(4?,5?),6	2,4	0,-3,+3,+5	2	1,3
Atomic mass (g/mol)	9.012	50.9415	58.9332	78.96	95.94	118.710	121.760	137.327	204.3833
Series	alkali-earth metals	transition metals	transition metals	non-metals	transition metals	metals	metals (metalloids)	alkali-earth metals	metals
Year of discovery	1798	1830	1735	1817	1778	unknown[a]	unknown[a]	1808	1861
Physical state[b]	solid	solid	solid	solid	solid	solid	solid	solid	solid
CAS number	7440-41-7	7440-62-2	7440-48-4	7782-49-2	7439-98-7	7440-31-5	7440-36-0	7440-39-3	7440-28-0
Melting Point (°C)	1287	1910	1495	221	2623	231.93	630.63	727	304
Boiling Point (°C)	2471	3407	2927	685	4639	2602	1587	1897	1473
Electronegativity (Pauling)	1.57	1.63	1.88	2.55	2.16	1.96	2.05	0.89	1.8
Density (g/ml) at 20°C	1.848	6.11[c]	8.9	4.79[d]	10.22	7.31	6.691	3.5	11.85

All data are taken from Lide (2001).
[a]already known to ancient people; [b]at 20°C and 1 atm; [c]at 18.7°C; [d]*T* not reported

Table 10. Concentration of the considered elements in various environmental compartments – data not pertaining to the Netherlands.

	Seawater [µg.l^{-1}]		Surface water [µg.l^{-1}]	Groundwater [µg.l^{-1}]	Soil [mg.kg^{-1}]
Source	1	2	2	2	1
Beryllium	0.0006	2.10^{-5}-9.10^{-5}	0.05-1	--	0.01-40
Vanadium	0.9-2.5	<0.3-2.1	0.6-1.6	--	3-500
Cobalt	0.01-4.1	0.03	0.19	-	0.05-65
Selenium	0.052-0.2	0.004-0.009	0.15-0.33	0.1-0.001	0.0112
Molybdenum	4-10	8.9-13.5	0.1-1	0.1-1	0.1-40
Tin	0.002-0.81	0.3-1.22	0.03-0.09	-	1-200
Antimony	0.18-5.6	0.21-0.53	0.06	0.01-0.5	0.2-10
Barium	2-63	20	45	4.6-34	100-3000
Thallium	0.019	0.009-0.016[3]	<0.01	-	0.1-0.8

Sources: 1 = Bowen (1979); 2 = Zuurdeeg (1992); 3 = Sager (1994).

2.2 Use, production and discharge

2.2.1 Beryllium

Beryllium compounds are divalent (Be^{2+}). The beryllium atom has a small radius, causing strong binding of its valence electrons, high electronegativitiy, and stability in lattices of beryllium minerals. Beryllium easily reacts with oxygen and forms very stable BeO surface films, providing high resistance to corrosion and water etc. Beryllium is used in brake discs of plane brakes, in golf clubs, bicycle frames and in springs in the form of berylliumbronze (beryllium-copper alloys), since berylliumbronze is antimagnetic, firm and elastic. Approximately 72% of the world production is in the form of berylliumbronze or other alloys and about 20% is used as the free metal in aerospace-, spacecraft-, weapon- and nuclear industries. Some of many applications in these areas are x-ray transmission windows, space vehicle optics, missile guidance systems, nuclear warhead triggering devices, fuel containers, heat shields, mirrors etc. (ATSDR, 2000). Further areas of use are electronics (springs, switches, relays, connectors etc.) and medical applications (pacemakers, dental alloys). The world production of beryllium minerals in 1980-1984 was estimated to be 10,000 tonnes of which 400 tonnes were beryllium. In 2000, the USA used 390 tons of beryllium.
At high pH, beryllium has been observed to be able to substitute magnesium in some micro-organisms, algae and crops, whereas below pH 7 it becomes toxic to aquatic and terrestrial plants (regardless of magnesium levels). Beryllium probably inhibits phosphatases in plants; its bioavailability in soils is dependent on pH and cation exchange capacity (CEC). Toxicity to fish, daphnia and salamanders occurs in the $mg.l^{-1}$ range, based on LC_{50} values.
(Source: WHO, 1990a). ATSDR (2000) states that several evaluating institutions have classified beryllium and/or beryllium compounds as probably carcinogenic.

2.2.2 Vanadium

Vanadium is widespread thoughout the lithosphere, estimated at 0.017% and ranked above copper, zinc and lead. Vanadium is obtained from minerals -that usually have low vanadium content- through mining together with other metals or from fossil fuels (oil, coal, tars, bitumens and asphaltites). V_2O_5 (vanadium pentoxide) is the most common commercial form of vanadium: it is water- and acid soluble. Global production (V_2O_5) in the first half of the 1980's was 34,000-45,000 tonnes, while 35,000 tonnes is reported for 1990. V^{3+} is basic and its salts (e.g. V_2O_3) are strong reducing agents. Vanadium is being used in alloys with steel, because of the hardness of these alloys. These types of alloys are often used in armoured cars, safes in atomic energy industry, aircraft construction and space technology. Vanadium steel is suitable for the manufacturing of tools that are to function under severe conditions. Vanadium is also used as a catalyst in chemical industry in production processes of anti-fouling paints and various chemicals. Power and heat producing plants using fossil fuels cause emission of vanadium to the air, and coal waste burning in mining areas also contributes. Furthermore, industry producing steel alloys or handling vanadium combinations will emit relatively high amounts.
(Sources: WHO, 1999; Byerrum *et al.*, 1974; ATSDR, 1992c; Kjøholt *et al.*, 2003; Newland, 1982)

2.2.3 Cobalt

Cobalt is an essential trace element. A well known cobalt compound is vitamin B12 (cyanocobalamin), which is synthesised by the gut flora but also by bacteria, macrophytes, blue-green algae and actinomycetes. It resembles iron and nickel in physical and chemical properties and is mined from nickel-, silver-, lead-, copper- and iron ores. Cobalt is widely used as pigment in glassmaking, ceramic and paint industries, as catalyst in petroleum

industry, in electrical and military industry. Cobalt alloys have a high wear-resistance and high corrosion resistance and are used in applications requiring those properties (e.g. razor blades). Superalloys are used under circumstances with elevated temperatures and high mechanical stress (e.g. gas turbines of aircraft engines). Furthermore, cobalt alloys have outstanding magnetic properties.
(Source: ATSDR, 2001)

2.2.4 Selenium

Coal combustion and crude oil processing are human activities causing environmental input of Se. Other input sources of Se input are sulphide ore mining and erosion of seliniferous rocks or soils; these are of no importance in the Netherlands. The copper refining industry is a source of selenium, which is further processed a.o. in pigments (used in plastics, paints, enamels, inks, rubber), glass, anti-dandruff shampoos and fungicides. The capacity for electric conductivity of selenium (semiconductor) is strongly dependent on the amount of light it receives, a property that is being used in light meters.
(Sources: WHO, 1987; ATSDR, 2002)

2.2.5 Molybdenum

Molybdenum is considered an essential trace element. The concentration in the earth's crust is low (0.001%) and the fractions present in the ores from which it is enriched to form MoS_2 are also low. The consumption in the USA was approximately 15,000 tons in 2000. Metallic molybdenum is used in the construction of electric lighting bulbs and vacuum electronic devices; molybdenum wires are also used in anodes, cathodes, filament holders etc.. Both pure molybdenum and molybdenum alloys are processed as resistance wire in electric heaters and ovens. Molybdenum is the metal with the highest resistance against breaking and molybdenum alloys produce materials that are very firm, have a high tensile strength and are very heat resistant. They are therefore very useful for processing in engines of jet turbines and rocket engines. Molybdenum also has applications as flame retardant and smoke oppressor in textile and plastic. The main anthropogenic source of molybdenum in the air is burning of fossil fuels, while mining activities are the major source for emission to aquatic systems. Industrial discharges, manufacturing by-products and municipal wastes are also known to contribute to molybdenum presence in the hydrosphere and atmosphere.
(Sources: Izmerov, 1988; Kjøholt *et al.*, 2003; Parker, 1986)

2.2.6 Tin

Tin is an element which occurs in nature in 9 mineral forms. It is thought to be essential to rats, but probably not to other species. The estimated world production of tin around 1980 was 225,000 tonnes/year, while in the Netherlands 3463 tonnes was produced in 1988. Tin has its main applications in production of tin plate for use in containers (aerosol-, food- and beverage containers), solder, pewter, coins, bronzes, type metal (printing) jewellery and in alloys such as dental amalgams and titanium alloys used in aircraft industry. Inorganic tin compounds are used in various applications such as glass strengthening, catalysts, stabilisers in perfumes and soaps and as dental anticariogenic agents. Tin forms inorganic compounds in the 2+ (stannous) and 4+ (stannic) oxidation state. There are many Sn (II) compounds with various applications: e.g. $SnCl_2$ (reducing agent) as mordant in dye printing and SnF_2 in toothpastes etc. Tin (II) compounds are easily oxidised to Sn (IV). Sn (IV) compounds also have a wide application in industry (SnO_2) or technology ($SnCl_4$). Since the amount of wastes from tin processing is low and the degree of recovery in industry is high, contamination of the environment with tin is thought to be low.

Tin has also found many applications in organotin compounds, which are not subject of this report. Organotin compounds have applications in plastics (stabiliser), polyurethane foam and silicone. Trisubstituted organotins are used as fungicides, bactericides, anthelminthics and rodent repellents. Tributyltin (TBT) has had widespread use as antifouling agent in marine shipping paint but actions for phasing out these applications are ongoing due to established harmful effects on marine animals like e.g. the purple snail and the dogwhelk.
(Sources: WHO, 1980, Slooff *et al.*, 1993, ATSDR, 1992b)

2.2.7 Antimony

Antimony is a heavy metal, that is considered to be non-essential. It is diffusely distributed over the earth, found at many locations although very rarely in its native form (over 90 mineral forms are known). It was already used by ancient people as archaeological findings have shown. Half of the antimony produced nowadays is used to make alloys (with mainly iron, lead and tin) that have many applications, the other part is used to form various compounds. The world antimony production was estimated to be 150,000 tonnes (year unknown; Kjøholt *et al.*, 2003) while import in the Netherlands was approximately 1700 tonnes in 1988 (Slooff *et al.*, 1992). An important use of antimony oxide (Sb_2O_3) is that as flame retardant in e.g. textiles and plastics along with e.g. polybrominated diphenylethers; due to recognised adverse effects of the latter, use of antimony in this application can be expected to drop in the future. Antimony is used in solder to increase the hardness, is added to lead of batteries, to increase the hardness and corrosion durability and it is being used in shot cartridges. Consumption of antimony in alloys with lead however, is decreasing due to replacement with alloys having less environmental impact (Kjøholt *et al.*, 2003). Antimony has high stability against acids and bases and it is also being processed in protective layers of metal and in fireworks to add colour to the fire. Inorganic pigment applications are found in paints, plastics, glass enamels and glazes.
(Sources: Izmerov, 1984; Slooff, 1992)

2.2.8 Barium

Barium is a non-essential trace element, that has a widely distributed natural occurrence. It is strongly electropositive, and reacts exothermically with ammonia, water, oxygen, hydrogen, halogens and sulphur, and therefore occurs only in the combined (2+) state. It is used as gas trapping agent due to its ability to bind oxygen, nitrogen and hydrogen. In nature, it occurs in minerals with sulphate or carbonate and it is found in fossil fuel, igneous rocks, feldspar and micas. Barite ore (mainly barium sulphate) is the largest natural source of barium; barite production from ore was estimated to be 5.7×10^6 tonnes/year globally in 1985. Barium is processed in lubricants, ceramics (bricks and tiles) and in fireworks to give colour to the fire. It is used as a pigment and as a loader for paper, soap, rubber and linoleum. It is also used in oil and gas drilling muds and as stabiliser for plastics. Barium reaches surface water with industrial waste water and soil with fly ash or sewage effluent in landfills. Barium is known to inhibit several cellular processes in micro-organisms and has applications in various types of pesticides. Barium meal is used in radiotherapy as oral application, which might be a relevant contribution to surface water concentrations.
(Sources: WHO, 1990b; ATSDR, 1992a)

2.2.9 Thallium

Thallium is ubiquitous in nature and is found especially in sulphide ores, usually at low concentrations. An estimated global industrial consumption of 10-15 tonnes/year was estimated for 1991. Activity of mineral smelters, coal burning power generating plants, brickwork and cement plants generate man-made emissions to air and in waste deposits of approx. 2000-5000 tonnes/year. A large fraction of thallium is released into the atmosphere,

since thallium compounds are volatile at high temperatures. Furhter sources of thallium emmission are iron and steel production, nonferrous-metal (e.g. Zn, Cd) smelting and gold production. Thallium belongs to the heavy metals, it is placed next to lead in the period table. Like lead, it is soft and malleable. Thallium is used in the fabrication of glass with a very low melting point, by adding thallium combinations to the glass. It is used as thallium sulphide in infrared detectors, since the conductivity of thallium sulphide changes under the influence of infrared wavelengths. It has been used as rodenticide and insecticide and there are indications of inhibition of soil nitrification in the range of 1-10 $mg.kg^{-1}$.
(Source: WHO, 1996; Ewers, 1988; Schoer, 1984)

2.3 Occurrence and background concentrations

2.3.1 Occurence – general remarks

This report handles on the toxicity of nine elements to the ecosystem, based on toxicity data established for individual species. For most elements, the form in which they naturally occur on earth is in a mineral form, embedded in rocks or fossil fuels. Mining and extraction have to be employed to obtain the various elements in a more pure form in which they can be further processed to eventually reach their many applications. These anthropogenic activities but also geochemical, meteorological and biological processes lead to both local and global distribution of the elements over the different environmental compartments (air, sea, freshwater, soil, sediment). Here again, the elemental state of an element will seldom prevail, since the combination of chemical conditions of the specific environment (pH, redox potential, presence of ligands, organic matter, suspended matter, inorganic (counter)ions etc.) and the chemical properties of the element will determine its speciation. It would be beyond the scope of this report to fully investigate the speciation of each element in each compartment. It is however, important to realise that the information in Table 9 contains general information on the elements that is not applicable to occurrence in most environmental compartments where ion-combinations of the elements in various oxidation states will occur. A general picture of occurrence of the nine elements is given in Table 10, which shows ranges of concentrations for seawater, surface water, groundwater and soil. These data were collected from various locations all over the world and bear no direct relevance to the Netherlands. Sections 2.3.3.1-2.3.3.9 briefly address occurence of the selected elements.

2.3.2 Background concentrations in the Netherlands

Background concentrations are necessary in order to derive MPCs when using the added risk approach. The present information on background concentrations in soil, sediment, groundwater and surface water for the elements investigated here, dates from 1992. De Bruijn and Denneman (1992) published a study on background concentrations of which the values were taken over by Van de Plassche and De Bruijn (1992) in the risk limit derivation. Crommentuijn *et al*. (1997) used the same background concentrations[3] in the risk limit derivation for metals, making use of the added risk approach; while Verbruggen *et al*. (2001) used the same data for derivation of SRC_{ECO}s (among which are Co, Mo and Ba). To our knowledge, the only new published data on background concentrations are for groundwater (Fraters *et al.*, 2001; Meinardi *et al.*, 2003; see section 1.4.1 for details).

For surface water geometric mean values are used rather than 90^{th} percentile values. Van de Plassche and De Bruijn (1992) argued that since the concentrations used to derive these

[3] Some slight modifications were used by Crommentuijn *et al*., e.g. total surface water concentrations were recalculated to dissolved concentrations, but in principle, the same data set was used.

values could not be regarded as free from anthropogenic influences, the geometric mean values are the most representative for the background concentrations in the Netherlands.

Data on concentrations for the nine elements in seawater relevant to the Dutch situation, could not be found. We have addressed a request for information on measured concentrations of the elements in seawater to the information desk of the Ministry of Transport, Public Works and Water Management (V&W). To this request, the National Institute for Coastal and Marine Management (RIKZ) has answered that in their database, no analysis results are present for these compounds in seawater. In the earlier reports in which the ERLs for these elements were derived, these concentrations were also not reported. Van de Plassche and De Bruijn (1992) have not derived ERLs for marine water and Crommentuijn *et al*. (1997), using the added risk approach, have derived MPAs for marine water but not MPCs, because of missing background concentrations. In this report therefore, due to the lack of concentrations measurements in seawater, we will derive only NAs, MPAs and SRA_{ECO}s for marine water, not NCs, MPCs and SRC_{ECO}s.

In the following sections (2.3.3.1-2.3.3.9), estimated concentrations of the elements in *standard soil* will be reported. Standard soil contains 25% clay and 10% organic matter and was used in the former methodology for Dutch risk limit derivation to enable comparison of concentrations in different soils (Traas, 2001). When in the following sections 'reference lines' are mentioned, we refer to De Bruijn and Denneman (1992) for background information. These authors have collected natural background concentrations of all nine elements that are subject to this report, based on samples taken in various Dutch soils in relatively unpolluted areas. Total concentrations of metals in the soil were correlated to the percentage lutum (%L) and/or the percentage organic matter (%H) of the soils using linear regression. The regression line was shifted along the *y*-axis until approximately 90% of the measurements in the soils were below the line. This resulting regression line is called reference line. The background concentration (C_b) is an estimate of the 90th percentile concentration of an element in standard soil, *calculated* using the reference line. For five of the nine elements, reference lines were derived, that relate the element concentration to the lutum content of the soil.

Because the reported background concentrations for freshwater are expressed as total concentrations and the NA, MPA and SRA_{ECO} are based on dissolved concentrations, C_b is recalculated according to the guidance given in Traas (2001, Annex 10):

$$C_{b,dissolved} = \frac{C_{b,total}}{1 + K_{ppm} \times 0.001 \times 0.03}$$

with:

$C_{b,\ total}$	total background concentration ($\mu g.l^{-1}$)
$C_{b,\ dissolved}$	dissolved background concentration ($\mu g.l^{-1}$)
K_{ppm}	partition coefficient suspended matter:water ($l.kg^{-1}$)
0.001	conversion constant ($kg.g^{-1}$)
0.03	suspended matter content ($g.l^{-1}$)

2.3.3 Occurence and background in the Netherlands

Sections 2.3.3.1-2.3.3.9 consist of two parts. The first part addresses the general occurence of each element on earth (minerals, rocks, fossil sources) and its predominant form in our

surrounding environment (e.g. soil, surface water). The second part is a summary of background concentrations selected for the Netherlands, as used within the project INS and therefore, within this report.

2.3.3.1 Beryllium

General occurence

Beryllium occurs naturally in the earth's surface in rocks, at 1-15 $mg.kg^{-1}$; approximately 50 mineral forms are known (ATSDR, 2000; Taylor *et al.*, 2003). Beryllium is reactive and does not occur in the elemental state, but mostly in Be^{2+} ion combinations of which most have a low –yet pH dependent– solubility. Combinations of pH (neutral) and low solubility normally cause concentrations of beryllium to be low in aquatic environments (Kjøholt *et al.*, 2003). Between pH 6-8 $Be(OH)_2$, that has low solubility ($K_{sp}=10^{-21}$), controls speciation. Transformation to insoluble carbonates ($\{(Be(CO_3)_2Be(OH)_2\}$) or sulphates ($BeSO_4$) are also of environmental importance (ATSDR, 2000). In sediment and soil, beryllium will be probably be present in immobile form. Resembling aluminium in its basic and solubility properties, beryllium is enriched a.o. in clays (Newland, 1982). Bioconcentration in plants and animals is low (ATSDR, 2000).

Background concentrations

The following concentrations were derived/measured for the Netherlands (De Bruijn and Denneman, 1992):

- the background concentration based on the reference line for beryllium in Dutch standard soil is 1.1 $mg.kg^{-1}$,
- in groundwater, a natural reference concentration of 0.05 $\mu g.l^{-1}$ is proposed, which is the upper limit[4] of Be measurements from environments classified as natural,
- *estimated* surface water concentration was 0.017 $\mu g.l^{-1}$ (geometric mean[5]); the dissolved surface water concentration was calculated to be 0.017 $\mu g.l^{-1}$.
- reference line: 0.3 + 0.033L.

2.3.3.2 Vanadium

General occurence

Vanadium is a rare metal, yet it is widespread. Metallic vanadium does not occur in nature, but over 70 vanadium minerals are known. The average vanadium concentration in the earth's crust is ~150 $mg.kg^{-1}$, applying to various rocks and soil types. Igneous rocks and shale contain 200-300 $mg.kg^{-1}$, while podzol, forest soil and sandy soils contain 20-50 $mg.kg^{-1}$ (Byerrum *et al.*, 1974). In freshwater environments, vanadium most commonly occurs as the vanadate (V^{5+}) ion in $H_2VO_4^-$ and HVO_4^{2-} species under oxidising conditions and as vanadyl ion (V^{4+}) in VO^{2+} and $VO(OH)^+$ species under reducing conditions. All ion-species adsorb and complex strongly to minerals, oxides or organic matter. Under oxidising conditions in soil, some mobility is observed, more in neutral and alkaline soils than under acidic conditions. Bioconcentration in marine plants and invertebrates is thought to be higher than in terrestrial plants and animals. (Sources for the above section: ATSDR, 1992c; Kjøholt *et al.*, 2003; Newland, 1982).

Background concentrations

[4] Upper limit of Be measurements in groundwater. This value is proposed as 90th percentile, i.e. a natural reference value (De Bruijn and Denneman, 1992).

[5] Concentration *calculated* from datasets of Northern European and non-Northern European surface waters, with limited translatability to the Dutch situation.

The following concentrations were derived/measured for the Netherlands (De Bruijn and Denneman, 1992):
- background concentrations in soils of Dutch natural reserves ranged from 2.3-53.8 $mg.kg^{-1}$,
- the background concentration based on the reference line for vanadium in Dutch standard soil is 42 $mg.kg^{-1}$,
- in groundwater, the 90th percentile was 1.2 $\mu g.l^{-1}$,
- *estimated* surface water concentration was 0.96 $\mu g.l^{-1}$ (geometric mean[5]); this was recalculated to a dissolved concentration of 0.82 $\mu g.l^{-1}$,
- reference line: 12 + 1.2L.

2.3.3.3 Cobalt

General occurence

In aqueous environments, a small fraction is in dissolved form, and the major portion is either adsorbed or co-precipitated with iron and manganese oxides, precipitated as carbonate and hydroxides compounds or associated with minerals in the sediment. Binding to humic substances is strong. In soil, adsorption to similar adsorbents occurs whereas adsorption to clay minerals occurs to a lesser extent. A concentration range for cobalt in soils of 1-40 $mg.kg^{-1}$ is reported while the average concentration in U.S. soils is 7.2 $mg.kg^{-1}$. For sediments, comparable levels are reported: generally <20 $mg.kg^{-1}$. Surface water concentrations in the U.S. are generally <1 $\mu g.l^{-1}$ in pristine and 1-10 $\mu g.l^{-1}$ in populated areas. Biomagnification of cobalt through the foodchain is thought to occur. Source for above section: ATSDR (2001).

Background concentrations

The following concentrations were derived/measured for the Netherlands (De Bruijn and Denneman, 1992):
- background concentrations in soils of Dutch natural reserves ranged from 0.1-13.3 $mg.kg^{-1}$,
- the background concentration based on the reference line for cobalt in Dutch standard soil is 9 $mg.kg^{-1}$,
- in groundwater, the 90th percentile was 0.63 $\mu g.l^{-1}$,
- *estimated* surface water concentration was 0.22 $\mu g.l^{-1}$ (geometric mean[5]); this was recalculated to a dissolved concentration of 0.19 $\mu g.l^{-1}$,
- reference line: 2 + 0.28L.

2.3.3.4 Selenium

General occurence

Selenium appears ubiquitous, but is unevenly distributed: regions with very low or very high natural levels (seliniferous areas) can be identified. There is no clear picture of the importance of anthropogenic, geophysical or biological processes in the distribution of Selenium. Se has four oxidation states: selenate (Se^{6+}), selenite (Se^{4+}), elemental Se (Se^{0}) and selenide (Se^{2-}). Although all forms can be present in aquatic environments, selenate and selenite are the most soluble forms and are most common to the aquatic compartment. Elemental Se and inorganic selenides (metal selenides) have low bioavailability and are considered to possess low environmental hazard. Selenides also occur in the form of organic complexes such as methyl- and dimethyldiselenide and selenoamino acids, which are of biological origin (Maier and Knight, 1994). Aquatic biota accumulate soluble Se forms, and subsequently reduce the more oxidised selenate and selenite forms to selenide. Methylselenides are volatile and known to be formed by vascular plants, aquatic animals and micro-organisms. Selenomethionine and

selenocystenine are selenoaminoacids that can be synthesised by primary producers of aquatic systems and also by higher plants (Brown and Shrift, 1982). Selenium closely resembles sulphur in chemical properties; Se is placed directly under S in the periodic table of the elements. However, in the differences in chemical properties (a.o. atomic radius, bond lengths, degree of ionisation) lies the root of the mechanism of selenium toxicity. Sulphur has a key role in three dimensional protein shape, by forming S-S bonds that determine the tertiary structure and the proper functioning of proteins or enzymes. When S is erroneously displaced by Se in amino acids, the formation of these bonds is prevented and dysfunctional proteins and enzymes are the result (Lemly, 2002). Teratogenic effects are a direct consequence of this displacement, and for Se, these are well established in fish, but also in birds and mammals (e.g.Lemly, 1993; Gunn *et al.*, 1976). Apart from its toxicity, selenium is also an essential trace element to man, animals and plants (Mortvedt *et al.*, 1991;World Health Organization, 1987).

Background concentrations

The following concentrations were derived/measured for the Netherlands (De Bruijn and Denneman, 1992):

- the background concentration for selenium is 0.7 $mg.kg^{-1}$ (note: this is the 90^{th} percentile of naturally occurring levels and is not specifically related to standard soil),
- in groundwater, the 90^{th} percentile was 0.024 $\mu g.l^{-1}$,
- *estimated* surface water concentration was 0.042 $\mu g.l^{-1}$ (geometric mean[5]); this was recalculated to a dissolved concentration of 0.041 $\mu g.l^{-1}$,
- no reference line, 90^{th} percentile of measurements in soils: 0.7 $mg.kg^{-1}$, not expressed in standard soil. The number of measurements and their reliability was too low to construct a reference line.

2.3.3.5 Molybdenum

General occurence

Mo is typically found as the soluble molybdate ion, MoO_4^{2-}, in oxidised environments (Kjøholt *et al.*, 2003). Molybdate predominates above pH 6 while at lower pH, polymerisation occurs and forms like paramolybate, $Mo_7O_{24}^{6-}$ (at pH ~4) predominate (Parker, 1986).

Background concentrations

The following concentrations were derived/measured for the Netherlands (De Bruijn and Denneman, 1992):

- the background concentration of molybdenum is 0.5 $mg.kg^{-1}$ (note: this is the 90^{th} percentile of naturally occurring levels and is not specifically related to standard soil),
- in groundwater, the 90^{th} percentile was 0.69 $\mu g.l^{-1}$,
- *estimated* surface water concentration was 1.4 $\mu g.l^{-1}$ (geometric mean[6]); the calculated dissolved concentration was also 1.3 $\mu g.l^{-1}$,
- no reference line, 90^{th} percentile of measurements in soils: 0.5 $mg.kg^{-1}$, not expressed in standard soil.

[6] Concentration *calculated* from datasets of Northern European lowland surface waters. This concentration is expected to be indicative for Dutch surface waters.

2.3.3.6 Tin

General occurence

Tin occurs in the Sn^{2+} or Sn^{4+} state, of which the 2+ valence will predominate in reduced environments and the 4+ state probably dominates in ambient waters. Sn is thought to be relatively immobile in soil (Bockting *et al.*, 1992).

Background concentrations

The following concentrations were derived/measured for the Netherlands (De Bruijn and Denneman, 1992):

- background concentrations in soils of Dutch natural reserves ranged from 0.6-28.1 $mg.kg^{-1}$,
- the background concentration based on the reference line for tin in Dutch standard soil is 19 $mg.kg^{-1}$,
- in groundwater, the 90th percentile was <2 $\mu g.l^{-1}$ (detection limit),
- *estimated* surface water concentration was 0.1 $\mu g.l^{-1}$ (90th-percentile[5,7]) ; this was recalculated to a dissolved concentration of 0.0082 $\mu g.l^{-1}$,
- reference line: 4 + 0.6L.

2.3.3.7 Antimony

General occurence

The dominant oxidation states of in aqueous environments are Sb (III) and Sb (V). Both ions hydrolyse easily and are present as $Sb(OH)_3$ and $Sb(OH)_6^-$. (Kjøholt *et al.*, 2003). Slooff *et al*. (1992) report soil concentrations that range from 0.3-3.0 $mg.kg^{-1}$ in five soil types of natural reserves. Other sites (not contaminated) show a range of 0.2-6.4 $mg.kg^{-1}$. In water, antimony is probably present in dissolved form for a large fraction due to the relatively high solubility of antimonite or antimonate ions, while adsorption will occur to mineral surfaces. Precipitation occurs with iron and aluminium oxides. In general, transport of dissolved antimony is thought to be the main transport route to, eventually, the oceans (Slooff *et al.*, 1992).

Background concentrations

The following concentrations were derived/measured for the Netherlands (De Bruijn and Denneman, 1992):

- the background concentration for antimony[8] is 3 $mg.kg^{-1}$,
- in groundwater, the 90th percentile was 0.091 $\mu g.l^{-1}$,
- *estimated* surface water concentration was 0.32 $\mu g.l^{-1}$ (geometric mean[5]); this was recalculated to a dissolved concentration of 0.29 $\mu g.l^{-1}$,
- no reference line, there was no clear relationship with clay or organic matter content.

2.3.3.8 Barium

General occurence

Natural occurrence of barium in groundwater is caused by leaching and erosion of rocks. Although it precipitates as insoluble salts ($BaSO_4$ or $BaCO_3$) and adsorbs to particulate matter barium is commonly found in surface waters. Anthropogenic activities thought to be primarily

[7] The rationale to choose the 90th-percentile value as background concentration for tin, is explained in De Bruijn and Denneman (1992). There is no reason to deviate from their proposal.

[8] A reference line for Sb was not derived because lutum and organic carbon content could not describe Sb concentrations in soil adequately. For this reason, a fixed value was chosen as background concentration. This value was set at 3 mg/kg, all measured concentrations were below this value (De Bruijn and Denneman, 1992).

responsible for barium release to the environment are oil and gas drilling muds and the waste handling of both. Waste muds may be spread onto land (relevance of this emission route for the Netherlands is unknown) or released into the ocean in offshore oil or gas drilling. Source: ATSDR (1992a).

Background concentrations
The following concentrations were derived/measured for the Netherlands (De Bruijn and Denneman, 1992):
- background concentrations in soils of Dutch natural reserves ranged from 3.55-243 $mg.kg^{-1}$,
- the background concentration based on the reference line for barium in Dutch standard soil is 155 $mg.kg^{-1}$,
- in groundwater, the 90th percentile was 197 $\mu g.l^{-1}$,
- *estimated* surface water concentration was 76 $\mu g.l^{-1}$ (geometric mean[6]); this was recalculated to a dissolved concentration of 73 $\mu g.l^{-1}$,
- reference line: 30 + 5L.

2.3.3.9 Thallium
General occurence
Thallium occurs ubiquitously, although occurrence as thallium minerals is extremely rare and it is rather present as trace element in other minerals. Thallium occurs as Tl^{+} or Tl^{3+}, compounds formed with both valence states are easily soluble in water. In freshwater, Tl occurs predominantly in the monovalent state. In seawater, oxidation from Tl^{+} to Tl^{3+} is possible because of the oxygen content and stabilisation of the formed trivalent state by chloro-complexes ($Tl(OH)_2Cl$). In soil, Tl is immobile, it binds to clay, organic matter or Fe and Mn oxides. Sources: Sager, 1994; Schoer, 1984

Background concentrations
The following concentrations were derived/measured for the Netherlands (De Bruijn and Denneman, 1992):
- no background levels for Dutch soils were found for thallium. Values of 1.5 and 1.6 $mg.kg^{-1}$ are mentioned as indications for levels in 'global dust' and the continental crust, respectively. Sager (1994) reports mean values of 0.5, 0.2 and 0.36 $mg.kg^{-1}$ for soils in Austria. A background value of 1.0 $mg.kg^{-1}$ is reported in Crommentuijn *et al*. (1997), as advised by the Technical Soil Protection Committee and in the guidance for risk limit derivation (Traas, 2001).
- in groundwater, the 90th percentile was $<2 \mu g.l^{-1}$ (detection limit),
- *estimated* surface water concentration was 0.04 $\mu g.l^{-1}$ (geometric mean[5]); this was recalculated to a dissolved concentration of 0.038 $\mu g.l^{-1}$,
- no reference line was available, because no concentrations in Dutch soils were found (De Bruijn and Denneman, 1992).

Table 11 summarises the data from the preceding sections relevant to the Netherlands and presents the background concentrations that will be used in risk limit derivation.

Table 11. Background concentrations of nine elements in surface water, groundwater and soil.

Element	C_b freshwater[a] total [µg.l^{-1}]	C_b freshwater dissolved [µg.l^{-1}]	C_b groundwater dissolved [µg.l^{-1}]	C_b marine dissolved [µg.l^{-1}]	C_b soil total [mg.kg^{-1}]	C_b sediment[b] total [mg.kg^{-1}]
Be	0.017	0.017	0.05	n.a.	1.1	1.1
V	0.96	0.82	1.2	n.a.	42	42
Co	0.22	0.19	0.63	n.a.	9	9
Se	0.042	0.041	0.024	n.a.	0.7	0.7
Mo	1.4	1.3	0.69	n.a.	0.5	0.5
Sn	0.1	0.0082	<2	n.a.	19	19
Sb	0.32	0.29	0.091	n.a.	3	3
Ba	76	73	197	n.a.	155	155
Tl	0.04	0.038	<2	n.a.	1.0[b]	1.0[c]

n.a. = not available.
[a] C_b freshwater are based geometric mean values.
[b] In absence of background concentrations for sediment, the background concentrations for soil are used (Van de Plassche and De Bruijn, 1992).
[c] Crommentuijn et al. (1997). Adjusted based on the advice of the Technical Soil Protection Committee (advice given in 1994).

Note that the background concentrations for sediment were set equal to the background concentrations for soil by Van de Plassche and De Bruijn (1992) because sediment data were not available.
No background concentrations for the marine environment were found. Apparently, ERLs for the marine environment have not been derived in the past for these elements. The lack of background concentrations hampers the derivation of ERLs in this document. However, the MPAs that will be derived may still be used for ERL derivation when background concentrations are set in a later stage.

2.3.4 Occurrence in air

All of the nine elements investigated enter the atmosphere (in various rates) due to anthropogenic activities like burning of fossil fuels (power plants on gas, oil and coal), industrial use, burning of solid waste or -more or less- natural events like forest fires or volcanic activity. Atmospheric transport is probably an important spreading route for these elements. Dry and wet deposition fluxes to soil (and groundwater) and surface water (and sediment) may indicate whether these routes contribute significantly to environmental concentrations in the Netherlands. Such estimations are beyond the scope of this report. Moreover, since there is no information concerning ecotoxicological effects of concentrations in air, we have not attempted to collect measurement data.

3. Methods

3.1 Data Search

In 1992, Van de Plassche and De Bruijn (1992) derived environmental quality standards for the Netherlands for the nine elements that are the subject of this report. The underlying toxicity data were published in a separate report (Van de Plassche *et al.*, 1992). Since these data were peer reviewed in 1992, we have used the 1992 toxicity data as a basis for the present report, principally without reviewing these again. In practice, several papers had to be checked for parameters during the course of the project. The most important papers were also ckecked. Some specific remarks on the handling of these data are made in section 4.2. The starting point taken for literature search for the present report was 1991.

In April 2003 an on-line literature search was performed for the period 1991 – April 2001 using the TOXLINE PLUS database. CURRENT CONTENTS records were searched additionally from 2001 – April 2003. This literature search was used to retrieve ecotoxicological information as well as information on partitioning coefficients of the elements.

Since 2003, RIVM maintains a database, called e-toxBase, which contains ecotoxicological data on many substances (a.o. the US-EPA ECOTOX database). For each of the elements investigated here, we have searched this database. For all relevant entries, the original publications were retrieved and assessed for usefulness in this project. When the original data in which e-toxBase entries were published were inaccessible to us, e.g. because data were reported in reports or conference proceedings that could not be obtained, the data were not selected for risk limit derivation.

3.2 Data selection and treatment

3.2.1 Selection of data

A toxicity study is considered reliable if the design of the experiment is in agreement with internationally accepted guidelines, e.g. OECD guidelines. To judge studies that have not been performed according to these guidelines, criteria were developed for this project, as documented in Traas (2001). Effects on growth, reproduction or survival are used in the derivation of ERLs, or other parameters that bear relationship to population dynamics. After selection, toxicity studies are divided in terrestrial and aquatic data, and the aquatic data are subdivided in freshwater and marine data. All categories are further subdivided in chronic and acute toxicity studies.

3.2.2 Treatment of data

3.2.2.1 Calculation of EC10 or EC50 values

In some cases a recalculation of the data presented in published papers was performed: (i) when the method of derivation of a NOEC or L(E)C50 was not clearly stated in the original work and (ii) when it was possible to derive a NOEC or EC10 (chronic study) or an L(E)C50 (acute study) in case these values were not presented in the original work.
In case results were graphically presented in published papers, we scanned the graph. We then used the software program TechDig (Jones, 1998) to digitise the data plotted in the graph. This program allows to read data from digital images of a graph with a high precision, and co-ordinates of data in the graph are automatically converted to numbers, thus recreating a

approximation of the original data set. The resulting dataset was then processed in MS Excel® (if necessary), after which a dose response relationship was fitted through the data.

To this end, the following method was used: a logistic equation (Equation 2) was fitted through effect data versus the $\log_{10}$ of concentrations (preferably measured values) using non-linear regression (GraphPad Software Inc., 1996). The following three parameter logistic equation was the starting point:

$$y = \frac{Top}{1+e^{(x-\log EC50)\cdot slope}} \qquad \text{Equation 1}$$

In which y is the response parameter, Top is the maximum response, x is the $\log_{10}$ of the toxicant concentration, logEC50 is the $\log_{10}$ of the EC50 and slope is the steepness of the curve. An expression for slope was obtained by inserting $\{x = \log_{10}(EC10), y = 0.9\times Top\}$ in Equation 1. Substituting the obtained expression for slope in equation 1 and rearranging gives:

$$y = \frac{Top}{1+e^{\left((x-\log EC50)\cdot\frac{2.197225}{\log EC50-\log EC10}\right)}} \qquad \text{Equation 2}$$

In this way, both the EC50 and the EC10 were calculated. When data of a chronic experiment were fitted, an EC10 was calculated, which is interpreted as NOEC (ECB, 2003). Recalculation of data is mentioned in the footnotes of the tables in Appendix 2 and 3.

3.2.2.2 No normalisation to standard soil and standard sediment

Results from toxicity studies with terrestrial or sediment organisms (including microbial processes and enzymatic reactions) are *not* normalised to standard soil or standard sediment. This is deviant from earlier ERL derivations; the rationale behind this change is outlined in section 1.3.4.1.

3.2.2.3 Averaging toxicity data

Aquatic data

The general procedure is as follows. After selection of all toxicity data useful for derivation of risk limits, these data are divided over taxonomic groups and tabulated. Next, it is investigated if there are species for which multiple (>1) toxicity data for the same endpoint (mortality, growth, etc) are available. The TGD states in the section on effect assessment of aquatic organisms, that when more than one toxicity value is found for one species and for the same endpoint, the geometric mean of toxicity values should be calculated. This step may still result in species for which multiple (>1) endpoints are tabulated (in some cases, the effect concentrations will now be geometric means). Finally, the lowest value (the most sensitive toxicity endpoint) of the available data per species is selected. When assessment factors are applied, this means that the lowest value within a taxonomic group is selected. When refined effect assessment is applied, this means that the lowest value per species (chronic data only) is selected for statistical extrapolation.

We have applied these rules with the following exceptions:

- When an effect of test conditions was expected to be the cause of variation in toxicity values. For example, water hardness of the test water or life stage of the tested animal has,

in many cases, a clear influence on the outcome of a toxicity test with metals. If this became clear for a certain test species, data were not averaged for risk limit derivation.
- When the metal salt tested was suspected to be the cause of variation in toxicity values. Different valence states or different species of one metal (e.g. SeO_4^{2-} or SeO_3^{2-}) may exhibit different toxicity to the same organism. In practice, the number of toxicity studies is usually too small for a statistical investigation. Therefore, when it could not be excluded that the form in which the element was applied in a toxicity test was the cause of variation in toxicity, data were not averaged for risk limit derivation.

Terrestrial data

The results of terrestrial toxicity experiments with metals are not normalised to standard soil (section 3.2.2.2). Soil properties can influence the outcome of the experiment, i.e. they may also determine the height of the concentration exerting a certain effect (viz. L(E)C50 or NOEC). For this reason, individual toxicity results for one species or process with the same endpoint are not averaged in this study. There are two exceptions:
- when more than one toxicity result was available for the same species (or process or enzyme reaction) in the same soil, for the same valence state of the element and for the same endpoint, the geometric mean of the results was calculated.
- when more than one toxicity result was available for the same species (or process or enzyme reaction) in the same soil, for the same valence state of the element and for different endpoints, the lowest of these values was selected.

Table 12 shows all possible combinations and which rule was applied to the data before use in MPA derivation.

Table 12. Decision scheme for treatment of terrestrial toxicity data to be used in MPA derivation.

Rule no.	species/ process	soil	element valence	toxicity endpoint	method applied to tox results to derive SRA_{ECO} entries
1	identical	identical	identical	identical	geometric mean of two results
2	identical	identical	identical	*different*	use lowest of two results
3	identical	identical	*different*	identical	use both results
4	identical	identical	*different*	*different*	use both results
5	identical	*different*	identical	identical	use both results
6	identical	*different*	identical	*different*	use both results
7	identical	*different*	*different*	identical	use both results
8	identical	*different*	*different*	*different*	use both results

The procedure described above for averaging (or not averaging) results of toxicity studies applies to ERL derivation using assessment factors as well as statistical extrapolation.

3.2.2.4 Toxicity data on microbial processes in soil

In appendix 4 of Van de Plassche *et al*. (1992) the toxicity data for soil organisms are tabulated, including the data that were not used for extrapolation. Data not used for extrapolation in 1992 were those on microbial processes for Ba, Be, Co, Mo, Se, Sn and V, which included parameters such as mineralisation, nitrification and several enzyme activities. The reason for rejecting the data on microbial processes was that the discussion on how to use these data in risk limit derivation was ongoing at that time. By now, toxicity data for microbial processes are considered an indispensable contribution to an adequate protection of the terrestrial ecosystem. Therefore, we have now incorporated these data. Data for Ba, Co and Mo have recently been used in the derivation of ecotoxicological serious risk concentrations ($SRC_{ECO,}$ Verbruggen *et al.*, 2001).

The way in which the available data on soil microbial processes and enzyme reactions are expressed, is an EC_x value at a fixed concentration, in which x is the percentage of inhibition found. In many cases one effect concentration at one metal concentration in the soil is given per soil type. We derived NOEC values from this type of data with the method provided by the TGD guidance. This involves dividing the EC_x or LOEC (synonym with EC_x in this case) by a fixed factor. We have applied the following rule:

$10\% < \text{LOEC} \leq 20\%$ effect: NOEC=LOEC/2,

which is a slight modification[9] compared to the TGD, in that EC20 values are now included in the effect assessment whereas the TGD excludes studies that report 20% effect (TGD: 10%<LOEC<20% effect: NOEC=LOEC/2). For those studies that showed less than 10% effect, the LOEC was set equal to the NOEC. Some studies reported 0% effect, these studies were excluded from the risk limit derivation. All data tabulated by Van de Plassche *et al*. (1992) showing an effect >20% were also excluded. The NOEC values obtained in the described manner were used in risk limit derivation.

In several cases of the studies on microbial processes and enzyme activities, two effect concentrations at two different soil concentrations in one soil type were available. In principle, this suffices to draw a logistic dose response model through these two points, enabling calculation of an EC10 (without confidence limits since only one logistic curve can be drawn through two data points), which could then be set equal to a NOEC. We have chosen not to apply this method to these data for the following reasons. First, the difference between two effects (i.e. percentages of inhibition) was often relatively small (distance on the *y*-axis of the dose response relationship). Second, in many cases the distance between the two concentrations was very high (*x*-axis of the dose response relationship). Both arguments cause extreme extrapolations to reach EC10 values. This results in unrealistically low EC10 values without any knowledge on the confidence interval of the EC10. Moreover, the use of one method applied to all data was preferred for reasons of clarity and consistency in the end results. In conclusion, this method was considered unsuitable for application to this data set and it was therefore not used.
Results from this type of studies could therefore only be used if one (or both) of the two tested concentrations showed ≤ 20% effect. However, studies in which both effect concentrations showed ≤ 20% effect have not been encountered.

3.2.2.5 Freshwater and marine toxicity data

To investigate whether freshwater or marine data exhibited a different sensitivity to a toxicant, a *t*-test was employed to log transformed toxicity data. The selected data for ERL derivation were used for these tests. A two tailed *t*-test (α=0.05) was used. In case of unequal variances (tested prior to the *t*-test using an *F*-test) a *t*-test with Welch's correction was performed. All statistical tests were performed using GraphPad Prism software (GraphPad Software Inc., 1996). Acute freshwater data were tested versus acute marine data and chronic freshwater data were tested versus chronic marine data. The decision to join or separate freshwater and marine toxicity data was taken on a case by case basis. Both the outcome of the *t*-tests and the characteristics of the dataset (e.g. the number of data, number of taxa represented in the dataset) were taken into consideration.

[9] This modification is motivated because EC20 values are regularly reported in scientific literature. These studies should otherwise be rejected. Valuable results may be rejected in this way. To our opinion there is no plausible argumentation to reject a study showing 20% effect, but to accept a study showing (e.g.) 19.5%.

3.3 Derivation of ERLs

In ERL derivation for metals, the added risk approach is followed. For details, see Crommentuijn *et al*. (1997) and Verbruggen *et al*. (2001). In principle, after selection and treatment of the available toxicity data as described in section 3.2, an *addition* is calculated from these data. Calculation methods for this addition or reference to guidance documents are given in sections 3.3.1 to 3.3.3. The effect concentrations from the collected laboratory toxicity tests are expressed in (nominal) concentrations. The specific ERL (MPC, NC or SRC_{ECO}) is the sum of the calculated addition and the background concentration C_b, according to:

$$NC = C_b + NA, \qquad MPC = C_b + MPA, \qquad SRC_{ECO} = C_b + SRA_{ECO}$$

3.3.1 Derivation of maximum permissible addition (MPA)

The maximum permissible addition (MPA) is derived using assessment factors if chronic toxicity data are available for less than eight taxonomic groups. The assessment factors are applied as laid down in the TGD (ECB, 2003). The TGD handles on predicted no effect concentrations (PNECs), which are read as equivalent to MPAs for metals in this report.

According to the TGD, MPAs may be derived using a 'statistical extrapolation technique' (e.g. as described by Aldenberg and Jaworska (2000)) only when NOECs for at least 10 different species, divided over 8 taxonomic groups, are available. The NOECs should result from chronic toxicity experiments. Only for selenium the dataset of aquatic, chronic toxicity studies was large enough to allow for statistical extrapolation. The MPAs for all other elements were derived by applying assessment factors.

N.B. 1. For the application of assessment factors to soil toxicity data, the TGD places all data on microbial processes and enzyme reactions in one trophic level (see also section 1.3.3, this report). Since soil toxicity data are not averaged for ERL derivation (this report, section 3.2.2.3), this means that the lowest value of all data on microbial processes and enzyme reactions is used for the trophic level 'micro-organisms' in ERL derivation. This is different when statistical extrapolation would be applied. In that case terrestrial micro-organisms and enzyme activities are treated separately from the other trophic levels.

N.B. 2. Please note that, since the TGD methodology for risk limit derivation is followed in this report, the derived risk limits will *not* be harmonised according to the equilibrium partitioning theory (EqP). This step was incorporated in the former INS methodology but it is not part of the TGD guidance (cf. sections 1.3.1 and 1.3.2).

3.3.2 Derivation of negligible addition (NA)

Dividing the MPAs by 100 derives NAs. This factor of 100 is supposed to function as protection against mixture toxicity, since species in the environment are always exposed to mixtures of chemicals and complex mixtures of chemicals are generally best described as concentration-additive (Van Leeuwen *et al.*, 1996; Deneer, 2000).

3.3.3 Derivation of serious risk addition (SRA_{ECO})

The SRC_{ECO} is derived specifically within the Dutch national framework of environmental standard setting. Hence, there is no guidance on this topic in the TGD. We have followed the procedure of deriving SRC_{ECO} as described in Verbruggen *et al*. (2001). A short description of the procedure is given in the following.

For metals, the SRC_{ECO} is the sum of C_b and SRA_{ECO} (section 3.3). For the SRA_{ECO} for the water compartment, an assessment factor of 10 is applied to the geometric mean of the selected acute toxicity data, which results in an $SRA_{ECO, acute}$. This $SRA_{ECO, acute}$ is then compared to the geometric mean of all selected chronic data, the $SRA_{ECO, chronic}$. The lowest of the two values is the SRA_{ECO} for the water compartment. When chronic data for 4 (or more) taxonomic groups are available (and toxicity data are log-normally distributed), refined risk assessment is applied ('statistical extrapolation') and the comparison with acute data is no longer made.

For the SRC_{ECO} derivation for the soil compartment, all available toxicity data are separated in toxicity data for microbial processes and enzymatic reactions and toxicity data for other species. For both groups of toxicity data, the $SRA_{ECO, acute}$ divided by an assessment factor of 10 is compared to the $SRA_{ECO, chronic}$. The lowest of the two SRA_{ECO} values is the SRA_{ECO} for each of the two divisions of soil toxicity data. The lowest of the $SRA_{ECO, processes\&enzymes}$ and $SRA_{ECO, other\ species}$ is finally selected as SRA_{ECO}.

Calculating geometric means
The SRA_{ECO} should express a weighted mean over all available toxicity data for the terrestrial ecosystem. This differs from MPA derivation when assessment factors are used (see also section 1.3.3 and section 3.3.1, N.B. 1). The procedure for calculation of the geometric mean of toxicity data sets for a compartment is outlined in the following.

Aquatic data
1. Using the toxicity data tables in the appendices, toxicity data are listed per species.
2. If, for a given species, >1 data are available for a toxicity endpoint, the geometric mean is calculated for that endpoint.
3. If, for a given species, toxicity data for the same endpoint were obtained in studies that were conducted using different metal salts, different hardness values etc., the geometric mean of these results is calculated for that species.
4. If, for a given species, >1 endpoints are available, the *lowest* value is selected for SRA_{ECO} derivation.
5. Next, in order to calculate the SRA_{ECO}, the geometric mean of over all species present in the dataset is calculated (one entry per species).

Terrestrial data
1. Using the toxicity data tables in the appendices, toxicity data are listed per species, microbial process or enzymatic reaction.
2. If, for a given species, microbial process or enzymatic reaction, >1 data are available for a toxicity endpoint, the geometric mean is calculated for that endpoint.
3. If, for a given species, microbial process or enzymatic reaction, toxicity data for the same endpoint were obtained in studies that were conducted in different soils or using different metal salts, etc., the geometric mean of these results is calculated for that species.
4. If, for a given species, microbial process or enzymatic reaction, >1 endpoints are available, the *lowest* value is selected for SRA_{ECO} derivation.
5. Next, in order to calculate the SRA_{ECO}, the geometric mean of over all species present in the dataset is calculated (one entry per species).

In the methodology for SRA_{ECO} derivation each individual microbial process or enzymatic reaction for which data are available, is treated as a separate entry in the calculation of the geometric mean.

Furthermore, toxicity data in soil are not normalised to standard soil. Consequently, toxicity data for the same species, microbial process or enzyme reaction, measured in different soils are treated as separate entries in SRA_{ECO} derivation. In order to give a clear picture of the decision scheme on how to incorporate toxicity data in SRA_{ECO} derivation, a scheme is drawn up (Table 12, p. 43). This scheme applies to species, microbial processes and enzyme reactions.

4. Toxicity data and derivation of MPAs and NAs for water

4.1 Data and analysis

All evaluated toxicity data are summarised in the toxicity data tables shown in Appendix 2. Methods employed to derive the preferred parameters LC50 and EC50 for acute tests and EC10 or NOEC for chronic tests, are described in section 3.2.2. Appendix 4 tabulates the aggregated data that are used for ERL derivation: the geometric mean or the lowest value per species per taxon is presented. ERLs are derived as described in section 3.3. The following sections contain the derivations of ERLs for the aquatic compartment (section 4.3).

4.2 Specific problems

Several toxicity studies performed by Bringmann and Kühn were used by Van de Plassche *et al*. (1992) in their ERL derivation. In most of the Bringmann and Kühn papers, the results were already expressed in mg metal ion per litre, i.e. in the same units as we present our data in the toxicity data tables. However, in the tables of Van de Plassche *et al*. some of the data were erroneously recalculated again to mg metal ion per litre. We have studied the original papers and corrected the results of these toxicity tests where necessary.

For several of their studies, Bringmann and Kühn report a 'toxische Grenzkonzentration' (TGK) as an end result. Van de Plassche *et al*. interpreted this TGK as a LOEC which was divided by 2 in order to calculate a NOEC for the specific study: NOEC=TGK/2. However, Bringmann and Kühn state in their papers that the TGK is in fact close to 0% effect. It should therefore be treated as a NOEC without dividing it (see also Traas, 2001).

In the ERL derivation of Van de Plassche *et al*. (1992), the guidance for deriving risk limits allowed the calculation of a NOEC from a chronic study by dividing a LOEC, EC50 or LC50 by 10. In the present guidance (TGD), this is no longer permitted. Therefore, for those studies involved, we have tried to recalculate an EC10 from the data presented by the authors (as described in section 3.2.2.1), or rejected the study when this was not possible.

In the aquatic toxicity data for vanadium the selection of data from the study of Stendhal and Sprague (1982) needs some explication. This study is a fish toxicity test with vanadium, well performed, under continuous flow conditions. The latter is important, since this means that prolonged exposure is possible. The authors report results of eight experiments with LC50 values at 96 hours and in addition, for several of the tests, LC50 values at longer exposure durations (e.g. LC50s for the same test after 5, 7, 8 , 9, 10, 11 and 12 days of exposure). A second set of 11 LC50 values (additional experiments) at 7 days exposures is also presented. It is desirable to incorporate these additional results in the risk assessment and not reject them for the reason of a deviating exposure time. We have chosen to select all LC50 values determined at 7 days exposure from this study. This choice is based on the argument that a 7 day exposure time can also be defined as acute. The study has also shown that 7 day LC50 values generally are a factor of 2-3 lower than 4 day LC50 values. Consequently, as one accepts a wider definition of 'acute' exposure (as opposed to one invariable, fixed period of time), one allows some variation within the toxicity data selected for risk limit derivation. With regard to fish toxicity, we prefer to see acute a little wider than only 96 hour exposures, rather than to reject valuable test results. The test performed according to the OECD 204

guideline (OECD, 1984; prolonged fish toxicity test) is a 14 day study that is also regarded as acute within the INS project framework.

4.3 Derivation of ERLs for water

Appendix 4 shows the chronic (NOEC) and acute (L(E)C50 values per taxonomic group that were selected for ERL derivation, for all nine elements. The aquatic toxicity data that were selected for all nine elements are presented in Appendix 2.

For the derivation of ERLs, salt and freshwater data are combined if there are no (statistical) reasons to keep the data separated. In those cases the ERL is derived using the combined dataset. For an overview of the derived ERLs see section 4.5.

4.3.1 Beryllium

Aquatic toxicity data on Be can be found in Table A2. 1, Table A2. 10, Table A2. 19 and Table A2. 32 in Appendix 2. Data used for ERL derivation can be found in Table A4. 1 in Appendix 4. Chronic toxicity data were found for freshwater organisms only.

Freshwater
Acute toxicity data were found for bacteria, algae, nematodes, crustaceans, annelids and fish. The base set for acute toxicity data is complete. Chronic toxicity data were found for bacteria, cyanobacteria, protozoa, algae and fish. Since chronic toxicity data are available for two trophic levels, an assessment factor of 50 should be applied to the lowest NOEC, found for *Entosiphon sulcatum*. The MPA_{water} is therefore 0.004/50 = 0.00008 $mg.l^{-1}$ or 0.08 $\mu g.l^{-1}$.

Marine
Since no chronic toxicity data on marine aquatic organisms are available, the MPA is derived using the freshwater data with application of an assessment factor of 500.
MPA_{marine} = 0.004/500 = 0.000008 $mg.l^{-1}$ or 0.008 $\mu g.l^{-1}$.

SRA_{ECO}
Chronic toxicity data for more than four (n=5) taxonomic groups are available. The SRA_{ECO} is therefore derived using statistical extrapolation. The chronic toxicity data selected for ERL derivation are distributed log-normally (P=0.1). SRA_{ECO} is 0.049 $mg.l^{-1}$ or 49 $\mu g.l^{-1}$ (90% CI 13 - 180 $\mu g.l^{-1}$).

4.3.2 Vanadium

Aquatic toxicity data on V can be found in Table A2. 2, Table A2. 11, Table A2. 20, Table A2. 28 and Table A2. 33 in Appendix 2. Data used for ERL derivation can be found in Table A4. 2 in Appendix 4. Acute and chronic toxicity data were found for both freshwater and marine organisms. The sensitivity of freshwater and marine organisms to V was not significantly different (P=0.52 for acute toxicity data and P=0.99 for chronic toxicity data), therefore all aquatic data were combined to one data set for ERL derivation.

Freshwater
Acute toxicity data were found for protozoa, coelenterata, molluscs, annelids, crustaceans, insects, echinoderms and fish. Chronic toxicity data were found for algae, crustaceans and fish. The base set for acute toxicity data is not complete. However, the omission of algea in the acute data is compensated for by chronic data for algea. An assessment factor of 10 may be applied to the lowest NOEC, found for *Jordanella floridae* in a test that started with eggs. The MPA_{water} is therefore 0.041/10 = 0.0041 $mg.l^{-1}$ or 4.1 $\mu g.l^{-1}$.

Marine
The MPA is derived using the combined dataset with application of an assessment factor of 100. The MPA_{marine} = 0.041/100 = 0.00041 mg.l^{-1} or 0.41 µg.l^{-1}.

SRA_{ECO}
Chronic toxicity data for three taxonomic groups are available. The SRA_{ECO} calculated as the geometric mean of acute toxicity data selected for ERL derivation and an assessment factor of 10 is 0.39 mg.l^{-1}, while the SRA_{ECO} based on the geometric mean of chronic toxicity data selected for ERL derivation is 0.098 mg.l^{-1}. The lowest value is selected, therefore the SRA_{ECO} is 0.098 mg.l^{-1} or 98 µg.l^{-1}.

4.3.3 Cobalt
Aquatic toxicity data on Co can be found in Table A2. 3, Table A2. 12, Table A2. 21, Table A2. 29 and Table A2. 34 in Appendix 2. Data used for ERL derivation can be found in Table A4. 3 in Appendix 4. Acute and chronic toxicity data were found for both freshwater and marine organisms. The sensitivity of freshwater and marine organisms to Co was not significantly different for acute toxicity data (P=0.19), while for chronic data the sensitivity was significantly different (P=0.027). Inspection of data shows that in the chronic marine toxicity dataset, two values (NOEC for a crustacean and a fish) are much higher than most other entries (also the chronic freshwater data). These two entries are too few to conclude that marine organisms are less sensitive than freshwater organisms. Moreover, the acute toxicity data do show that a difference in sensitivity is not to be expected. In conclusion, the basis to keep the datasets for marine and freshwater toxicity data separated, is too small. Therefore, all aquatic data were combined to one data set for ERL derivation.

Freshwater
Acute toxicity data were found for bacteria, protozoa, algae, macrophytes, platyhelminthes, nematodes, rotifers, molluscs, annelids, crustaceans, insects, fish and amphibians. Chronic toxicity data were found for cyanobacteria, algae, macrophytes, platyhelminthes, crustaceans and fish. The base set for acute toxicity data is complete. An assessment factor of 10 may be applied to the lowest NOEC. The MPA_{water} is therefore 0.005/10 = 0.0005 mg.l^{-1} or 0.5 µg.l^{-1}.

Marine
There are two chronic studies available with marine crustaceans. Although crustacea as a taxonomic group is not additional with respect to the chronic freshwater toxicity dataset for Co, the species represented in the chronic marine tests are typically marine and are considered to represent additional information. Therefore, the MPA is derived by applying an assessment factor of 50 on the combined dataset. The MPA_{marine} = 0.005/50 = 0.0001 mg.l^{-1} or 0.1 µg.l^{-1}.

SRA_{ECO}
Chronic toxicity data for more than four (*n*=6) taxonomic groups are available. The SRA_{ECO} is therefore derived using statistical extrapolation. The chronic toxicity data selected for ERL derivation data are distributed log-normally. The SRA_{ECO} is 0.746 mg.l^{-1} or 746 µg.l^{-1} (90% CI 260 – 2200 µg.l^{-1}).

4.3.4 Selenium
Toxicity data were only averaged geometrically if data were available for the same species, endpoint, hardness and selenium salt and if the results did not give rise to doubts on appropriateness of averaging. Since especially selenite and selenate exhibit marked differences in toxicity, in many cases, therefore, we did not average data but selected the lowest value if more than one test result was available for one species and the same endpoint.

Freshwater
Aquatic toxicity data on Se can be found in Table A2. 4, Table A2. 13, Table A2. 22, Table A2. 30, and Table A2. 35 in Appendix 2. Data used for ERL derivation can be found in Table A4. 4 in Appendix 4. Acute and chronic toxicity data were found for both freshwater and marine organisms. The sensitivity of freshwater and marine organisms was not significantly different (P=0.53) for acute toxicity data nor for chronic toxicity data (P=0.07). Freshwater and marine datasets were therefore combined for ERL derivation.

Acute toxicity data were found for cyanobacteria, protozoa, algae, macrophytes, rotifers, molluscs, crustaceans, insects, annelids, fish, and amphibians. Chronic toxicity data were found for bacteria, cyanobacteria, protozoa, algae, macrophytes, crustaceans, insects and fish. The base set for acute toxicity data is complete. Since chronic toxicity data are divided over 8 taxonomic groups, for 36 species, the MPA may be derived using statistical extrapolation. We have fitted a normal distribution through the ^{10}log of the chronic data (i.e. NOEC or EC10 values) presented in Table A4. 4 (Appendix 4) using the methodology described by Aldenberg and Jaworska (2002). The sample of 23 toxicity data passes the goodness-of-fit test on normal distribution, indicating that application of the extrapolation method is justified. Goodness-of-fit, species sensitivity distribution (SSD) and its fifth percentile (HC_5) were calculated using the Microsoft Excel application ETX-2000 (Van Vlaardingen *et al.*, 2003).

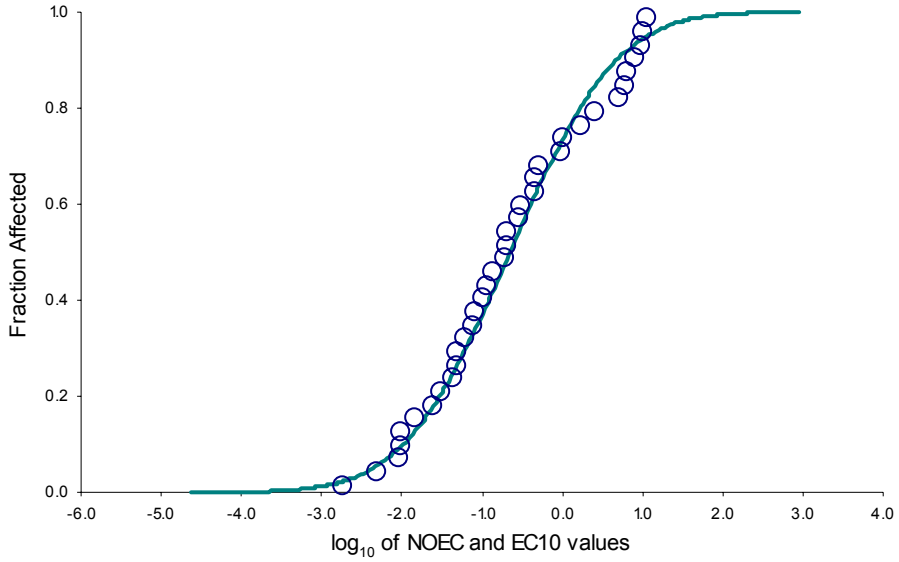

Figure 3. Species sensitivity distribution of chronic selenium toxicity to aquatic organisms. Freshwater and marine data combined. HC_5 = 4.2 µg.l^{-1} (1.3-10); n= *36.*

Figure 3 shows the SSD of freshwater organisms for selenium. The median HC_5 is calculated to be 4.2 µg.l^{-1} (90% confidence interval: 1.3–10 µg.l^{-1}). One NOEC value is below the HC_5, this is a NOEC of 1.8 µg.l^{-1} for growth of the protozoan species *Entosiphon sulcatum*. In decreasing order of toxicity, there are 10 NOEC values for algae, crustaceans and fish species before a NOEC value for a protozoan species occurs again. From this ranking, we tentatively conclude that the protozoans are not a taxon that is particularly sensitive to selenium.

Application of an assessment factor to the HC_5
The TGD states that an assessment factor of 1-5 should be applied to the HC_5, and deviating from a factor of 5 'should be fully justified'. Several considerations are given, which will be addressed in the following.

- *Data quality*. The quality of chronic data is considered to be good. All studies are 'true' chronic studies in the sense that they span either a complete life cycle of the test organism or at least cover sensitive life stages.
- *Diversity of taxa in SSD*. Organisms of various trophic levels are represented in the data set, which is therefore considered to be an adequate reflection of an aquatic ecosystem.
- *Mode of action*. The mode of action of selenium is not yet fully elucidated. The toxicology in freshwater systems is thought to be caused by the synthesis of selenoamino acids (selenocysteine and selenomethionine) that act as analogues of their sulphur analogues (cysteine and methionine). When enzymes are formed -erroneously- with selenoamino acids in place of their sulphur analogues, the differences between selenium and sulphur in atomic size and ionisation properties cause interference in formation of disulphide bridges of the enzyme. This can have major consequences for the tertiary structure of the resulting enzyme and may cause its malfunction or disfunction (Maier and Knight, 1994; Brown and Shrift, 1982). Acute toxic responses in mammals and waterfowl may also involve formation of superoxides causing tissue damage (Lemly, 2002). Selenium has also been shown to be teratogenic to fish in laboratory and field in reproduction studies besides pathological alteration of several internal organs (Lemly, 2002; Lemly, 1993).
- *Statistical uncertainty in HC_5*. As reported above, the HC_5 is 4.2 $\mu g.l^{-1}$ with a 90% confidence interval stretching from 1.3–10 $\mu g.l^{-1}$. The width of the confidence interval around the HC_5 indicates that uncertainty in the HC_5 is relatively small. This is caused by the sample size of n =36 and the close agreement of the data to the fitted normal distribution.
- *Mesocosm/field studies*. Two studies of this type were found. In the first study the effects of selenium on microbial communities in the laboratory or in outdoor experimental streams was investigated (Pratt and Bowers, 1990). The most sensitive responses (expressed as MATC) were observed at 17.3 $\mu g.l^{-1}$ for outdoor and at 14.4 $\mu g.l^{-1}$ for laboratory experiments. This would give NOEC values of approximately 12 $\mu g.l^{-1}$ and
- 10 $\mu g.l^{-1}$, respectively. This is a factor 2.5 to 3 above the HC_5. A second study (Crane *et al.*, 1992) investigated selenium toxicity in freshwater ponds and focused on the effects on abundance of several invertebrate species and on perch reproduction. At 25 $\mu g.l^{-1}$, the invertebrate community was affected only to a limited extent, while perch reproduction was seriously affected. At 10 $\mu g.l^{-1}$ or lower, no effects on fish reproduction were found. The HC_5 of 4.2 $\mu g.l^{-1}$ is also protective for the effects found in this study, by a factor of 2.5.
- *NOEC values below the HC_5*. One NOEC is below the HC_5: a NOEC of 1.8 $\mu g.l^{-1}$ determined for growth of the protozoan species *Entosiphon sulcatum*.

Since the mode of action of selenium is not yet fully clear and effects in the mesocosm studies are relatively close to the HC_5 value, we conclude that an assessment factor of 2 should be applied to the HC_5 to derive the MPA. Therefore, $MPA_{aquatic} = 4.2/2 = 2.1$ $\mu g.l^{-1}$.

When the MPA would have been derived using direct application of assessment factors, a factor of 10 should have been applied to the lowest NOEC. This would give an MPA of $1.8/10 = 0.18$ $\mu g.l^{-1}$. This value is much lower than the HC_5 and would approach the background concentration of selenium (0.041 $\mu g.l^{-1}$). To our opinion, an MPA based on assessment factors would disregard the high amount of experimental information showing that an MPA of 4.2 $\mu g.l^{-1}$ is protective to many of the species and effects investigated.

Marine
The mean of the marine toxicity data for selenium is higher than of the freshwater data, both for acute and chronic data, although not significantly different when tested at the 0.05 level. To our opinion it is therefore appropiate to use the MPA derived for the combined aquatic dataset for the marine compartment: MPA_{marine} = 2.1 µg.l^{-1}.

SRA_{ECO}
Chronic toxicity data for more than four (*n*=8) taxonomic groups are available. The SRA_{ECO} is therefore derived using statistical extrapolation. The chronic toxicity data selected for ERL derivation data are distributed log-normally (P=0.1). SRA_{ECO} is 0.223 mg.l^{-1} or 223 µg.l^{-1} (90% CI 110 – 440 µg.l^{-1}).

4.3.5 Molybdenum
Aquatic toxicity data on Mo can be found in Table A2. 5, Table A2. 14, Table A2. 23 and Table A2. 36 in Appendix 2. Data used for ERL derivation can be found in Table A4. 5 in Appendix 4. Acute toxicity data were found for both freshwater and marine organisms and chronic toxicity data were found for freshwater organisms only. The sensitivity of acute freshwater and marine organisms to Mo was not significantly different (P=0.56), therefore all acute data were combined to one data set for ERL derivation.

Freshwater
Acute toxicity data were found for molluscs, annelids, crustaceans, insects and fish. One chronic toxicity study was found with algae. The base set for acute toxicity data is not complete. Acute toxicity data for algae are lacking. However, a chronic toxicity study with algal species is available, which gives information on the toxicity for that trophic level. EC50 values found for annelids and insects are lower than the NOEC found for algae. Based on the (limited) data available we infer that algae are not the most sensitive taxonomic level. We therefore consider it valid to apply an assessment factor of 1000 to the lowest EC50. The MPA_{water} is therefore 29/1000 = 0.0029 mg.l^{-1} or 29 µg.l^{-1}.

The lowest EC50 value that was found in literature was 0.46 mg.l^{-1}, for mortality of the non-biting midge *Chironomus plumosus*, determined in a 96 h test (Fargašová, 1998). This test result however, is very low compared to all other EC50 values that were obtained for molybdenum. Figure 4 shows a species sensitivity distribution of the combined freshwater and marine acute toxicity dataset for molybdenum, with the EC50 value for *C. plumosus* plotted on the *x*-axis (black dot). In the same paper, an EC50 value of 4.6 mg/l for *Tubifex tubifex* was reported, which is also plotted (black diamond).

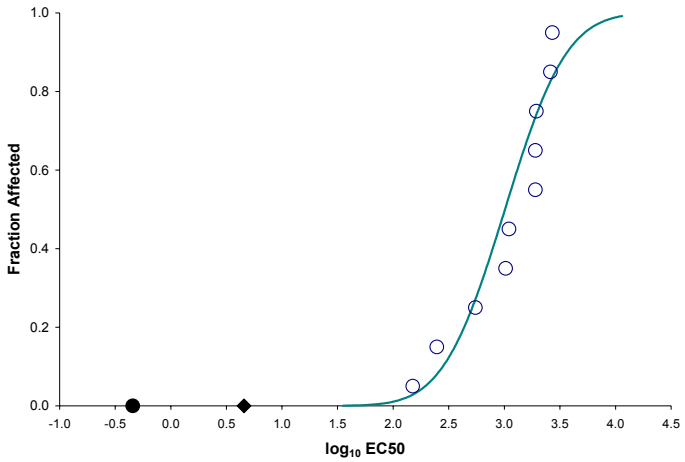

Figure 4. Species sensitivity distribution of acute molybdenum toxicity (open dots). Also shown are LC50 values for T. tubifex (black diamond) and C. plumosus (black dot).

The paper in which the results for molybdenum were published (Fargašová, 1998) reported EC50 values for some other metals as well. A more detailed comparison can also be made for copper (Cu^{2+}), for which a large numer of acute toxicity data for *Chironomus* species were obtained from the RIVM e-toxBase (see section 3.1). Figure 5 shows the acute toxicity data (EC50 and LC50 values) of Cu^{2+} as retrieved from the e-toxBase for various *Chironomus* species, with the EC50 for *C. plumosus* plotted as a black dot. This test result is clearly an outlier, as was found molybdenum toxicity on *C. plumosus*.

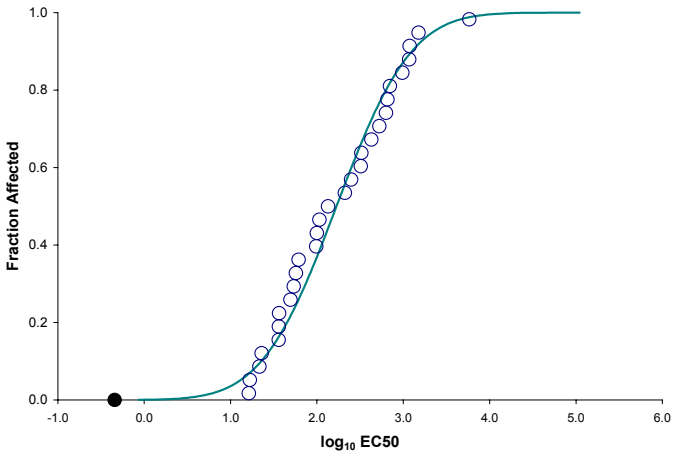

Figure 5. Species sensitivity distribution of acute Cu^{2+} toxicity (open dots) for several Chironomus species. Also shown is the LC50 value for C. plumosus (black dot) from Fargašová (1998).

Based on the anomaly of these test results compared to SSDs, it was decided to reject the study for ERL derivation, i.e. both the results for *C. plumosus* as well as those for *T. tubifex*. The study results are shown in Table A2. 36 (Toxicity of molybdenum to aquatic organisms, data not used).

Marine

In the acute marine toxicity data there is additional information for only one taxonomic group (molluscs). This is too few to lower the assessment factor from 10000 to 1000. Therefore, the

MPA is derived using the combined dataset with application of an assessment factor of 10000. The MPA_{marine} = 29/10000 = 0.0029 $mg.l^{-1}$ or 2.9 $\mu g.l^{-1}$.

SRA_{ECO}
One chronic toxicity datum is available. The SRA_{ECO} calculated as the geometric mean of acute toxicity data selected for ERL derivation and applying an assessment factor of 10 is 66 $mg.l^{-1}$, while the SRA_{ECO} based on the one chronic toxicity study is 54 $mg.l^{-1}$. The lowest value is selected, therefore the SRA_{ECO} is 54.0 $mg.l^{-1}$ or 54000 $\mu g.l^{-1}$.

4.3.6 Tin

Aquatic toxicity data on Sn can be found in Table A2. 6, Table A2. 15, Table A2. 24 and Table A2. 37 in Appendix 2. Data used for ERL derivation can be found in Table A4. 6 in Appendix 4. Acute toxicity data were found for both freshwater and marine organisms and chronic toxicity data were found for freshwater organisms only. The sensitivity of acute freshwater and marine organisms to Sn was not significantly different (P=0.13), therefore all acute data were combined to one data set for ERL derivation.

Freshwater
Acute toxicity data were found for bacteria, cyanobacteria, protozoa, algae, annelids, crustaceans, insects and fish. Chronic toxicity data were found for cyanobacteria, algae, crustaceans and fish. The base set for acute toxicity data is complete. Chronic toxicity data are available for three trophic levels. An assessment factor of 10 may be applied to the lowest NOEC, for the growth rate of *Synechocystis aquatilis*. The MPA_{water} is therefore 0.030/10 = 0.003 $mg.l^{-1}$ or 3.0 $\mu g.l^{-1}$.

Marine
No toxicity data on additional marine taxonomic groups are available. The MPA is derived using the combined dataset with application of an assessment factor of 100.
The MPA_{marine} = 0.030/100 = 0.0003 $mg.l^{-1}$ or 0.3 $\mu g.l^{-1}$.

SRA_{ECO}
Chronic toxicity data for four taxonomic groups are available. The SRA_{ECO} is therefore derived using statistical extrapolation. The chronic toxicity data selected for ERL derivation are distributed log-normally (P=0.1). SRA_{ECO} is 0.40 $mg.l^{-1}$ or
400 $\mu g.l^{-1}$ (90% CI 39 – 4100 $\mu g.l^{-1}$).

4.3.7 Antimony

As mentioned in section 1.2, an EU-RAR is for antimony tri-oxide is available in draft status. For that reason, MPC and NC values will not be derived in the present report. When a finalised version of the current draft EU-RAR is issued, RIVM can present the MPCs and NCs based on the EU-RAR in a concise report.

SRA_{ECO}
The aquatic toxicity data for antimony collected for this report are presented in Table A2. 7, Table A2. 16, Table A2. 25 and Table A2. 38. Data used for SRA_{ECO} derivation can be found in Table A4. 7 in Appendix 4. Acute toxicity data were found for both freshwater and marine organisms and chronic toxicity data were found for freshwater organisms only. Since chronic toxicity data for five taxa are available, the SRA_{ECO} is based on the chronic dataset and calculated using statitical extrapolation. The data are distributed log-normally (P=0.1) and SRA_{ECO} = 11 $mg.l^{-1}$ or 11085 $\mu g.l^{-1}$ (90% CI 832 – 150000 $\mu g.l^{-1}$).

4.3.8 Barium

Aquatic toxicity data on Ba can be found in Table A2. 8, Table A2. 17, Table A2. 26, Table A2. 31 and Table A2. 39 in Appendix 2. Data used for ERL derivation can be found in Table A4. 8 in Appendix 4. Acute and chronic toxicity data were found for both freshwater and marine organisms. The sensitivity of acute freshwater and marine organisms to Ba was not significantly different (P=0.59), therefore all acute data were combined to one data set for ERL derivation. The sensitivity between chronic freshwater and marine data was not tested statistically, since only one chronic marine test result was obtained. The resulting EC10 values from the marine study (8.9 and 14.7 $mg.l^{-1}$) are within the range of results obtained for freshwater species: 2.9-182 mg/l.

Freshwater

Acute toxicity data were found for bacteria, protozoa, macrophytes, platyhelminthes, nematodes, rotifers, molluscs, crustaceans and fish. Chronic toxicity data were found for cyanobacteria, algae, bryophytes, macrophytes and crustaceans. Strictly, the base set for acute toxicity data is not complete since data on algae are missing. This is compensated for by a chronic test with algae showing that algae are not extremely sensitive to barium. Moreover, there are also data on bacteria and cyanobacteria that represent the algal trophic level (primary producers). Chronic toxicity data representing two trophic levels of the base set are available: algae + cyanobacteria and crustaceans. The macrophyte and bryophyte data are not considered as extra trophic levels although they can not be considered to belong to the levels associated with algae/cyanobacteria or crustacea. The chronic information on the trophic level containing crustacea covers the trophic level showing the lowest L(E)C50 value (for the mollusc *Mytilus californianus*) since both taxa can be considered as primay consumers. An assessment factor of 50 may therefore be applied to the lowest NOEC for reproduction of *Dapnia magna*. The MPA_{water} is 2.9/50 = 0.058 $mg.l^{-1}$ or 58 $\mu g.l^{-1}$.

Note that this MPA is only a factor of 3.2 below the lowest acute toxicity result of 190 $\mu g.l^{-1}$.

Marine

No additional chronic marine toxicity data are available. The MPA is derived using the combined dataset by application of an assessment factor of 500.
The MPA_{marine} = 2.9/500 = 0.0058 $mg.l^{-1}$ or 5.8 $\mu g.l^{-1}$.

SRA_{ECO}

Chronic toxicity data for five taxonomic groups are available. The SRA_{ECO} is therefore derived using statistical extrapolation. The chronic toxicity data selected for ERL derivation are distributed log-normally (P=0.1). SRA_{ECO} is 15.1 $mg.l^{-1}$ or
15111 $\mu g.l^{-1}$ (90% CI 6800 – 33400 $\mu g.l^{-1}$).

4.3.9 Thallium

Aquatic toxicity data on Tl can be found in Table A2. 9, Table A2. 18, Table A2. 27 and Table A2. 40 in Appendix 2. Data used for ERL derivation can be found in Table A4. 9 in Appendix 4. Acute toxicity data were found for both freshwater and marine organisms and chronic toxicity data were found for freshwater organisms only. The sensitivity of acute freshwater and marine organisms to Tl was not significantly different (P=0.86), therefore all acute data were combined to one data set for ERL derivation.

Freshwater
Acute toxicity data were found for bacteria, algae, fungi, macrophytes, nematodes, rotifers, crustaceans and fish. Chronic toxicity data were found for algae, macrophytes, crustaceans and fish. The base set for acute toxicity data is complete. Chronic toxicity data at three trophic levels are available. An assessment factor of 10 may be applied to the lowest NOEC for reproduction of *Hyalella azteca*. The MPA_{water} is therefore 0.0016/10 = 0.00016 $mg.l^{-1}$ or 0.16 $\mu g.l^{-1}$.

A chronic study on the effect of $TlSO_4$ to *Lemna minor* reported an EC50 value of 8 $\mu g.l^{-1}$. (Brown and Rattigan, 1979). The study was not used for risk limit derivation since for chronic studies, NOECs or EC10 values are used. It is reported in Table A2. 40. The MPA_{water} protects for effects to this species, since it is a factor of 50 lower than the EC50 value.

Marine
No additional chronic marine toxicity data are available. The MPA is derived using the combined dataset with application of an assessment factor of 100.
The MPA_{marine} = 0.0016/100 = 0.000016 $mg.l^{-1}$ or 0.016 $\mu g.l^{-1}$.

SRA_{ECO}
Chronic toxicity data for four taxonomic groups are available. The SRA_{ECO} is therefore derived using statistical extrapolation. The chronic toxicity data selected for ERL derivation are distributed log-normally (P=0.1). SRA_{ECO} is 0.0065 $mg.l^{-1}$ or 6.5 $\mu g.l^{-1}$ (90% CI 1.6 – 27 $\mu g.l^{-1}$).

4.4 Summary of MPA_{water}

Table 13 and Table 14 show the MPAs that were derived for the freshwater and marine aquatic environment.

Table 13. Final NAs, MPAs and $SRAs_{ECO}$ for freshwater, for nine trace elements.

Element	Symbol	Method of ERL derivation	Assessment factor applied to derive MPA	NA [µg.l^{-1}]	MPA [µg.l^{-1}]	SRA_{ECO} [µg.l^{-1}]
beryllium	Be	AF	50	0.00080	0.080	49
vanadium	V	AF	10	0.041	4.1	98
cobalt	Co	AF	10	0.0050	0.50	746
selenium	Se	SE	2	0.021	2.1	223
molybdenum	Mo	AF	1000	0.2900	29	54000
tin	Sn	AF	10	0.03	3.0	400
antimony	Sb	AF	–[a]	–[a]	–[a]	11085
barium	Ba	AF	50	0.58	58	15111
thallium	Tl	AF	10	0.0016	0.16	6.5

AF= assessment factors, SE = statistical extrapolation.
[a]no NA and MPA derived (see section 1.2.1).

Table 14. Final NAs, MPAs and $SRAs_{ECO}$ for the marine environment, for nine trace elements.

Element	Symbol	Method of ERL derivation	Assessment factor applied to derive MPA	NA [µg.l^{-1}]	MPA [µg.l^{-1}]	SRA_{ECO} [µg.l^{-1}]
beryllium	Be	AF	500	0.000080	0.0080	49
vanadium	V	AF	100	0.0041	0.41	98
cobalt	Co	AF	50	0.0010	0.10	746
selenium	Se	AF	50	0.021	2.1	223
molybdenum	Mo	AF	10000	0.029	2.9	54000
tin	Sn	AF	100	0.0030	0.30	400
antimony	Sb	AF	–[a]	–[a]	–[a]	11085
barium	Ba	AF	500	0.058	5.8	15111
thallium	Tl	AF	100	0.00016	0.016	6.5

AF= assessment factors.
[a]no NA and MPA derived (see section 1.2.1).

4.5 ERLs for the aquatic compartments

In order to arrive at ERLs for both aquatic compartments, the NAs, MPAs, and SRA_{ECO}s derived in the previous chapters (Table 13 and Table 14) should be added to the respective background concentrations. Background concentrations are presented in section 2.3.2 (Table 11). No background concentrations were found for the marine environment. No ERLs can be derived for this compartment. When measurements for background concentrations become available in the future, the NA, MPA and SRA_{ECO} values from Table 18 can be used to derive ERLs for the marine environment. Table 15 shows the resulting ERLs for the freshwater compartment (dissolved fraction) and Table 16 shows the resulting freshwater ERLs for the total water phase. The ERL_{total} values were calculated from the $ERLs_{dissolved}$ (Table 15) using the inverse of the equation shown in section 2.3.2. Table 17 shows the final ERLs for the groundwater compartment (dissolved). The final NC, MPC and SRC_{ECO} values are rounded off to two significant digits.

Table 15. Final NCs, MPCs, and SRC_{ECO}s (dissolved water phase) for freshwater, for nine trace elements.

			Dissolved			Dissolved		
Element	Symbol	Dissolved C_b [µg.l^{-1}]	NA [µg.l^{-1}]	MPA [µg.l^{-1}]	SRA_{ECO} [µg.l^{-1}]	NC [µg.l^{-1}]	MPC [µg.l^{-1}]	SRC_{ECO} [µg.l^{-1}]
beryllium	Be	0.017	0.00080	0.080	49	0.018	0.097	49
vanadium	V	0.82	0.041	4.1	98	0.86	4.9	99
cobalt	Co	0.19	0.0050	0.50	746	0.20	0.69	750
selenium	Se	0.041	0.021	2.1	223	0.062	2.1	220
molybdenum	Mo	1.3	0.2900	29	54000	1.6	30	54000
tin	Sn	0.0082	0.03	3.0	400	0.038	3.0	400
antimony	Sb	0.29	–[a]	–[a]	11085	–[a]	–[a]	11000
barium	Ba	73	0.58	58	15111	74	130	15000
thallium	Tl	0.038	0.0016	0.16	6.5	0.040	0.20	6.5

[a]no NA, MPA, NC and MPC derived (see section 1.2.1).

Table 16. Final NCs, MPCs, and SRC_{ECO}s (total water phase) for freshwater, for nine trace elements.

		Total		
Element	Symbol	NC [µg.l^{-1}]	MPC [µg.l^{-1}]	SRC_{ECO} [µg.l^{-1}]
beryllium	Be	0.018	0.10	51
vanadium	V	1.0	5.8	120
cobalt	Co	0.23	0.81	880
selenium	Se	0.063	2.2	230
molybdenum	Mo	1.7	31	56000
tin	Sn	0.46	37	4900
antimony	Sb	–[a]	–[a]	12000
barium	Ba	77	140	16000
thallium	Tl	0.041	0.21	6.8

[a]no NC, and MPC derived (see section 1.2.1).

Table 17. Final NCs, MPCs, and SRC_{ECO}s for groundwater (dissolved water phase), for nine trace elements.

Element	Symbol	Dissolved C_b [µg.l^{-1}]	Dissolved NA [µg.l^{-1}]	Dissolved MPA [µg.l^{-1}]	Dissolved SRA_{ECO} [µg.l^{-1}]	Dissolved NC [µg.l^{-1}]	Dissolved MPC [µg.l^{-1}]	Dissolved SRC_{ECO} [µg.l^{-1}]
beryllium	Be	0.05	0.00080	0.08	49	0.051	0.13	49
vanadium	V	1.2	0.041	4.1	98	1.24	5.3	99
cobalt	Co	0.63	0.0050	0.50	746	0.64	1.1	750
selenium	Se	0.024	0.021	2.1	223	0.045	2.1	220
molybdenum	Mo	0.69	0.2900	29	54000	1.0	30	54000
tin	Sn	2	0.030	3.0	400	2.0	5.0	400
antimony	Sb	0.091	–[a]	–[a]	11085	–[a]	–[a]	11000
barium	Ba	197	0.58	58	15111	200	260	15000
thallium	Tl	2	0.0016	0.16	6.5	2.0	2.2	8.5

[a]no NA, MPA, NC and MPC derived (see section 1.2.1).

Table 18. Final NAs, MPAs, and $SRAs_{ECO}$ for marine water (dissolved water phase), for nine trace elements.

Element	Symbol	Dissolved NA [µg.l^{-1}]	Dissolved MPA [µg.l^{-1}]	Dissolved SRA_{ECO} [µg.l^{-1}]
beryllium	Be	0.000080	0.0080	49
vanadium	V	0.0041	0.41	98
cobalt	Co	0.0010	0.10	746
selenium	Se	0.021	2.1	223
molybdenum	Mo	0.029	2.9	54000
tin	Sn	0.0030	0.30	400
antimony	Sb	–[a]	–[a]	11085
barium	Ba	0.058	5.8	15111
thallium	Tl	0.00016	0.016	6.5

[a]no NA and MPA derived (see section 1.2.1).

5. Toxicity data and derivation of ERLs for soil and sediment

5.1 Data and analysis

All evaluated toxicity data are summarised in the toxicity data tables shown in Appendix 3. There are no toxicity data for sediment organisms, therefore all ERLs for sediment will be derived using EqP. Methods employed to derive the preferred parameters LC50 and EC50 for acute tests and EC10 or NOEC for chronic tests, are described in section 3.2.2. Appendix 5 tabulates the aggregated data that are used for ERL derivation: the geometric mean or the lowest value per species per taxon is presented. ERLs are derived as described in section 3.3. The following sections contain a short description of the EqP method (section 5.2) and the partition coefficients used (section 5.3). Sections 5.4 - 5.6 contain the derivations of ERLs for the soil compartment and the sediment compartment, respectively.

5.2 Equilibrium partitioning

In order to calculate an MPA_{soil} or $MPA_{sediment}$ from an MPA_{water} using equilibrium partitioning (EqP), the method described in the TGD is followed (sections 2.3.5.3; 3.5.3 and 3.6.2.1). The following equation is used:

$$MPA_{\text{comp, ww, EqP}} = \frac{K_{\text{comp-water}} \cdot MPA_{\text{water}} \cdot 1000}{RHO_{\text{comp}}} \qquad \text{Equation 3}$$

with comp $\in$ {soil, suspended matter}[10]

in which:

$MPA_{comp, ww, EqP}$	maximum permissible addition for compartment *comp* ($\mu g.kg_{ww}^{-1}$)
$K_{comp-water}$	soil or sediment to water partition coefficient ($m^3.m^{-3}$)
MPA_{water}	maximum permissible addition for the water compartment ($\mu g.l^{-1}$)
1000	conversion factor from m^3 to litres ($l.m^{-3}$)
RHO_{comp}	bulk density of wet soil or sediment (suspended matter) ($kg.m^{-3}$)

The $MPA_{comp, ww, EqP}$ is recalculated to a dry weight value ($MPA_{comp, dw, EqP}$). For equations and defaults values, we refer to the TGD.

5.3 Partition coefficients

5.3.1 K_p values for soil

The partitioning of heavy metals in soils has been the subject of several RIVM reports in the last decade, however, the more exotic elements considered in the current report were often not included in those investigations. Concurrent with the risk limit derivation by Van de Plassche and De Bruijn (1992), partition coefficients for soil:water and sediment:water were derived by Bockting *et al.* (1992) for the nine elements that are investigated in this report. Crommentuijn *et al*. (1997) published environmental risk limits for metals and used the K_p values reported by Bockting. An evaluation of K_p datasets used within the RIVM performed in 1998 (Koops *et al.*, 1998) advised against the use of the Bockting K_p data for soil because the dataset was said

[10] Note that for sediment EqP, the TGD uses the suspended matter characteristics.

to be poorly underpinned and showed a lack of consistency compared to other datasets. However, no alternative dataset on partitioning for the elements under investigation was presented. In the update of the ecotoxicological SRCs (Verbruggen *et al.*, 2001) soil-K_p values for barium, cobalt and molybdenum selected by Otte *et al*. (2001) were used. These will also be used in equilibrium partitioning calculations in the current report. The values of Otte *et al*. are taken from the review of Sauvé *et al*. (2000). In this paper, a K_d[11] for Se is also published, which will be used in this report as well (Table 19).

5.3.2 K_p values for sediment

When toxicity data for sediment inhabiting species are lacking, EqP theory is used to derive risk limits for sediment. Following EU-guidance, the $MPA_{sediment}$ is set equal to the $MPA_{suspended\ matter}$, which is calculated from the MPA_{water} using EqP. Bockting *et al.* (1992) published suspended matter-K_p values which will be used in this study; note that these are different from the sediment-K_p values used by Van de Plassche and De Bruijn (1992). The sediment-K_p values used in 1992 were derived from the suspended matter-K_p values by dividing all individual suspended matter-K_p values by 1.5. Consequently, we are now using the original field based suspended matter-K_p values published by Bockting *et al.* (1992). We have calculated the geometric mean K_p values for suspended matter based on the individual data published by Bockting *et al*., since only geometric mean K_p values for sediment were tabulated. Since we have relied on the underlying data rather than rounded off values, this may have caused slight differences in the resulting values.

In addition, a literature search on partitioning data was performed. This resulted in very few papers on sorption of the elements under investigation. No data were retrieved on suspended matter:water partitioning.

Table 19. Mean of log partition coefficients (K_p in l/kg) for soil:water and suspended matter:water for nine trace elements.

Element	log K_p soil:water	Source	log K_p suspended matter:water	Source
Be	1.58[a]	1	2.93	1
V	2.49	1	3.76	1
Co	2.08	3 (in 2)	3.78	1
Se	1.18	3	2.80	1
Mo	1.60	3 (in 2)	3.11	1
Sn	3.28[b]	1	5.57	1
Sb	1.92	1	3.59	1
Ba	3.40	3 (in 2)	3.18	1
Tl	2.20[c]	1	3.18[d]	1

General: a coefficient of variation of approx. 30% should be applied to the log K_p values. This variation was thought to be caused by pH variation between experiments. However, at that time, modelling of pH influence on partitioning behaviour could not be performed.
[a]No soil sorption data were available for Be, adsorption of Be is assumed to be comparable with Mg; [b]No soil sorption data were available for Sn, adsorption of Sn is assumed to be comparable with Pb; [c]No soil sorption data were available for Tl, it was estimated to be more mobile than Zn and Cu; [d]This value is based on the value for sediment presented by Bockting *et al*.; $K_{p,\ susp\ matter}=1.5*K_{p,\ sediment}$ was applied here, in analogy with Bockting *et al*. (1992). Sources. 1 = Bockting *et al.* (1992), 2 = Otte *et al*., 2001; 3 = Sauvé *et al*. 2000.

In Table 19, mean values of log K_p values (l/kg) are given. It must be stated that Bockting *et al.* (1992) have listed several recommendations for further investigations and Van de Plassche

[11] K_d values as reported in Sauvé *et al*. (2000) have been used as K_p values in Otte *et al*. (2001). The definitions of both distribution constants is equal: the -concentration independent- ratio of the concentration in soil over the concentration in water.

and De Bruijn (1992) have readdressed that issue. In their derivation of ecotoxicological serious risk concentrations, Verbruggen *et al*. (2001) have pointed to the uncertainty of ERLs for sediment using EqP, caused by the variation in K_p values for metals in sediment. They compared K_p values from different data sets compiled by different authors, which revealed marked differences.

5.4 ERLs for soil

5.4.1 Beryllium

MPA

Terrestrial toxicity data on Be can be found in Table A3. 4 and Table A3. 11 in Appendix 3. Data used for ERL derivation can be found in Table A5. 1 in Appendix 5. No acute toxicity data were found. Chronic toxicity data were found for macrophytes, annelids, insects and microbial processes. Since toxicity data for three trophic levels are available, an assessment factor of 10 may be applied to the lowest NOEC (or EC10) value, for soil respiration in sandy loam. The $MPA_{soil} = 4.3/10 = 0.43$ mg.kg^{-1}.

SRA_{ECO}

For Be, no acute terrestrial toxicity data were found. The number of taxonomic groups in the chronic data and the number of microbial processes and enzymatic reactions are both less than four. SRA_{ECO} calculated as the geometric mean of toxicity data for microbial processes and enzymatic reactions selected for ERL derivation was 25 mg.kg^{-1}, while the SRA_{ECO} based on the geometric mean of chronic toxicity data for other soil species selected for ERL derivation was 75 mg.kg^{-1}. The SRA_{ECO} derived using EqP is 1.9 mg.kg^{-1}. The lowest value is selected, therefore the SRA_{ECO} is 1.9 mg.kg^{-1}.

5.4.2 Vanadium

MPA

Terrestrial toxicity data on V can be found in Table A3. 1, Table A3. 5 and Table A3. 12 in Appendix 3. Data used for ERL derivation can be found in Table A5. 2 in Appendix 5. Acute toxicity data were found for macrophytes and annelids. Chronic toxicity data were found for macrophytes, microbial processes and enzymatic reactions. Since chronic toxicity data for two trophic levels are available, an assessment factor of 50 may be applied to the lowest NOEC (or EC10) value, for soil respiration in silt loam. The $MPA_{soil} = 1.6/50 = 0.032$ mg.kg^{-1}.

SRA_{ECO}

Toxicity data for more than 4 microbial processes and/or enzymatic reactions were found. The data selected for ERL derivation data are not distributed log-normally. This is caused by the fact that several data come from the same type of study, from which the same concentration was used to derive a NOEC. The SRA_{ECO} is calculated as the geometric mean of the data selected for ERL derivation, which is 84 mg.kg^{-1}, while the SRA_{ECO} based on the chronic toxicity data for other soil species selected for ERL derivation was 25 mg.kg^{-1} (only one result available). The lowest value is selected, therefore the SRA_{ECO} is 25 mg.kg^{-1}.

5.4.3 Cobalt

MPA

Terrestrial toxicity data on Co can be found in Table A3. 6 and Table A3. 13 in Appendix 3. Data used for ERL derivation can be found in Table A5. 3 in Appendix 5. No acute toxicity data were found. Chronic toxicity data were found for macrophytes, annelids, microbial processes and enzymatic reactions. Since chronic toxicity data for three trophic levels are

available, an assessment factor of 10 may be applied to the lowest NOEC (or EC10) value, for soil respiration in sandy loam. The MPA_{soil} = 2.3/10 = 0.23 $mg.kg^{-1}$.

SRA_{ECO}
For Co, no acute terrestrial toxicity data were found. Toxicity data for more than 4 microbial processes and/or enzymatic reactions were found. The SRA_{ECO} is therefore derived using statistical extrapolation. The toxicity data selected for ERL derivation are distributed log-normally (P=0.05), SRA_{ECO} is 203 $mg.kg^{-1}$ (90% CI 103 – 400 $\mu g.l^{-1}$). The SRA_{ECO} based on chronic toxicity data for other soil species selected for ERL derivation, was calculated as the geometric mean: 15 $mg.kg^{-1}$. The lowest value is selected, therefore the SRA_{ECO} is 15 $mg.kg^{-1}$.

5.4.4 Selenium

MPA
Terrestrial toxicity data on Se can be found in Table A3. 7, Table A3. 14 in Appendix 3. Data used for ERL derivation can be found in Table A5. 4 in Appendix 5. No acute toxicity data were found. Chronic toxicity data were found for macrophytes, microbial processes and enzymatic reactions. Since chronic toxicity data for two trophic levels are available, an assessment factor of 50 may be applied to the lowest NOEC (or EC10) value, for *Sorghum vulgare* in sandy soil. The MPA_{soil} = 0.29/50 = 0.0058 $mg.kg^{-1}$.

Two plant studies with Se that could not be used are, however, worthwhile to be discussed (TN&A Associates, 2000). In a study with *M. sativa* in sandy soil, all concentrations gave an effect which was >50%, while the control plants were performing well. This means that even the EC50 is below the lowest tested concentration of 0.25 $mg.kg^{-1}$ soil. A NOEC could not be derived from this study. In a study with *H. vulgare* an EC10 is estimated which is a factor of 20 below the lowest test concentration (0.25 $mg.kg^{-1}$). However, this test result is not used for ERL derivation because the dose response relationship could not be described adequately using available dose-effect models. Both these studies indicate that Se might be more toxic to plant species than suggested by the current studies used for ERL derivation. However, the MPA derived is very low and should be protective for these effects. It allows for an addition of only 0.9% of the background concentration.

SRA_{ECO}
For Se, no acute terrestrial toxicity data were found. Toxicity data for more than 4 microbial processes and/or enzymatic reactions were found. The SRA_{ECO} is therefore derived using statistical extrapolation. The chronic toxicity data selected for ERL derivation are distributed log-normally (P=0.1). SRA_{ECO} is 130 $mg.kg^{-1}$ (90% CI 95 – 190 $\mu g.l^{-1}$). The SRA_{ECO} based on chronic toxicity data for other soil species selected for ERL derivation, was calculated as the geometric mean: 1.2 $mg.kg^{-1}$. The SRA_{ECO} derived using EqP is 3.4 $mg.kg^{-1}$. The lowest value is selected, therefore the SRA_{ECO} is 1.2 $mg.kg^{-1}$.

5.4.5 Molybdenum

MPA
Terrestrial toxicity data on Mo can be found in Table A3. 15 in Appendix 3. Data used for ERL derivation can be found in Table A5. 5 in Appendix 5. No acute toxicity data were found. Chronic toxicity data were found for microbial processes and enzymatic reactions. Since these toxicity data represent one trophic level, an assessment factor of 100 should be applied to the lowest NOEC (or EC10) value, for inhibition of urease activity in clay loam. The $MPA_{soil, direct}$ = 76/100 = 0.76 $mg.kg^{-1}$.

The MPA_{soil} should also be calculated from the MPA_{water} using equilibrium partitioning since there are no test results available on plants or earthworms (see section 1.3.2). Using a log K_p soil of 1.60 and an MPA_{water} of 29 µg.l^{-1}, an $MPA_{soil, EqP}$ of 1.2 mg.kg$_{dw}^{-1}$ is calculated. Since the $MPA_{soil, direct}$ is lower than the MPA calculated via EqP, the $MPA_{soil, direct}$ is selected.

SRA_{ECO}
For Mo, no data were found on acute terrestrial toxicity and no chronic toxicity data on species were found. Toxicity data for 4 microbial processes and/or enzymatic reactions were found. The SRA_{ECO} is therefore derived using statistical extrapolation. The chronic toxicity data selected for ERL derivation are distributed log-normally (P=0.1). SRA_{ECO} is 269 mg.kg^{-1} (90% CI 155 – 468 µg.l^{-1}). The SRA_{ECO} derived using EqP is 2200 mg.kg^{-1}. The lowest value is selected, therefore the SRA_{ECO} is 269 mg.kg^{-1}.

5.4.6 Tin

MPA
Terrestrial toxicity data on Sn can be found in Table A3. 16 in Appendix 3. Data used for ERL derivation can be found in Table A5. 6 in Appendix 5. No acute toxicity data were found. Chronic toxicity data were found for microbial processes and enzymatic reactions. Since these toxicity data represent one trophic level, an assessment factor of 100 should be applied to the lowest NOEC (or EC10) value, for soil respiration in silt loam.
The MPA_{soil} = 6.8/100 = 0.068 mg.kg^{-1}.

The MPA_{soil} should also be calculated from the MPA_{water} using equilibrium partitioning since there were no test results available on plants or earthworms (see section 1.3.2). Using a log K_p soil of 3.28 and an MPA_{water} of 3.0 µg.l^{-1}, an $MPA_{soil, EqP}$ of 5.7 mg.kg$_{dw}^{-1}$ is calculated. Since the $MPA_{soil, direct}$ is lower than the MPA calculated via EqP, the $MPA_{soil, direct}$ is selected.

SRA_{ECO}
For Sn, no data were found on acute terrestrial toxicity and no chronic toxicity data on species were found. Toxicity data for more than 4 microbial processes and/or enzymatic reactions were found. The SRA_{ECO} is therefore derived using statistical extrapolation. The chronic toxicity data selected for ERL derivation are distributed log-normally (P=0.1). SRA_{ECO} is 250 mg.kg^{-1} (90% CI 155 – 401 µg.l^{-1}). The SRA_{ECO} derived using EqP is 690 mg.kg^{-1}. The lowest value is selected, therefore the SRA_{ECO} is 249 mg.kg^{-1}.

5.4.7 Antimony

As mentioned in section 1.2, an EU-RAR is for antimony tri-oxide is available in draft status. For that reason, MPC and NC values will not be derived in the present report. When a finalised version of the current draft EU-RAR is issued, RIVM can present the MPCs and NCs based on the EU-RAR in a concise report.

SRA_{ECO}
The terrestrial toxicity data collected for antimony are presented in Table A3. 8 and Table A3. 24. Data used for SRA_{ECO} derivation can be found in Table A5. 7 in Appendix 5. Toxicity data for 3 taxonomic groups were found. Since no acute toxicity data were found, the SRA_{ECO} is calculated as the geometric mean of the chronic data. SRA_{ECO} is 51 mg.kg^{-1}. The SRA_{ECO} derived using EqP is 924 mg.kg^{-1}. The lowest value is selected, therefore the SRA_{ECO} is 51 mg.kg^{-1}.

5.4.8 Barium

MPA

Terrestrial toxicity data on Ba can be found in Table A3. 2, Table A3. 9 and Table A3. 17 in Appendix 3. Data used for ERL derivation can be found in Table A5. 8 in Appendix 5. Acute toxicity data were found for macrophytes and annelids. Chronic toxicity data were found for annelids, insects and enzymatic reactions. Since chronic toxicity data for three trophic levels are available, an assessment factor of 10 may be applied to the lowest NOEC (or EC10) value, for reproduction of *Folsomia candida*. The MPA_{soil} = 82/10 = 8.2 $mg.kg^{-1}$.

SRA_{ECO}

Toxicity data for 4 microbial processes and/or enzymatic reactions were found. The SRA_{ECO} is therefore derived using statistical extrapolation. The chronic toxicity data selected for ERL derivation are distributed log-normally (P=0.025). SRA_{ECO} is 990 $mg.kg^{-1}$ (90% CI 720 – 1400 $mg.kg^{-1}$). The SRA_{ECO} based on the geometric mean of chronic toxicity data for other soil species selected for ERL derivation is 206 $mg.kg^{-1}$. The SRA_{ECO} derived using EqP is 42000 $mg.kg^{-1}$. The lowest value is selected, therefore the SRA_{ECO} is 206 $mg.kg^{-1}$.

5.4.9 Thallium

MPA

Terrestrial toxicity data on Tl can be found in Table A3. 3and Table A3. 10 in Appendix 3. Data used for ERL derivation can be found in Table A5. 9 in Appendix 5. Acute toxicity data were found for macrophytes and annelids. Chronic toxicity data were found for macrophytes, molluscs and annelids. Since chronic toxicity data for three trophic levels are available, an assessment factor of 10 may be applied to the lowest NOEC (or EC10) value.
The MPA_{soil} = 1.0/10 = 0.10 $mg.kg^{-1}$.

SRA_{ECO}

For Tl, no toxicity data were found on microbial processes and enzymatic reactions. Chronic toxicity data for 3 taxonomic groups were found. Therefore, the SRA_{ECO}, calculated as the geometric mean of acute toxicity data with an assessment factor of 10, is also calculated and is found to be 5.8 $mg.kg^{-1}$. The SRA_{ECO} calculated as the geometric mean for chronic toxicity data for soil species is 1.5 $mg.kg^{-1}$. The SRA_{ECO} derived using EqP is 1.0 $mg.kg^{-1}$. The lowest value is selected, therefore the SRA_{ECO} is 1.0 $mg.kg^{-1}$.

5.5 Summary of NA, MPA and SRA_{ECO} for soil

Table 20 shows the resulting NAs, MPAs and SRA_{ECO}s for soil.

Table 20. Final MPAs, NAs and SRA_{ECO} for soil, for nine trace elements.

Element	Symbol	Method of ERL derivation	AF applied to derive MPA	NA [$mg.kg_{dw}^{-1}$]	MPA [$mg.kg_{dw}^{-1}$]	SRA_{ECO} [$mg.kg_{dw}^{-1}$]
beryllium	Be	AF	10	0.0043	0.43	1.9
vanadium	V	AF	50	0.00032	0.032	25
cobalt	Co	AF	10	0.0023	0.23	15
selenium	Se	AF	50	0.000058	0.0058	1.2
molybdenum	Mo	AF	100	0.00758	0.76	269
tin	Sn	AF	100	0.00068	0.068	249
antimony	Sb	–[a]	–[a]	–[a]	–[a]	51
barium	Ba	AF	10	0.082	8.2	206
thallium	Tl	AF	10	0.001	0.10	1.0

n.a. = not applicable; AF= assessment factors.
[a]no NA and MPA derived (see section 1.2.1).

5.6 NA, MPA and SRA_{ECO} for sediment

No data are found for sediment toxicity of the studied compounds. All $MPA_{sediment}$ (and $NA_{sediment}$) and $SRA_{ECO,\ sediment}$ are therefore calculated using EqP as shown in Table 21. Following the TGD guidance, suspended matter characteristics and suspended matter K_p-values should be used when EqP to derive for sediment ERLs. See section 5.2 for equations and section 5.3.2 for K_p values.

Table 21. Final MPAs, NAs and SRA_{ECO} for sediment, for nine trace elements.

Element	Symbol	Method of ERL derivation	NA [$mg.kg_{dw}^{-1}$]	MPA [$mg.kg_{dw}^{-1}$]	SRA_{ECO} [$mg.kg_{dw}^{-1}$]
beryllium	Be	EqP	0.00068	0.078	42
vanadium	V	EqP	0.24	24	564
cobalt	Co	EqP	0.030	3.0	4497
selenium	Se	EqP	0.013	1.3	142
molybdenum	Mo	EqP	0.37	37	69760
tin	Sn	EqP	56	5586	148489
antimony	Sb	–[a]	–[a]	–[a]	43167
barium	Ba	EqP	0.88	88	22925
thallium	Tl	EqP	0.0024	0.24	10

EqP = equilibrium partitioning.
[a]no NA and MPA derived (see section 1.2.1).

5.7 ERLs for the soil and sediment compartment

In order to arrive at ERLs for both the soil and sediment compartment, the NAs, MPAs, and SRA_{ECO}s derived in the previous chapters (Table 20 and Table 21) should be added to the respective background concentrations. Background concentrations are presented in section 2.3.2 (Table 11). Table 22 shows the resulting ERLs for the soil compartment, Table 23 shows resulting ERLs for the sediment compartment. The resulting ERLs are rounded off to two significant digits.

Table 22. Final NCs, MPCs, and SRC_{ECO}s for soil, for nine trace elements.

Element	Symbol	C_b [mg.kg^{-1}]	NA [mg.kg^{-1}]	MPA [mg.kg^{-1}]	SRA_{ECO} [mg.kg^{-1}]	NC [mg.kg^{-1}]	MPC [mg.kg^{-1}]	SRC_{ECO} [mg.kg^{-1}]
beryllium	Be	1.1	0.0043	0.43	1.9	1.1	1.5	3.0
vanadium	V	42	0.00032	0.032	25	42	42	67
cobalt	Co	9	0.0023	0.23	15	9.0	9.2	24
selenium	Se	0.7	0.000058	0.0058	1.2	0.70	0.71	1.9
molybdenum	Mo	0.5	0.00758	0.76	269	0.51	1.3	270
tin	Sn	19	0.00068	0.068	249	19	19	270
antimony	Sb	3	–[a]	–[a]	51	–[a]	–[a]	54
barium	Ba	155	0.082	8.2	206	160	160	360
thallium	Tl	1.0	0.001	0.10	1.0	1.0	1.1	2.0

[a]no NA, MPA, NC and MPC derived (see section 1.2.1).

Table 23. Final NCs, MPCs, and SRC_{ECO}s for sediment, for nine trace elements.

Element	Symbol	C_b [mg.kg^{-1}]	NA [mg.kg^{-1}]	MPA [mg.kg^{-1}]	SRA_{ECO} [mg.kg^{-1}]	NC [mg.kg^{-1}]	MPC [mg.kg^{-1}]	SRC_{ECO} [mg.kg^{-1}]
beryllium	Be	1.1	0.00068	0.078	42	1.1	1.2	43
vanadium	V	42	0.24	24	564	42	66	610
cobalt	Co	9	0.030	3.0	4497	9.0	12	4500
selenium	Se	0.7	0.013	1.3	142	0.71	2.0	140
molybdenum	Mo	0.5	0.37	37	69760	0.87	38	70000
tin	Sn	19	56	5586	148489	75	5600	150000
antimony	Sb	3	–[a]	–[a]	43167	–[a]	–[a]	43000
barium	Ba	155	0.88	88	22925	160	240	23000
thallium	Tl	1.0	0.0024	0.24	10	1.0	1.2	11

[a]no NA, MPA, NC and MPC derived (see section 1.2.1).

6. Overview of ERLs, comparison with existing Dutch EQSs

Table 24 to Table 27 show the ERLs as derived in this project together with the EQS values that are currently adopted by the Ministry of VROM (Stuurgroep INS, 1999). Recent values for EQSs can be retrieved via the internet at the URL: http://www.stoffen-risico.nl. For the nine elements investigated here, the EQS values at this site are identical to the values published in Stuurgroep INS (1999).
The following comparisons will be made:

1. The target value (TV) is an EQS that is usually based on the NC. In the tables below, we compare TVs set by the Ministry of VROM to NCs derived in this report.
2. The MPC is not an EQS and is usually not reported by the Ministry of VROM. Comparison of MPCs to EQSs can therefore not be made. We have therefore chosen to compare MPCs derived in this report to the most recent MPC reported by RIVM.

The SRC_{ECO} is not an EQS and for the elements investigated here it is usually not reported by the Ministry of VROM. The SRC_{ECO} is used as basis for the intervention value (IW), but the IW may also be based on toxicity data for humans. It would be beyond the scope of this report to trace the background of each individual IW value. Furthermore, for most compartments (for the elements investigated here), IW have not been set. For these reasons we do not present SRC_{ECO} values in this section.

In the tables below, the ERLs derived in this report are given in two significant digits.

6.1 Surface water

Table 24. Existing target values and maximum permissible concentrations versus negligible concentrations and maximum permissible concentrations derived in this report for surface water. Dissolved concentrations are reported throughout the table.

Element	Symbol	TV source: 1 [µg.l^{-1}]	NC *this report* [µg.l^{-1}]	MPC source: 1 [µg.l^{-1}]	MPC *this report* [µg.l^{-1}]
beryllium	Be	0.02	0.018	0.2	0.097
vanadium	V	0.9	0.86	4.3	4.9
cobalt	Co	0.2	0.20	2.8	0.69
selenium	Se	0.09	0.062	5.3	2.1
molybdenum	Mo	4.3	1.6	290	30
tin	Sn	0.2	0.038	18	3.0
antimony	Sb	0.4	–[a]	6.5	–[a]
barium	Ba	75	74	220	130
thallium	Tl	0.06	0.040	1.6	0.20

TV = target value; NC = negligible concentration; MPC = maximum permissible concentration.
source 1 = Stuurgroep INS (1999).
[a]no NA and MPA derived (see section 1.2.1).

Comparison of existing TV and NC, shows no or very slight changes (within a factor of 3) for Be, V, Co, Se, Ba and Tl. Changes in MPC and NC for Mo and Sn are discussed in the following.

The NC for Mo has decreased from 4.3 to 1.3, which is equal to the C_b of 1.3 µg.l^{-1}. Since NCs are calculated as MPC/100, one has to look to the MPC (or MPA in the case of metals) for the cause of change. The reason here is that an assessment factor of 1000 is applied to the lowest acute toxicity result (according to TGD assessment factor scheme) to derive the MPA

in this report, while the TV is based on an MPA which was derived using an assessment factor of 100 (assessment factor scheme according to modified EPA method used; Crommentuijn *et al.*, 1997.) This results in MPAs of 29 and 290 µg.l^{-1}, respectively, and MPCs of 30 and 290 µg.l^{-1} as can be seen in Table 24. Dividing the MPAs by 100 and adding these NAs to C_b gives NC values: NC = C_b + MPA/100. This accounts for the TV of 4.3 and the NC of 1.6 µg.l^{-1} as reported in Table 24. Concluding: the change of assessment factor scheme to be used in standard setting has caused these ERLs for Mo to decrease.

The NC for Sn decreases from 0.2 to 0.038 µg.l^{-1} (still more than a factor of 10 above C_b). In this case new chronic toxicity data have become available. The same assessment factor (factor of 10) was applied to derive the MPA in both cases, but the lowest NOEC from a chronic study changed from 180 µg.l^{-1} to 30 µg.l^{-1}. Concluding: the availability of new data has caused a decrease in the ERLs for Sn.

Most MPCs derived in this report decrease, and those for Be, V, Se and Ba are close to a factor of 2 of the earlier derived MPCs. The change in MPC for Mo is caused by identical reasons as discussed in the previous sections. For Tl, the MPC decreases by a factor of 8. This is caused because more toxicity data have become available, which included enough *chronic* toxicity data to apply an assessment factor of 10. The previous MPC was derived using an assessment factor of 100 to the lowest *acute* toxicity result. For Sn, the finding of new toxicity data have lead to a lower MPC. For Co, the MPC derived now is lower than the previous MPC since, following TGD guidance, the MPC has to be derived using assessment factors (data are available for 6 taxonomic groups), which means: applying a factor of 10 to the lowest NOEC. In the dataset used by Van de Plassche *et al*. in 1992, the same NOEC was also the lowest value, but the MPC was then derived using statistical extrapolation.

6.2 Groundwater

Table 25. Existing target values and maximum permissible concentrations versus negligible concentrations and maximum permissible concentrations derived in this report for groundwater. Dissolved concentrations are reported throughout the table.

Element	Symbol	TV source: 1 [µg.l^{-1}]	NC *this report* [µg.l^{-1}]	MPC source: 2 [µg.l^{-1}]	MPC *this report* [µg.l^{-1}]
beryllium	Be	0.05[a]	0.051	0.21	0.13
vanadium	V	1.2[a]	1.24	4.7	5.3
cobalt	Co	0.7[a]	0.64	3.2	1.1
selenium	Se	0.07[a]	0.045	5.3	2.1
molybdenum	Mo	3.6[a]	1.0	290	30
tin	Sn	2.2[a]	2.0	20	5.0
antimony	Sb	0.15[a]	–[b]	6.3	–[b]
barium	Ba	200[a]	200	350	260
thallium	Tl	2[1]	2.0	3.6	2.2

TV = target value; NC = negligible concentration; MPC = maximum permissible concentration.
[a]deep groundwater.
[b]no NA and MPA derived (see section 1.2.1).
source 1 = Stuurgroep INS (1999).
source 2 = Crommentuijn *et al*. (1997).

For groundwater, differences between NCs derived in this report and existing TVs are small in most cases, except for Mo. The NC for Mo is 1.0 µg.l^{-1}, while its TV is 3.6 µg.l^{-1} (newly derived value is lower) and the NC for Sb is 0.57 µg.l^{-1}, while its TV is 0.15 µg.l^{-1} (newly derived value is higher). These differences are caused by a change in the value of the MPA, for the same reasons as described in section 6.1.

6.3 Soil

Table 26. Existing target values and maximum permissible concentrations versus negligible concentrations and maximum permissible concentrations derived in this report for soil.

Element	Symbol	TV source: 1 [mg.kg^{-1}]	NC *this report* [mg.kg^{-1}]	MPC source: 2 [mg.kg^{-1}]	MPC *this report* [mg.kg^{-1}]
beryllium	Be	1.1	1.1	1.1	1.5
vanadium	V	42	42	43	42
cobalt	Co	9	9.0	33	9.2
selenium	Se	0.7	0.70	0.81	0.71
molybdenum	Mo	3	0.51	254	1.3
tin	Sn	–	19	53	19
antimony	Sb	3	–[a]	3.5	–[a]
barium	Ba	160	160	165	160
thallium	Tl	1	1.0	1.3	1.1

- = no value available in Stuurgroep INS (1999).
TV = target value; NC = negligible concentration; MPC = maximum permissible concentration.
source 1 = Stuurgroep INS (1999).
source 2 = Crommentuijn *et al*. (1997)
[a]no NA and MPA derived (see section 1.2.1).

The NCs for soil are equal to the TVs, except for Mo. The NC for Mo proposed here is 0.51, while its TV was 3 mg.kg^{-1}. The reason that newly derived NCs are equal to the existing TVs is that the NCs are equal to C_b. Since NC is calculated as NC = C_b + NA and NA is only a fraction of C_b for the elements investigated here, the NC values become equal to the background concentration. The MPA for Mo was 253 mg.kg^{-1} (Crommentuijn *et al.*, 1997), which gave an NA of 2.5 mg.kg^{-1}. The MPC was based on equilibrium partitioning, since there were no soil toxicity data for Mo when this MPC was derived (Van de Plassche *et al.*, 1992). In this report however, we have incorporated the toxicity data for soil micro-organisms and enzymatic reactions (already mentioned in Van de Plassche *et al*., but not used), which resulted in an MPA_{soil} of 0.76 mg.kg^{-1}. Since the NA is 1/100th of the MPA, and C_b is 0.5 mg.kg^{-1} for Mo, the NC becomes equal to C_b, as is the case for the other elements investigated here.

Five out of eight MPCs for soil (Be, V, Se, Ba, Tl) that were derived using equilibrium partitioning (Crommentuijn *et al.*, 1997), are more or less equal to the MPCs in this report, which are derived using soil toxicity data. This is surprising, since the use of EqP in the derivation of ERLs for these elements is regarded as a step which bears a high intrinsic variation (Van Beelen *et al.*, 2003; Sauvé *et al.*, 2000). This is caused a.o. by the selection and/or availability of K_p values; e.g. soil K_p values for Be, Ba and Tl were not available and K_p values for other metals were used instead.

For Co, Mo and Sn, the difference between ‘old’ and ‘new’ MPCs is higher. For Co and Sn, the MPC decreases with a factor of 2-3; while for Mo the decrease is roughly a factor of 200. A large part of this difference for Mo can be explained from the use of assessment factors. The existing (‘old’) MPC for water was rather high, since an assessment factor of 100 was applied to derive it (a factor of 1000 has been applied to the same test result elsewhere in this report), consequently, the MPC_{soil} was also relatively high, since it had been derived using equilibrium partitioning. The MPC_{soil} derived in this report (not derived using EqP) is also derived using a relatively high assessment factor of 100 because data for only one trophic level are available. This example illustrates the impact of assessment factors and changing of guidance on the height of ERLs.

6.4 Sediment

Table 27. Existing target values and maximum permissible concentrations versus negligible concentrations and maximum permissible concentrations derived in this report for sediment.

Element	Symbol	TV source: 1 [mg.kg^{-1}]	NC *this report* [mg.kg^{-1}]	MPC source: 1 [mg.kg^{-1}]	MPC *this report* [mg.kg^{-1}]
beryllium	Be	1.1	1.1	1.2	1.2
vanadium	V	42	42	56	66
cobalt	Co	9	9.0	19	12
selenium	Se	0.7	0.71	2.9	2.0
molybdenum	Mo	3	0.87	200	38
tin	Sn	-	75	-	5600
antimony	Sb	3	–[a]	15	–[a]
barium	Ba	160	160	300	240
thallium	Tl	1	1.0	2.6	1.2

- = no value available in Stuurgroep INS (1999).
TV = target value; NC = negligible concentration; MPC = maximum permissible concentration.
source 1 = Stuurgroep INS (1999).
[a]no NA and MPA derived (see section 1.2.1).

Background values for sediment have been set equal to those for soil, because no measurement data for sediment are available. If the NA is small compared to C_b, NC will equal C_b, as is the case for all soil NC values (see the section directly below Table 26). For sediment, this is also the case for sixt of the eight elements discussed here. For Mo the NA is in the same order of magnitude as C_b itself, resulting in an NC value of 0.87 mg.kg^{-1}. For Mo this is lower than the existing TV. The change in NA has several reasons: (i) in the equilibrium partitioning method used, K_p values for suspended matter have been used rather than for sediment (according to TGD guidance); (ii) the MPAs for water have changed due to the change in assessment factor scheme. The same reasons are the cause for the change in the MPC value for Mo. For the other elements (Be, V, Co, Se, Ba and Tl), the MPCs derived in this report are all close to the existing MPC values, i.e. within a factor of 2 from the MPCs given in Stuurgroep INS (1999).

7. Preliminary risk analysis

A preliminary risk analysis can be made for the freshwater and groundwater compartment. For other compartments (soil, sediment, seawater), no measurement data are available.

7.1 Occurrence in major Dutch rivers and lakes

Table 28 - Table 33 show measurements of several elements in major rivers and lakes in the Netherlands. No data were found for molybdenum, tin and thallium. We have chosen to present the following data selection (if available):

- data from 1998, 1999 and 2000, since these were the most recent data available,
- data from 1972 to 1997 are reported as median or average values over the entire period,
- for each main Dutch river, an upstream, midstream and downstream location was selected as far as data were available,
- data for lakes.

Four data sources were used:

- data from Baggelaar and Baggelaar (1995) represent sampling periods and are presented as median values (since these were reported as such),
- raw data from the WaterBase database (RIZA/RIKZ, 2003) were used to calculate the yearly average, standard deviation and number of samples for the 1998, 1999 and 2000 sampling series. For the periods (column 3 in Table 28-Table 33) that span more than 1 year, the WaterBase data were used to calculate an average over the entire period. In calculations of average values, values below the detection limit and values reported as '0' (zero) were excluded.
- data from RIWA (RIWA, 2002; RIWA, 2000) were also used. Although RIWA data and WaterBase (RIZA) data are often reported for the same locations and the same year, all samples from measurement series are independent (Baars, 2003).

The yearly averages calculated from the WaterBase data at all available locations are presented in Appendix 6. For concentrations reported for a one year period (i.e. 1998, 1999 and 2000) average values for one year are reported; for the data from sampling periods longer than 1 year (see column 3), the reported value is a *median* over the entire sampling period for data from Baggelaar and Baggelaar (1995), and an *average* for data from the WaterBase database (RIZA/RIKZ, 2003). Note that when a period of several years is reported, the beginning and end of the sampling series is given, sampling has not necessarily taken place in each year within that period.

Table 28. Beryllium concentrations in major rivers and lakes in the Netherlands.

River or lake	location	year or period	Concentration [µg.l^{-1}]	Standard deviation	*n*	Reference
Drentse Aa	De Punt	1977-1981	0.078		4	RIZA/RIKZ, 2003
Rhine	Lobith	1983-1993	0.059			Baggelaar and Baggelaar, 1995
Lek	Hagestein	1986-1994	0.02			Baggelaar and Baggelaar, 1995
	Lekkanaal	1987-1994	0.04			Baggelaar and Baggelaar, 1995
	Nieuwegein	1998	0.08		13	RIWA, 2000
	Nieuwegein	1998	0.08	0.016	4	RIZA/RIKZ, 2003
	Nieuwegein	1999	0.11			RIWA, 2002
	Nieuwegein	1999	0.108	0.022	4	RIZA/RIKZ, 2003
	Nieuwegein	2000	0.13			RIWA, 2002
	Nieuwegein	2000	0.165	0.034	4	RIZA/RIKZ, 2003
	Vuren	1975-1981	0.098		7	RIZA/RIKZ, 2003
	Maassluis	1975-1981	0.092		6	RIZA/RIKZ, 2003

River or lake	location	year or period	Concentration [µg.l^{-1}]	Standard deviation	*n*	Reference
Meuse	Eijsden	1980-1993	0.02			Baggelaar and Baggelaar, 1995
	Heusden	1980-1988	0.07			Baggelaar and Baggelaar, 1995
	Gat $^{v}/_{d}$ Kerksloot	1986-1994	0.018			Baggelaar and Baggelaar, 1995
	Brakel	1986-1993	0.012			Baggelaar and Baggelaar, 1995
	Moerdijkbruggen	1975-1977	0.073		3	
	Keizersveer	1981-1994	0.01			Baggelaar and Baggelaar, 1995
	Keizersveer	1998	<d.l. (0.03)		40	RIWA, 2000
Haringvliet	Stellendam	1986-1993	0.01			Baggelaar and Baggelaar, 1995
Lake IJsselmeer	Andijk	1981-1993	0.025			Baggelaar and Baggelaar, 1995
	Andijk	1998	<d.l. (0.05)		13	RIWA, 2000
	Andijk	1999	<d.l. (0.05)		13	RIWA, 2002
Loosdrecht lakes	Loenderveense plas	1977-1980	0.02		4	RIZA/RIKZ, 2003

n = the number of samples within a year when a one year period is reported, and the number of years when an average value over more years is reported.

Table 29. Vanadium concentrations in major rivers and lakes in the Netherlands.

River or lake	location	year or period	Concentration [µg.l^{-1}]	*n*	Reference
Drentse Aa	De Punt	1977-1980	2.45	4	RIZA/RIKZ, 2003
Rhine	Lobith	1975-1981	9.59	6	RIZA/RIKZ, 2003
Lek	Hagestein	1981	5.77	1	RIZA/RIKZ, 2003
	Hagestein	1984-1993	6.0		Baggelaar and Baggelaar, 1995
Waal	Vuren	1975-1981	8.3	7	RIZA/RIKZ, 2003
	Maassluis	1975-1981	10.1	7	RIZA/RIKZ, 2003
IJssel	Kampen	1975-1981	8.115	7	RIZA/RIKZ, 2003
Meuse	Eijsden	1975-1981	8.14	7	RIZA/RIKZ, 2003
	Lith boven	1975-1978	6.36	4	RIZA/RIKZ, 2003
Amer	Moerdijkbruggen	1975-1978	8.95	3	RIZA/RIKZ, 2003
Scheldt	Schaar van Ouden Doel	1975-1981	25.4	6	RIZA/RIKZ, 2003
Lake IJsselmeer	Andijk	1981-1993	3.17		Baggelaar and Baggelaar, 1995
Loosdrecht lakes	Loenderveense plas	1975-1981	2	4	RIZA/RIKZ, 2003

n = the number of samples within a year when a one year period is reported, and the number of years when an average value over more years is reported.

Table 30. Cobalt concentrations in major rivers and lakes in the Netherlands.

River or lake	location	year or period	Concentration [µg.l^{-1}]	*n*	Reference
Drentse Aa	De Punt	1972-1982	1.594	3	RIZA/RIKZ, 2003
Rhine	Lobith	1972-1984	2.275	12	RIZA/RIKZ, 2003
Lek	Hagestein	1972-1982	1.813	7	RIZA/RIKZ, 2003
	Lekkanaal	1978-1985	0.925		Baggelaar and Baggelaar, 1995
	Vreeswijk	1978-1983	4.0		Baggelaar and Baggelaar, 1995
Waal	Vuren	1974-1982	2.01	7	RIZA/RIKZ, 2003
	Maassluis	1974-1982	1.42	3	RIZA/RIKZ, 2003
IJssel	Kampen	1977-1982	1.910	6	RIZA/RIKZ, 2003
Meuse	Eijsden	1972-1984	1.812	13	RIZA/RIKZ, 2003
	Eijsden	1980-1985	0.5		Baggelaar and Baggelaar, 1995
	Lith boven	1975-1981	2.239	7	RIZA/RIKZ, 2003
Hollands Diep	Klundert	1973-1974	1.833	2	RIZA/RIKZ, 2003
Lake IJsselmeer	Vrouwenzand	1975	1.667	1	RIZA/RIKZ, 2003
Loosdrecht lakes	Loenderveense plas	1972-1982	1.239	3	RIZA/RIKZ, 2003

n = the number of samples within a year when a one year period is reported, and the number of years when an average value over more years is reported.

Table 31. Selenium concentrations in major rivers and lakes in the Netherlands.

River or lake	location	year or period	Concentration [µg.l^{-1}]	Standard deviation	*n*	Reference
Drentse Aa	De Punt	1975-1981	1.000		4	RIZA/RIKZ, 2003
Rhine	Lobith	1984-1993	0.5			Baggelaar and Baggelaar, 1995
	Lobith	1975-1997	1.264		10	RIZA/RIKZ, 2003
	Lobith	1998	0.79			RIWA, 2000
	Lobith	1998	0.917	1.565	6	RIZA/RIKZ, 2003
	Lobith	1999	0.23			RIWA, 2002

River or lake	location	year or period	Concentration [µg.l^{-1}]	Standard deviation	*n*	Reference
	Lobith	1999	0.280	0.148	5	RIZA/RIKZ, 2003
	Lobith	2000	0.13			RIWA, 2002
	Lobith	2000	0.176	0.121	5	RIZA/RIKZ, 2003
Lek	Hagestein	1986-1994	0.5			Baggelaar and Baggelaar, 1995
	Lekkanaal	1987-1994	0.25[12]			Baggelaar and Baggelaar, 1995
	Nieuwegein	1998	<d.l.			RIWA, 2000
	Nieuwegein	1999	<d.l.			RIWA, 2002
	Nieuwegein	2000	<d.l.			RIWA, 2002
Waal	Vuren	1975-1981	1.673		6	RIZA/RIKZ, 2003
	Maassluis	1975-1981	1.454		6	RIZA/RIKZ, 2003
IJssel	Kampen	1975-1981	1.610		6	RIZA/RIKZ, 2003
Meuse	Eijsden	1975-1997	1.857		11	RIZA/RIKZ, 2003
	Eijsden	1998	0.36			RIWA, 2000
	Eijsden	1998	0.309	0.123	9	RIZA/RIKZ, 2003
	Eijsden	1999	0.345	0.131	11	RIZA/RIKZ, 2003
	Eijsden	2000	0.162	0.135	10	RIZA/RIKZ, 2003
Meuse	Gat $^{v}/_{d}$ Kerksloot	1986-1994	0.363			Baggelaar and Baggelaar, 1995
Meuse	Brakel	1986-1993	0.412			Baggelaar and Baggelaar, 1995
Meuse	Keizersveer	1984-1994	0.4			Baggelaar and Baggelaar, 1995
	Keizersveer	1998	0.22			RIWA, 2000
	Keizersveer	1998	0.281	0.191	10	RIZA/RIKZ, 2003
	Keizersveer	1999	0.270	0.156	2	RIZA/RIKZ, 2003
	Keizersveer	2000	1.150	0.212	2	RIZA/RIKZ, 2003
Wantij	Groote Rug	1986-1991	0.5			Baggelaar and Baggelaar, 1995
Haringvliet	Stellendam	1986-1993	1.0			Baggelaar and Baggelaar, 1995
		1998	<d.l.			RIWA, 2000
		1999	<d.l.			RIWA, 2002
Lake IJsselmeer	Andijk	1981-1993	1.0[1]			Baggelaar and Baggelaar, 1995
		1998	<d.l.			RIWA, 2000
		1999	<d.l.			RIWA, 2002
Loosdrecht lakes	Loenderveense plas	1975-1981	1.000		4	RIZA/RIKZ, 2003

n = the number of samples within a year when a one year period is reported, and the number of years when an average value over more years is reported.

Table 32. Antimony concentrations in major rivers and lakes in the Netherlands.

River or lake	location	year or period	Concentration [µg.l^{-1}]	Standard deviation	*n*	Reference
Drentse Aa	De Punt	1977	1		1	RIZA/RIKZ, 2003
Rhine	Lobith	1988-1993	0.5			Baggelaar and Baggelaar, 1995
	Lobith	1998	0.41			RIWA, 2000
	Lobith	1998	0.490	0.197	10	RIZA/RIKZ, 2003
	Lobith	1999	0.21			RIWA, 2002
	Lobith	1999	0.307	0.133	9	RIZA/RIKZ, 2003
	Lobith	2000	0.1			RIWA, 2002
	Lobith	2000	0.224	0.133	5	RIZA/RIKZ, 2003
Lek	Jutphaas	1976-1977	1.500		2	RIZA/RIKZ, 2003
Waal	Vuren	1975-1977	1.778		3	RIZA/RIKZ, 2003
	Maassluis	1975-1981	1.200		5	RIZA/RIKZ, 2003
IJssel	Kampen	1975-1978	1.639		4	RIZA/RIKZ, 2003
Meuse	Eijsden	1998	0.35			RIWA, 2000
	Lith boven	1975-1977	1.500		2	RIZA/RIKZ, 2003
	Keizersveer	1975-1978	1.500		4	RIZA/RIKZ, 2003
	Keizersveer	1988-1994	0.5			Baggelaar and Baggelaar, 1995
	Keizersveer	1998	0.27			RIWA, 2000
	Moerdijkbruggen	1975-1977	2.033		3	RIZA/RIKZ, 2003
Lake IJsselmeer	Vrouwenzand	1975-1980	1.217		5	RIZA/RIKZ, 2003
Loosdrecht lakes	Loenderveense plas	1977	1.000		1	RIZA/RIKZ, 2003

n = the number of samples within a year when a one year period is reported, and the number of years when an average value over more years is reported.

Table 33. Barium concentrations in major rivers and lakes in the Netherlands.

River or lake	location	year or period	Concentration [µg.l^{-1}]	Standard deviation	*n*	Reference
Drentse Aa	De Punt	1978-1983	42		6	RIZA/RIKZ, 2003
Rhine	Lobith	1978-1997	112		9	RIZA/RIKZ, 2003
	Lobith	1984-1993	150			Baggelaar and Baggelaar, 1995

River or lake	location	year or period	Concentration [µg.l^{-1}]	Standard deviation	*n*	Reference
	Lobith	1998	96			RIWA, 2000
	Lobith	1998	96	10	13	RIZA/RIKZ, 2003
	Lobith	1999	88			RIWA, 2002
	Lobith	1999	88	13	13	RIZA/RIKZ, 2003
	Lobith	2000	74			RIWA, 2002
	Lobith	2000	74	8	13	RIZA/RIKZ, 2003
Lek	Hagestein	1986-1994	140			Baggelaar and Baggelaar, 1995
	Lekkanaal	1987-1994	144			Baggelaar and Baggelaar, 1995
	Nieuwegein	1998	115			RIWA, 2000
	Nieuwegein	1998	121	43	4	RIZA/RIKZ, 2003
	Nieuwegein	1999	105			RIWA, 2002
	Nieuwegein	1999	97	29	4	RIZA/RIKZ, 2003
	Nieuwegein	2000	108			RIWA, 2002
	Nieuwegein	2000	120	23	4	RIZA/RIKZ, 2003
Waal	Vuren	1978-1981	123		4	RIZA/RIKZ, 2003
	Maassluis	1979-1981	97		3	RIZA/RIKZ, 2003
IJssel	Kampen	1978-1981	129		4	RIZA/RIKZ, 2003
Meuse	Eijsden	1978-1981	37		9	RIZA/RIKZ, 2003
	Eijsden	1980-1993	28			Baggelaar and Baggelaar, 1995
	Eijsden	1998	24	4	13	RIZA/RIKZ, 2003
	Eijsden	1999	26	3	13	RIZA/RIKZ, 2003
	Eijsden	2000	21	2	13	RIZA/RIKZ, 2003
Meuse	Heusden	1980-1988	58.0			Baggelaar and Baggelaar, 1995
Meuse	Gat $^{v}/_{d}$ Kerksloot	1986-1994	44			Baggelaar and Baggelaar, 1995
Meuse	Brakel	1986-1993	61			Baggelaar and Baggelaar, 1995
	Brakel	1998	38			RIWA, 2000
Meuse	Keizersveer	1985-1994	44.0			Baggelaar and Baggelaar, 1995
	Keizersveer	1998	30			RIWA, 2000
Wantij	Groote Rug	1986-1991	98.5			Baggelaar and Baggelaar, 1995
Haringvliet	Stellendam	1986-1993	69.5			Baggelaar and Baggelaar, 1995
	Stellendam	1998	55			RIWA, 2000
	Stellendam	1999	61			RIWA, 2002
Lake IJsselmeer	Andijk	1981-1993	76.4			Baggelaar and Baggelaar, 1995
	Andijk	1998	69			RIWA, 2000
	Andijk	1999	61			RIWA, 2002
	Andijk	2000	62			RIWA, 2002
Loosdrecht lakes	Loenderveense plas	1978-1982	89		5	RIZA/RIKZ, 2003

n = the number of samples within a year when a one year period is reported, and the number of years when an average value over more years is reported.

7.1.1 Preliminary risk analysis surface water

The elements of which measurements were available are Be, V, Co, Se, Sb and Ba. Obviously, Mo, Sn and Tl have not been monitored on a regular basis. The average values of water concentrations will be compared to the MPCs for surface water derived in this report. The results from this comparison should be interpreted as indicative since data from various locations and many sampling dates are compressed into long term (>1 year's) average values. Moreover, for a first identification of ecological risk one might prefer 90th percentile values of concentrations instead of average or median values to MPC values. However, 90th percentiles were not available for the majority of locations at the time of writing.

Beryllium

The MPC for Be derived in this report is 0.097 µg.l^{-1}. Average concentrations did not exceed the MPC in freshwater lakes or in the river Meuse. In the river Lek (tributary of the river Rhine), the MPC is exceeded at the location Nieuwegein by the more recent yearly averages (1999 and 2000). Figure 6 shows the data from Table A6. 2 in Appendix 6, in which yearly average concentrations for Nieuwegein are presented for the years 1988 to 2000. All yearly averages would be below the 'old' MPC of 0.2 µg.l^{-1} (Crommentuijn *et al.*, 1997). The major cause for the change in this MPC is caused by the change in methodology adopted for risk limit derivation: the MPC of 0.2 µg.l^{-1} was derived using statistical extrapolation while this is no longer allowed using TGD guidance and the available data for Be. Therefore the MPC has now been derived using an assessment factor (AF = 50). The result is the current value of

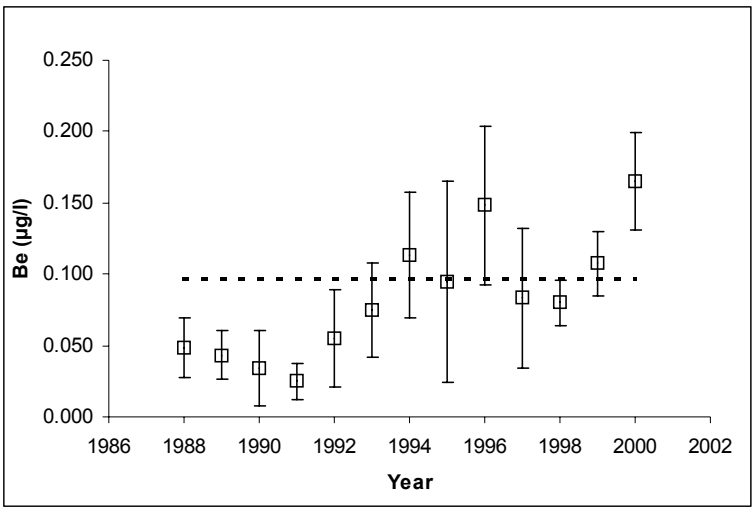

Figure 6. Yearly average concentrations of Be at Nieuwegein in the river Lek.
Error bars represent standard deviations. The dotted line is the MPC.

0.097 µg.l^{-1}. Figure 6 also shows that although there is considerable variation in the data, there seems to be an increase in Be concentrations in the river Lek at Nieuwegein since 1994.

Vanadium
The MPC for V derived in this report is 4.9 µg.l^{-1}. The concentrations found in the Drentse Aa and the two lakes are below this MPC. The long term averages in the major rivers and their tributaries are all above the MPC. The 'old' MPC was 4.3 µg.l^{-1}. This means that effects of these relatively high vanadium concentrations can not be excluded.

Cobalt
The MPC for Co derived in this report is 0.69 µg.l^{-1}. Nearly all average concentrations presented in Table 30 are above the MPC. The existing MPC, reported by Crommentuijn *et al*. (1997), derived by Van de Plassche *et al*. (1992) was 2.8 µg.l^{-1}. All average values in Table 30 are below this MPC value. As outlined in section 6.1 (last paragraph) the change in MPC is caused by the choice for a new methodology: the MPC in this report was derived using TGD guidance while statistical extrapolation was used by Van de Plassche *et al*. to derive the existing MPC.

Selenium
The MPC for Se derived in this report is 2.1 µg.l^{-1}. It is a factor of 2.5 lower compared to the existing MPC. All reported average concentrations of Selenium (Table 31) are below this MPC. A closer look on more extended Se measurement datasets, including maximum values or 90th percentiles might reveal if the MPC is actually exceeded and at what frequency. However, based on this comparison, exceedance of the MPC is expected to occur in a limited number of occasions.

Antimony
No MPC for Sb has been derived for reasons outlined in section 1.2.1. However, all reported average Sb concentrations (Table 32) are below the currently available MPC of 6.5 µg.l^{-1}. A closer investigation of Sb measurement series might reveal if there are peak concentrations that exceed the MPC.

Barium

Figure 7 shows series of yearly averages for Ba in the river Meuse and the river Rhine. Between 1981 and 1988, no data were available. The MPC for Ba, derived in this report (130 µg.l^{-1}) is also shown in the figure. The average concentrations found in the Drentse Aa and the two lakes (Table 33) are below this MPC.

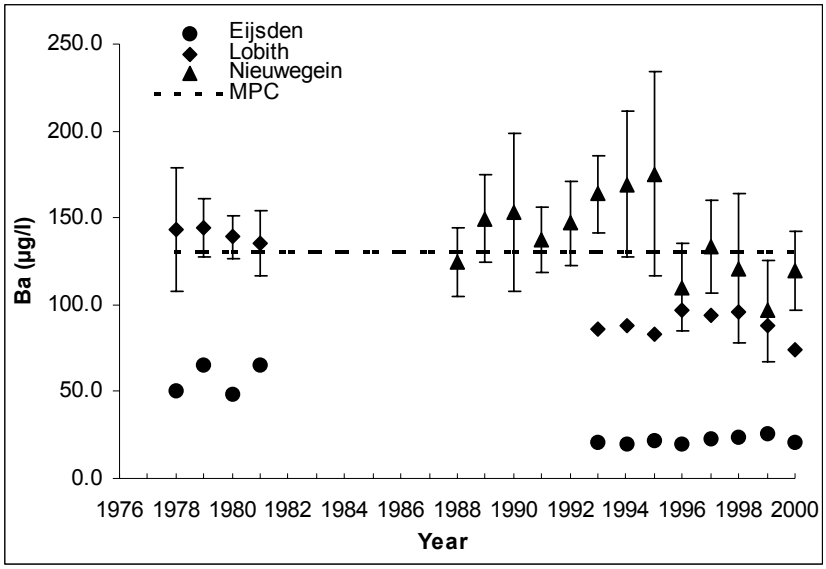

Figure 7. Yearly average concentrations of Ba at Eijsden (Meuse, upstream), Lobith (Rhine, upstream) and Nieuwegein (river Lek, downstream location of the Rhine).
Error bars represent standard deviations. Error bars of the river Meuse are within the symbols.
The dotted line is the MPC.

This graph clearly illustrates that for the river Rhine, at a downstream location (Nieuwegein), concentrations are higher than at an upstream location (Lobith). It also shows a decreasing trend in the height of the average value at Nieuwegein for the period 1996-2000 compared to 1988-1995, but also for the measurements at Lobith in 1978-1981 compared to the more recent measurements. Average values in the river Meuse are consistently lower than the values calculated for the river Rhine. In fact, the outcome of this analysis is that the concentrations in the Meuse are *below the adopted background concentration* of 73 µg.l^{-1}. This is also true for measurements available from the Drentse Aa and Lake IJsselmeer. The origin of the background concentration is as follows:
Crommentuijn *et al*. (1997) calculated a dissolved C_b of 73 µg.l^{-1} from a total C_b of 76 µg.l^{-1}. The value of 76 µg.l^{-1} originates from De Bruijn and Denneman (1992). It is the geometric mean value of 32 samples from brooks ('expected to be clean') from areas in the Northern European lowland and surrounding low mountain ranges. The average concentration at Eijsden (including the standard deviation) in the last decade is even below the 10th percentile of this background value, which was 49 µg.l^{-1}. From these data we conclude that the background concentration of Ba for surface water needs to be reconsidered. Consequently, the MPC of Ba for surface water derived in this report as well as the existing MPC can not be used, since C_b is part of the MPC. The MPA derived in this report is based on the toxicity data only and is still valid.

7.2 Groundwater

The groundwater compartment is spatially heterogeneous in both the vertical and horizontal direction. The composition of the upper groundwater is influenced by anthropogenic activities (land use, atmospheric deposition etc), while deeper groundwater (5-30 m below ground level) is much more dependent on the hydrological and geochemical characteristics of

locations (Fraters *et al.*, 2001). Therefore, preferably, measurement series of concentrations at many locations and different depths should be used. In principle, these data are available from RIVM monitoring networks and sampling campaigns and the report of Fraters *et al*. presents data which include the nine elements that are the subject of this report. A comprehensive, quantitative comparison would be beyond the scope and time frame of this project[12]. However, there are data available to make this comparison. In this section a qualitative comparison of groundwater concentrations is presented. Fraters *et al*. 2001 present graphs that show concentrations of trace elements in both upper groundwater and shallow to middle deep groundwater plotted against the percentile of measurements (see section 7.2.1 for definitions). We have visually interpreted the graphs for the intersection of the MPC derived in this report with the percentile of measurements. Table 34 presents the rough estimates of the percentage of measurements that exceed the MPC in shallow and deep groundwater.

7.2.1 Preliminary risk analysis groundwater

Table 34. Qualitative estimation of MPC exceedance in groundwater for nine trace elements. Presented is the percentage of measurements exceeding the MPC.

Element	Symbol	Upper groundwater % of data >MPC	Year	Shallow to middle deep groundwater % of data >MPC	Year
beryllium	Be	~10 – 80[1,2]	1996, 1999	~10 – 80[1]	1996
vanadium	V	~45 – 50	1999	0	1982
cobalt	Co	~80 – 95	1999	10	1982
selenium	Se	0 – 80[3]	1996	25	1982
molybdenum	Mo	0	1999	0	1982
tin	Sn	0[4]	1991, 1999	no data	
antimony	Sb	0	1999	0	1982
barium	Ba	0	1993-1997	~15	1990-1996
thallium	Tl	0	1999	no data	

All results based on data reported by Fraters *et al*. (2001). Where a range is given, it was not possible to distinguish one intersection value because (i) or measurement series for several soil types were presented, or (ii) a range of values was close to the MPC.
[1]detection limit > MPC.
[2]dependent on soil type and/or geographical location.
[3]80% exceedance for agriculture on sea clay
[4]no monitoring data series; however, available historical data indicate no exceedance.

Definitions of groundwater layers Fraters *et al*. (2001):

- upper groundwater is the upper meter of groundwater that occurs within 5 meters below the surface level,
- shallow groundwater is the groundwater between 5 and 15 meters below the surface level,
- middle deep groundwater is the groundwater between 15 and 30 meters below the surface level.

There are several assumptions underlying the MPC for groundwater, among which are: accepting the background concentration used to be valid for the type of groundwater concerned and accepting the MPA for surface water as representative for groundwater. Bearing these assumptions and the qualitative nature of the risk analysis in mind, the results in Table 34 show that for the upper groundwater, concentrations of Be, V, Co and Se exceed the MPC values derived in this report. For shallow to middle deep groundwater, no data were available for Sn and Tl, hampering a comparison to an environmental risk limit. For Be, Co, Se and Ba between 10 and 80% of groundwater measurements exceed the MPC in shallow to middle deep groundwater. No exceedance of the MPC was observed for V, Mo and Sb in

[12] One should reconsider the establishment of the background concentration (cf. section 1.4.1), compare data to the NC, pay attention to the detection limit, consider variation over regions and groundwater depth.

deeper groundwater. The results of this comparison show that effects on the groundwater ecosystem cannot be excluded for several elements.

8. Conclusions and recommendations

The existing dataset on ecotoxicological information for Beryllium (Be), Vanadium (V), Cobalt (Co), Selenium (Se), Molybdenum (Mo), Tin (Sn), Antimony (Sb), Barium (Ba) and Thallium (Tl) dated from 1992. Literature research was performed and the existing dataset was supplemented with new data. The existing environmental risk limits (ERLs) for these elements were derived in 1992 and re-evaluated in 1997 using the added risk approach since most of these elements are considered to be metals. We have derived ERLs using the supplemented dataset and the methodology for PNEC derivation as laid down in the TGD. At 1-1-2004, the existing methodology for ERL derivation in the Netherlands (formerly called INS-guidance) (Traas, 2001) is replaced by the TGD methodology developed for risk assessment of new and existing chemicals and recently biocides (ECB, 2003). The reasons for differences between the MPC values derived in this report compared to the existing values were either caused by the retrieval of new ecotoxicological information and/or the differences in methodology for ERL derivation. All ERLs derived in this report are presented in Table 35 to Table 38. Since an EU-RAR for antimony tri-oxide (Sb_2O_3) is in preparation, NC and MPC values for Sb were not derived.

All MPCs for soil derived in this report are based on soil ecotoxicological data, while the existing MPCs were all calculated from the MPC_{water} using equilibrium partitioning (EqP). This is result of the fact that several relevant soil toxicity studies were found and because the results of various toxicity studies on soil micro-organisms and soil enzyme activity were used for the ERL derivation. The data on micro-organisms and enzyme activity were already present in the 1992 dataset, but were not included in the ERL derivation.

Within the former INS guidance, EqP was always applied when deriving ERLs for soil (and sediment) using assessment factors and in the comparison of sediment, soil and water ERLs (termed harmonisation). In the current guidance EqP is no longer applied when more than 1 toxicity datum for soil organisms is available. Interestingly, 7 out of 8 newly derived MPCs for soil are close to the existing MPCs, i.e. within a factor of 3. Only for Mo, the MPC decreases by a factor of 200, which is a consequence of the use of different assessment factors and the use of soil ecotoxicological data rather than EqP.

Within the former INS guidance, a standardised lutum content was needed for the recalculation of metal toxicity data to a standard soil. The TGD does not define a lutum content for standard soil. For this reason, the new ERLs for soil are based on concentrations in soil (regardless of soil properties) rather than standard soil.

Sediment ERLs are all based on the ERLs for water EqP. No toxicity data on sediment dwelling organisms were found for each of the elements investigated. All ERLs are therefore based on equilibrium partitioning. Two major differences here are: (i) the ERLs for water have changed due to new data and different ERL derivation methodology and (ii) EqP in the TGD guidance is performed using suspended matter characteristics rather than sediment characteristics. Typically, the K_p suspended matter values used for EqP are a factor of 1.5 higher than the values that were used to derive the existing ERLs. The net result is an increase in sediment ERLs, within a factor of 2 for most elements. For Mo the MPC decreased by a factor of 4 mainly because the MPCwater decreased.

Mainly, current ERLs for surface water are lower than the previous ERLs. These changes are caused by the use of other assessment factors due to change in guidance and the retrieval of new toxicity data may have led to a further decrease in ERLs. One important cause for differences is the fact that in the former INS methodology, the use of statistical extrapolation to calculate an HC_5 was allowed for smaller datasets (when toxicity data from at least 4 taxa were available) while under TGD guidance this is allowed only for large datasets (when toxicity data from at least 8 taxa and 10 species are available).

Most ERLs for groundwater derived in this report are lower than the existing ERLs since groundwater ERLs are set equal to those for surface water (for metals this is only the *added* part of the standard, i.e. the negligible addition (NA), maximum permissible addition (MPA) or ecotoxicological serious risk addition (SRA_{ECO})). Most MPC values are lowered by a factor of 2-3 or less. Larger decrease in MPC values (Mo, Sn) is caused by change in methodology (Mo, use of different assessment factors) or the use of additional toxicity data (Sn).

Measured concentrations in surface water (major rivers and some lakes) in the Netherlands were available for Be, V, Co, Se, Sb and Ba. The MPC for Se and Sb (NB the MPC for Sb has not been updated) are not exceeded by yearly average concentrations or long term (>1 year) averages. It remains to be investigated if occurring peak concentrations are also below the MPC. The MPC is exceeded in surface waters for Be, V, Co and Ba. For Ba, a decreasing trend is observed in more recent years. Yearly averages in the Rhine at Lobith are now well below the MPC as opposed to the early eighties. At the downstream location of Nieuwegein, average concentrations from recent years are below, but close to the MPC. Occurrence of the MPC probably occurs at regular intervals at more downstream locations. Contrastingly, the Ba concentrations in the river Meuse are very low. They are even below the background concentration used in ERL setting. This C_b value dates from 1992 and needs to be reconsidered. A lower background concentration would lead to a lower MPC.

A qualitative comparison with groundwater concentrations shows that for the upper groundwater, the MPC for the Mo, Sn, Ba and Tl is not exceeded. Be, V, Co and Se exceed the MPC in upper groundwater at many of the sampled locations. In shallow to middle deep groundwater, Be also exceeds the MPC at many locations, while exceedance for Co, Se and Ba was estimated to occur at less than 25% of the locations. For Sn and Tl no values for shallow to middle deep groundwater were available.

The following conclusions can be drawn.

- The ERLs for soil for all eight elements are now based on soil ecotoxicological data, in contrast to the existing values that were based on EqP. For this reason, we considered the quality of these ERLs to be improved, although the datasets for some compounds are still small.
- For most elements, more data have become available on aquatic toxicity which has improved the quality of the aquatic datasets (see Appendix 1).
- The introduction of the TGD methodology in ERL derivation in combination with the retrieval of new toxicity data has led to lower ERLs, in most cases.
- There are no data on occurrence (measured concentrations) of the elements in the following environmental compartments:
    1. background concentrations or measurement series of the elements investigated in sea water and (freshwater) sediment;
    2. concentration measurements of Mo, Sn and Tl in freshwater;
    3. concentration measurements of all nine elements investigated in soil;

- The background concentration of Ba in surface water needs to be re-established.
- Long term average concentrations of Be, V, Co and Ba exceed the MPC in major rivers and lakes in the Netherlands, while long term averages for Se and Sb were below the MPC. Be concentrations in the river Lek at Nieuwegein show an increasing trend over the last decade and are now at or above the MPC.
- The MPC for the upper groundwater was exceeded at many locations (10-95%) for Be, V, Co and Se. In shallow to middle deep groundwater, concentrations exceeded the MPC at maximally 80% of the sampling locations for Be and ≤ 25% for Co, Se and Ba. For Sn and Tl no data were available for shallow to middle deep groundwater.

Tables showing all derived ERLs are presented below. The resulting ERLs (NC, MPC and SRC_{ECO}) have been rounded off to two significant digits.

Table 35. Overview of background concentrations, additions and environmental risk limits for nine trace elements for surface water (dissolved fraction).

		Dissolved	Dissolved		Dissolved		Dissolved	
Element	Symbol	C_b [µg.l^{-1}]	NA [µg.l^{-1}]	NC [µg.l^{-1}]	MPA [µg.l^{-1}]	MPC [µg.l^{-1}]	SRA_{ECO} [µg.l^{-1}]	SRC_{ECO} [µg.l^{-1}]
beryllium	Be	0.017	0.00080	0.018	0.080	0.097	49	49
vanadium	V	0.82	0.041	0.86	4.1	4.9	98	99
cobalt	Co	0.19	0.0050	0.20	0.50	0.69	750	750
selenium	Se	0.041	0.021	0.062	2.1	2.1	220	220
molybdenum	Mo	1.3	0.29	1.6	29	30	54000	54000
tin	Sn	0.0082	0.03	0.038	3.0	3.0	400	400
antimony	Sb	0.29	–[a]	–[a]	–[a]	–[a]	11000	11000
barium	Ba	73	0.58	74	58	130	15000	15000
thallium	Tl	0.038	0.0016	0.040	0.16	0.20	6.5	6.5

[a]no NA, NC, MPA and MPC derived (see section 1.2.1).

Table 36. Overview of environmental risk limits for nine trace elements for surface water (total water phase).

		Total		
Element	Symbol	NC [µg.l^{-1}]	MPC [µg.l^{-1}]	SRC_{ECO} [µg.l^{-1}]
beryllium	Be	0.018	0.10	51
vanadium	V	1.0	5.8	120
cobalt	Co	0.23	0.81	880
selenium	Se	0.063	2.2	230
molybdenum	Mo	1.7	31	56000
tin	Sn	0.46	37	4900
antimony	Sb	–[a]	–[a]	12000
barium	Ba	77	140	16000
thallium	Tl	0.041	0.21	6.8

[a]no NC and MPC derived (see section 1.2.1).

Table 37. Overview of background concentrations, additions and environmental risk limits for nine trace elements for groundwater (dissolved fraction).

Element	Symbol	Dissolved C_b [µg.l^{-1}]	Dissolved NA [µg.l^{-1}]	Dissolved NC [µg.l^{-1}]	Dissolved MPA [µg.l^{-1}]	Dissolved MPC [µg.l^{-1}]	Dissolved SRA_{ECO} [µg.l^{-1}]	Dissolved SRC_{ECO} [µg.l^{-1}]
beryllium	Be	0.05	0.00080	0.051	0.080	0.13	49	49
vanadium	V	1.2	0.041	1.2	4.1	5.3	98	99
cobalt	Co	0.63	0.0050	0.64	0.50	1.1	750	750
selenium	Se	0.024	0.021	0.045	2.1	2.1	220	220
molybdenum	Mo	0.69	0.29	1.0	29	30	54000	54000
tin	Sn	2	0.030	2.0	3.0	5.0	400	400
antimony	Sb	0.091	–[a]	–[a]	–[a]	–[a]	11000	11000
barium	Ba	197	0.58	200	58	260	15000	15000
thallium	Tl	2	0.0016	2.0	0.16	2.2	6.5	8.5

[a]no NA, NC, MPA and MPC derived (see section 1.2.1).

Since no background concentrations for seawater are available, NCs, MPCs and SRC_{ECO}s can not be calculated. We therefore present the Negligible addition (NA), maximum permissible addition (MPA) and ecotoxicological serious risk addition (SRA_{ECO}) derived for seawater (Table 38).

Table 38. Overview of background concentrations, additions and environmental risk limits for nine trace elements for sea water (dissolved fraction).

Element	Symbol	C_b [µg.l^{-1}]	NA [µg.l^{-1}]	NC [µg.l^{-1}]	MPA [µg.l^{-1}]	MPC [µg.l^{-1}]	SRA_{ECO} [µg.l^{-1}]	SRC_{ECO} [µg.l^{-1}]
beryllium	Be	–	0.000080	–	0.0080	–	49	–
vanadium	V	–	0.0041	–	0.41	–	98	–
cobalt	Co	–	0.0010	–	0.10	–	750	–
selenium	Se	–	0.021	–	2.1	–	220	–
molybdenum	Mo	–	0.029	–	2.9	–	54000	–
tin	Sn	–	0.0030	–	0.30	–	400	–
antimony	Sb	–	–[a]	–	–[a]	–	11000	–
barium	Ba	–	0.058	–	5.8	–	15000	–
thallium	Tl	–	0.00016	–	0.016	–	6.5	–

– means: no data available.
[a]no NA and MPA derived (see section 1.2.1).

Table 39. Overview of background concentrations, additions and environmental risk limits for nine trace elements for soil.

Element	Symbol	C_b [mg.kg^{-1}]	NA [mg.kg^{-1}]	NC [mg.kg^{-1}]	MPA [mg.kg^{-1}]	MPC [mg.kg^{-1}]	SRA_{ECO} [mg.kg^{-1}]	SRC_{ECO} [mg.kg^{-1}]
beryllium	Be	1.1	0.0043	1.1	0.43	1.5	1.9	3.0
vanadium	V	42	0.00032	42	0.032	42	25	67
cobalt	Co	9	0.0023	9.0	0.23	9.2	15	24
selenium	Se	0.7	0.000058	0.70	0.0058	0.71	1.2	1.9
molybdenum	Mo	0.5	0.0076	0.51	0.76	1.3	270	270
tin	Sn	19	0.00068	19	0.068	19	250	270
antimony	Sb	3	–[a]	–[a]	–[a]	–[a]	51	54
barium	Ba	155	0.082	160	8.2	160	210	360
thallium	Tl	1.0	0.001	1.0	0.10	1.1	1.0	2.0

The values in this table are expressed in mg.kg^{-1} soil (no characteristics), *not* in standard soil.
[a]no NA, NC, MPA and MPC derived (see section 1.2.1).

Table 40. Overview of background concentrations, additions and environmental risk limits for nine trace elements for sediment.

Element	Symbol	C_b [mg.kg^{-1}]	NA [mg.kg^{-1}]	NC [mg.kg^{-1}]	MPA [mg.kg^{-1}]	MPC [mg.kg^{-1}]	SRA_{ECO} [mg.kg^{-1}]	SRC_{ECO} [mg.kg^{-1}]
beryllium	Be	1.1	0.00068	1.1	0.078	1.2	42	43
vanadium	V	42	0.24	42	24	66	560	610
cobalt	Co	9	0.030	9.0	3.0	12	4500	4500
selenium	Se	0.7	0.013	0.71	1.3	2.0	140	140
molybdenum	Mo	0.5	0.37	0.87	37	38	70000	70000
tin	Sn	19	56	75	5600	5600	150000	150000
antimony	Sb	3	–[a]	–[a]	–[a]	–[a]	43000	43000
barium	Ba	155	0.88	160	88	240	23000	23000
thallium	Tl	1.0	0.0024	1.0	0.24	1.2	10	11

The values in this table are expressed in mg.kg^{-1} sediment (no characteristics), *not* in standard sediment.
[a]no NA, NC, MPA and MPC derived (see section 1.2.1).

Acknowledgements

Thanks are due ing. M. Adams, who was contact person at the Ministry of Housing, Spatial Planning and the Environment (VROM-DGM/SAS). We want to acknowledge dr. E.M.J. Verbruggen, dr. M.P.M. Janssen and dr. T.P. Traas who are involved in the RIVM-project 601501 in which the work was performed. They are also thanked for helpful comments and stimulating discussions along the way. We would like to thank dr. D.T.H.M. Sijm for critical reading and comments on the manuscript.

Thanks are also due to the researchers who kindly provided the technical reports of their toxicity data to us: dr. R.G. Kuperman and dr. R.T. Checkai and to the persons who have provided us reports and quality standards as a response to our enquiry for toxicological data: dr. U. Schneider, dr. I.H. Clausen, dr. D. Schudoma, dr. H.S. Larsen.

The results as presented in this report have been discussed by the members of the scientific advisory group (WK-INS), who are acknowledged for their contribution. The advisory group provides a non-binding scientific comment on the final draft of a report in order to advise the steering committee of the project ‘International and National environmental quality standards for Substances in the Netherlands’ (INS) on the scientific merits of the report.

References

Aldenberg T, Jaworska J, Traas TP. 2002. Normal Species sensitivity distributions and probabilistic ecological risk assessment. In: Posthuma L, Suter II GW, Traas TP, eds. Species sensitivity distributions in ecotoxicology. Boca Raton, USA: CRC Press. p. 49-102.

Aldenberg T, Jaworska JS. 2000. Uncertainty of the hazardous concentration and fraction affected for normal species sensitivity distributions. Ecotoxicol Environ Saf 46: 1-18.

ATSDR. 1992a. Toxicological profile for barium. Atlanta, Georgia, USA: Agency for Toxic Substances and Disease Registry. Report no. tp-91/03. 151 pp.

ATSDR. 1992b. Toxicological profile for tin and compounds. Atlanta, Georgia, USA: Agency for Toxic Substances and Disease Registry. Report no. tp-91/27. 161 pp.

ATSDR. 1992c. Toxicological profile for vanadium. Atlanta, Georgia, USA: Agency for Toxic Substances and Disease Registry. Report no. tp-91/29. 119 pp.

ATSDR. 2000. Toxicological profile for beryllium (update). Atlanta, Georgia, USA: Agency for Toxic Substances and Disease Registry. Report no. Draft for public comment. 257 pp.

ATSDR. 2001. Toxicological profile for cobalt (update). Atlanta, Georgia, USA: Agency for Toxic Substances and Disease Registry. Report no. Draft for public comment. 435 pp.

ATSDR. 2002. Toxicological profile for selenium (update). Atlanta, Georgia, USA: Agency for Toxic Substances and Disease Registry. Report no. Draft for public comment. 410 pp.

Baars P. 2003. RIZA, Steunpunt Emissies. e-mail dated 07-07-2003.

Baggelaar PK, Baggelaar DH. 1995. Trends in de oppervlaktewaterkwaliteit van Rijn en Maas. Amsterdam, the Netherlands: RIWA. 124 pp.

Bockting GJM, Van de Plassche EJ, Stuijs J, Canton JH. 1992. Soil-water partition coefficients for some trace metals. Bilthoven, the Netherlands: National Institute for Public Health and Environmental Protection. Report no. 679101003. 51 pp.

Bowen HJM. 1979. Environmental Chemistry of the Elements. London: Academic Press. 333 pp.

Brown BT, Rattigan BM. 1979. Toxicity of soluble copper and other metal ions to *Elodea canadensis*. Environ Pollut 20: 303-314.

Brown TA, Shrift A. 1982. Selenium: toxicity and tolerance in higher plants. Biol Rev 57: 59-84.

Byerrum RU, Eckardt RE, Hopkins Jr LL, Libsch JF, Zenz C, Gordon WA, Mountain JT, Hicks SP, Boaz Jr. T.D., Eds. 1974. Mecidal and Biologic effects of environmental pollutants. Vanadium. Washington, D.C., USA: National Academy of Sciences, Printing and Publishing Office. 117 pp.

Crane M, Flower T, Holmes D, Watson S. 1992. The toxicity of selenium in experimental freshwater ponds. Arch Environ Contam Toxicol 23: 440-452.

Crommentuijn T, Polder MD, Van de Plassche EJ. 1997. Maximum Permissible Concentrations and Negligible Concentrations for metals, taking background concentrations into account. Bilthoven, the Netherlands: National Institute for Public Health and Environmental Protection. Report no. 601501001. 260 pp.

De Bruijn JHM, Denneman CAJ. 1992. Achtergrondgehalten van negen sporen-metalen in oppervlaktewater, grondwater en grond van Nederland. Den Haag: Ministerie van Volkshuisvesting, Ruimtelijke Ordening en Milieubeheer. Report no. 1992/1 (in Dutch). 39 pp.

Deneer JW. 2000. Toxicity of mixtures of pesticides in aquatic systems. Pest Management Sci 56: 516-520.

ECB. 2003. Technical Guidance Document in support of Commission Directive 93/67/EEC

on Risk Assessment for new notified substances, Commision Regulation (EC) No 1488/94 on Risk Assessment for existing substances and Directive 98/9/EC of the European Parliament and of the Council concerning the placing of biocidal products on the market . Ispra, Italy: European Chemicals Bureau, Institute for Health and Consumer Protection.

EnvironmentalChemistry.com. *Periodic Table of the Elements* [Web Page] (Available at http://environmentalchemistry.com/yogi/periodic/) Accessed June 23, 2003.

Ewers U. 1988. Environmental exposure to thallium. Sci Total Environ 71: 285-292.

Fargašová A. 1998. Comparative acute toxicity of Cu2+, Cu+, Mn2+, Mo6+, Ni2+ and V5+ to *Chironomus plumosus* larvae and *Tubifex tubifex* worms . Biologia 53: 315-319.

Fraters B, Boumans LJM, Prins HP. 2001. Achtergrondconcentraties van 17 sporenmetalen in het grondwater van Nederland. Bilthoven, the Netherlands: National Institute for Public Health and the Environment. Report no. 711701017/2001. 136 pp.

GraphPad Software Inc. 1996. GraphPad Prism [computer program]. version 2.01. San Diego, CA, USA: GraphPad Software, Inc.

Gunn SA, Harr JR, Levander OA, Olson OE, Schroeder HJ, Allaway WH, Lakin HW, Boaz Jr. TD, subcommittee on selenium. 1976. Selenium. Medical and biological effects of environmental pollutants. Washington D.C., USA: National Academy of Sciences. Division of medical sciences, Assembly of life sciences. National Research Council. 203 pp.

INS. 1999. Integrale Normstelling Stoffen, Milieukwaliteitsnormen Bodem, Water en Lucht. The Hague, the Netherlands: Interdepartementale Stuurgroep INS (Ministeries van VROM, V&W, LNV en EZ), Ministerie van Volkshuisvesting, Ruimtelijke Ordening en Milieubeheer. Report no. 990573/h/03-00.

Izmerov NF. 1984. Scientific reviews of Soviet literature on toxicity and hazards of chemicals. Antimony. Moscow: International Register of Potentially Toxic Chemicals (IRPTC) and Centre of International Projects (GKNT). Report no. 71. 24 pp.

Izmerov NF. 1988. Scientific reviews of Soviet literature on toxicity and hazards of chemicals. Molybdenum. Moscow: International Register of Potentially Toxic Chemicals (IRPTC) and Centre of International Projects (GKNT). Report no. 105. 81 pp.

Janssen MPM, Traas TP, Rila J-P, Van Vlaardingen PLA. 2004. Guidance for deriving Dutch Environmental Risk Limits from EU-Risk Assessment Reports of existing substances. Bilthoven, the Netherlands: National Institute for Public Health and the Environment. Report no. 601501020. 35 pp.

Jones, R. B. 1998. TechDig [computer program]. version 2.0d. Mundelein, IL, USA: R.B. Jones.

Kjøholt J, Stuer-Lauridsen F, Skibsted Mogensen A, Havelund S. 2003. The elements in the second rank - an environmental problem now or in the future? Denmark: Danish environmental protection agency, Danish Ministry of the environment. Report no. Environmental Project (Miljøprojekt) No. 770. 108 pp.

Koops R, Van Grinsven JJM, Crommentuijn T, Van den Hoop MAGT, Swartjes FA, Kramer PRG, Peijnenburg WJGM. 1998. Evaluatie van door het RIVM gehanteerde partitiecoëfficiënten voor metalen. Bilthoven, the Netherlands: National Institute for Public Health and the Environment. Report no. 711401005. 84 pp.

Lemly AD. 1993. Teratogenic effects of selenium in natural populations of freshwater fish. Ecotoxicol Environ Saf 26: 181-204.

Lemly AD. 2002. Symptoms and implications of selenium toxicity in fish: the Belews Lake case example. Aquat Toxicol 57: 39-49.

Lide DR, ed. 2001. CRC Handbook of chemistry and physics. 82 ed. Boca Raton: CRC Press.

Maier KJ, Knight AW. 1994. Ecotoxicology of selenium in freshwater systems. Rev Environ Contam Toxicol 134: 31-48.

Meinardi CR, Groot MSM, Prins HP. 2003. Basiswaarden voor spoorelementen in het zoete grondwater van Nederland. Bilthoven, the Netherlands: National Institute for Public Health and the Environment. Report no. 714801028/2003. 43 pp.

Mortvedt JJ, Cox FR, Shuman LM, Welch RM, eds. 1991. Micronutrients in agriculture. 2nd ed. Madison, WI, USA: Soil Science Society of America, Inc. 760 pp.

Newland LW. 1982. Arsenic, Beryllium, Selenium and Vanadium. In: Hutzinger O, ed. The Handbook of Environmental Chemistry. Vol 3 Part B. Anthropogenic compounds. Berlin: Springer-Verlag. p. 27-67.

OECD. 1984. OECD guideline for testing of chemicals. "Fish, prolonged toxicity test: 14-day study". OECD 204. Paris: Organisation for Economic Co-operation and Development. 9 pp.

Otte PF, Lijzen JPA, Otte JG, Swartjes FA, Versluijs CW. 2001. Evaluation and revision of the CSOIL parameter set. Bilthoven, the Netherlands: National Institute for Public Health and the Environment. Report no. 711701021. 125 pp.

Parker GA. 1986. Molybdenum. In: Hutzinger O, ed. The Handbook of Environmental Chemistry. Vol 3 Part D. Anthropogenic compounds. Berlin: Springer-Verlag. p. 217-240.

Pratt JR, Bowers NJ. 1990. Effect of selenium on microbial communities in laboratory microcosms and outdoor streams. Toxic Assess Internat J 5: 293-307.

RIWA. 2000. Annual Report 1998. Amsterdam: RIWA. Report no. Part C The Rhine and the Meuse. 174 pp.

RIWA. 2002. Jaarverslag 1999-2000. Nieuwegein: RIWA. Report no. Deel A, De Rijn. 160 pp.

RIZA/RIKZ. Ministry of Transport, Public Works and Water Management. *WaterBase* [Web Page] (Available at http://www.waterbase.nl) Accessed July 3, 2003.

Sager M. 1994. Thallium. Toxicol Environ Chem 45: 11-32.

Sauvé S, Hendershot W, Allen HE. 2000. Solid-solution partitioning of metals in contaminated soils: dependence on pH, total metal burden, and organic matter. Environ Sci Technol 34: 1125-1131.

Schoer J. 1984. Thallium. In: Hutzinger O, ed. The Handbook of Environmental Chemistry. Vol 3 Part C. Anthropogenic compounds. Berlin: Springer-Verlag. p. 143-214.

Sijm D, Lijzen J, Peijnenburg W, Sneller E, Traas T, Verbruggen E. 2002. Biobeschikbaarheid in beleid...wat er aan vooraf ging en wat er nog komt. Resultaten van een workshop en het beleidsvervolg. Bilthoven, the Netherlands: National Institute for Public Health and the Environment. Report no. 607220006. 132 pp.

Slooff W, Bont PFH, Hesse JM, Annema JA. 1993. Exploratory report tin and tin compounds. Bilthoven, the Netherlands: National Institute for Public Health and Environmental Protection. Report no. 710401027. 73 pp.

Slooff W, Bont PFH, Hesse JM, Loos B. 1992. Eploratory report antimony and antimony compounds. Bilthoven, the Netherlands: National Institute for Public Health and Environmental Protection. Report no. 710401020. 40 pp.

Stendahl DH, Sprague JB. 1982. Effects of water hardness and pH on vanadium lethality to rainbow trout. Water Res 16: 1479-1488.

Stuurgroep INS. 1999. Integrale Normstelling Stoffen. Deel 4. Milieukwaliteitsnormen bodem, water, lucht. Oktober 1999. Den Haag, the Netherlands: Ministerie van Volkshuisvesting, Ruimtelijke Ordening en Milieubeheer. Report no. vrom 990573/h/03-00. 38 pp.

Taylor TP, Ding M, Ehler DS, Foreman TM, Kaszuba JP, Sauer NN. 2003. Beryllium in the environment: a review. J Environ Sci Health A38: 439-469.

TN&A Associates I. 2000. Plant toxicity testing to support development of ecological soil screening levels. Oak Ridge, TN USA: National Center for Environmental Assessment

(Washington DC, USA). Report no. SC-IDIQ-1999142-29.
Traas TP. 2001. Guidance document on deriving environmental risk limits. Bilthoven, the Netherlands: National Institute for Public Health and the Environment. Report no. 601501012. 117 pp.
Van Beelen P, Verbruggen EMJ, Peijnenburg WJGM. 2003. The evaluation of the equilibrium partitioning method using sensitivity distributions of species in water and soil. Chemosphere 52: 1153-1162.
Van de Plassche EJ, De Bruijn JHM. 1992. Towards integrated environmental quality objectives for surface water, groundwater, sediment and soil for nine trace metals. Bilthoven, the Netherlands: National Institute for Public Health and Environmental Protection. Report no. 679101005. 33 pp.
Van de Plassche EJ, Polder MD, Canton JH. 1992. Maximum permissible concentrations for water, sediment and soil derived from toxicity data for nine trace metals. Bilthoven, the Netherlands: National Institute for Public Health and Environmental Protection. Report no. 679101002. 93 pp.
Van Leeuwen CJ, Verhaar HJM, Hermens JLM. 1996. Quality criteria and risk assessment for mixtures of chemicals in the aquatic environment. Hum Ecol Risk Assess 2: 419-425.
Van Vlaardingen P. 2003. Tussenrapportage milieurisicogrenzen sporenelementen. Bilthoven, the Netherlands: RIVM, Expert Centre for Substances (SEC).
Van Vlaardingen, P., Traas, T. P., and Aldenberg, T. 2003. ETX-2000. A program to calculate risk limits and fraction affected, based on normal species sensitivity distributions [computer program]. version 1.412. Bilthoven, the Netherlands: National Institute for Public Health and the Environment.
Verbruggen EMJ, Posthumus R, Van Wezel AP. 2001. Ecotoxicological serious risk concentrations for soil, sediment and (ground)water: updated proposals for first series of compounds. Bilthoven, the Netherlands: National Institute for Public Health and the Environmental. Report no. 711701020. 263 pp.
VROM, Ministry of Housing, Spatial Planning and the Environment. 2001. Environmental Quality Standards in The Netherlands - 1999. A review of environmental quality standards and their policy framework in the Netherlands. 4th ed. Alphen aan den Rijn, The Netherlands: Kluwer. 627 pp.
World Health Organization. 1980. Environmental Health Criteria 15. Tin and Organotin compounds. Vammala, Finland: International Programme on Chemical Safety (ICPS). 109 pp.
World Health Organization. 1987. Environmental Health Criteria 58. Selenium. Vammala, Finland: International Programme on Chemical Safety (ICPS). 306 pp.
World Health Organization. 1990a. Environmental Health Criteria 106. Beryllium. Vammala, Finland: International Programme on Chemical Safety (ICPS). 210 pp.
World Health Organization. 1990b. Environmental Health Criteria 107. Barium. Vammala, Finland: International Programme on Chemical Safety (ICPS). 148 pp.
World Health Organization. 1996. Environmental Health Criteria 182. Thallium. Vammala, Finland: International Programme on Chemical Safety (ICPS). 274 pp.
World Health Organization. 1999. Environmental Health Criteria 81. Vanadium. Vammala, Finland: International Programme on Chemical Safety (ICPS). 170 pp.
Zuurdeeg BW, Van Enk RJ, Vriend SP. 1992. Natuurlijke achtergrondgehalten van zware metalen en enkele andere sporenelementen in Nederlands oppervlaktewater. Utrecht: GEOCHEM-Research. 204 pp.

Appendix 1: Toxicity datasets of 1992 vs 2004

In this appendix, a concise comparison of the ecotoxociological datasets of 1992 (Van de Plassche *et al.*, 1992) and this report is presented. The numbers of acute and chronic aquatic and terrestrial toxicity data were counted and are tabulated here. Such a comparison gives insight into the effect of a renewed literature search after a period of 12 years, in terms of data availability. Some remarks on the presented data:

- Not included are data that were considered to be *not useful* for the risk assessment;
- Freshwater and marine toxicity data are added into one category 'aquatic';
- Presented are the total number of *entries* in the toxicity data tables, not the number of studies or references retrieved.

Table A1. 1. Number of entries in the toxicity datasets for ERL derivation of nine trace elements by Van de Plassche et al. (1992).

	AQUATIC				TERRESTRIAL			
Element	**Acute**	Nr of taxa	**Chronic**	Nr of taxa	**Acute**	Nr of taxa	**Chronic**	Nr of taxa
Be	14	4	7	5	0	0	0	0
V	6	3	7	3	0	0	0	0
Co	16	6	9	4	0	0	2	1
Se	55	7	58	8	0	0	0	0
Mo	10	4	1	1	0	0	0	0
Sn	7	2	4	3	0	0	0	0
Sb	4	3	2	2	0	0	0	0
Ba	4	3	2	2	0	0	0	0
Tl	7	3	1	1	0	0	0	0

Table A1. 2. Number of entries in the toxicity datasets for ERL derivation of nine trace elements (Van Vlaardingen et al.*, this report, 2005).*

	AQUATIC				TERRESTRIAL			
Element	**Acute**	Nr of taxa	**Chronic**	Nr of taxa	**Acute**	Nr of taxa	**Chronic**	Nr of taxa
Be	22	7	7	5	0	0	17	4
V	52	7	8	3	3	2	20	2
Co	72	13	20	6	0	0	32	3
Se	181	10	51	8	0	0	53	2
Mo	13	4	1	1	0	0	11	1
Sn	19	8	7	4	0	0	24	1
Sb	19	5	6	4	0	0	8	3
Ba	37	9	12	5	4	2	24	3
Tl	24	8	8	4	3	2	9	3

Appendix 2. Information on aquatic toxicity

Legend

Species	organism used in the test, if available followed by age, size, weight or life stage. ad = adult, emb = embryo, juv = juvenile.
Analysed	Y = test substance analysed in test solution N = test substance not analysed in test solution or no data
Test type	CF = continuous flow, IF = intermittent flow, R = static with renewal, S = static
Purity	purity of active ingredient: rg = reagent grade, ag = analytical grade, tg = technical grade, lg= laboratory grade
Test water	am = artificial medium, asw = artificial seawater, de-ion w, dist w = distilled water, exp. stream = experimental stream, lw = lake water, nfs = natural filtered seawater, nw = natural water, nsw = natural sea water, rec w = reconstituted water, rec tw = reconsituted tap water (+additional salts), river w = river water, salt w = salt water, sw = sea water, syn w = synthetic water, tw = tap water.
Exposure time	h = hours, d = days, w = weeks, m = months, min. = minutes
Criterion	L(E)C50 = lowest short term test result showing 50% effect or mortality; NOEC = no observed effect concentration, ECx = effect concentration causing x% effect
Test endpoint	min. = mineralisation, cell no. = cell number; assimilation eff. = assimiliation efficiency
Value	test result; > and ≥ symbols = no effect observed at highest test concentration

Contents

Table A2. 1. Acute toxicity of beryllium to freshwater organisms.

Species	Species properties	A	Test type	Purity [%]	Test compound	Test water	pH	T [°C]	Hardness [mg $CaCO_3$/l]	Exp. time	Criterion	Test endpoint	Value [mg/l]	Notes	Reference
Algae															
Chlorococcales	mixed population	N	S		$Be(NO_3)_2$	fw		20		24 h	EC50	O2 production	1.5		Krebs, 1991
Nematoda															
Caenorhabditis elegans	ad. 3-4 d	N	S	rg	$BeSO_4$	am		20		96 h	LC50	mortality	0.14		Williams and Dusenbery, 1990
Crustacea															
Daphnia magna	< 24 h	N	S		$Be(NO_3)_2$	tw	7.6-7.7		286	24 h	EC50		18		Bringmann and Kühn, 1977a
Daphnia magna		N	S		$BeSO_4$	nw	7.2-7.8		235-260	48 h	EC50	immobility	2.8		Khangarot and Ray, 1989a
Annelida															
Tubifex tubifex		N	S		$BeSO_4$	nw	7.6		245	96 h	EC50		10		Khangarot, 1991
Pisces															
Ictalurus punctatus		Y	CF		$BeSO_4$		8.0		140	96 h	LC50	mortality	6.1		Cardwell et al, 1976
Lebistes reticulatus	3 m	N	S		$BeSO_4$	rw	5.1-7.0		400	96 h	LC50	mortality	19		Slonim and Slonim, 1973
Lebistes reticulatus	3 m	N	S		$BeSO_4$	rw	5.9-7.3		275	96 h	LC50	mortality	13		Slonim and Slonim, 1973
Lebistes reticulatus	3 m	N	S		$BeSO_4$	rw	6.0-6.7		150	96 h	LC50	mortality	5.8		Slonim and Slonim, 1973
Lebistes reticulatus	3 m	N	S		$BeSO_4$	rw	6.4-6.5		22	96 h	LC50	mortality	0.16		Slonim and Slonim, 1973
Leuciscus idus melanotus		N	S		$Be(NO_3)_2$	tw	7-8	20	255	48 h	LC50	mortality	6.7	1,2	Juhnke and Lüdemann, 1978
Leuciscus idus melanotus		N	S		$Be(NO_3)_2$	tw	7-8	20	255	48 h	LC50	mortality	0.54	1,2	Juhnke and Lüdemann, 1978
Rutilus rutilus	fry, 30-35 mm	N	S		$BeSO_4$	rec w	4.5		6	96 h	LC50	mortality	0.14	3	Jagoe et al., 1993
Rutilus rutilus	fry, 30-35 mm	N	S		$BeSO_4$	rec w	5.5		6	96 h	LC50	mortality	0.10		Jagoe et al., 1993
Perca fluviatilis	fry, 9-12 mm	N	S		$BeSO_4$	rec w	5.5		6	96 h	LC50	mortality	0.0813	4	Jagoe et al., 1993
Poecilia reticulata	3-4 mo, 0.1-0.25 g, 2.4-3.6 cm	Y	S	rg	$BeSO_4$	gw	7.8-8.2	23	400-500	96 h	LC50	mortality	20.3		Slonim, 1973
Poecilia reticulata	3-4 mo, 0.1-0.25 g, 2.4-3.6 cm	Y	S	rg	$BeSO_4$	gw+dw	6.3-6.5	23	20-25	96 h	LC50	mortality	0.19		Slonim, 1973
Amphibia															
Ambystoma opacum	larvae	N	S		$BeSO_4$	nw			400	96 h	LC50	mortality	32		Slonim and Ray, 1975
Ambystoma opacum	larvae	N	S		$BeSO_4$	nw			20-25	96 h	LC50	mortality	3.2		Slonim and Ray, 1975

Species	Species properties	A	Test type	Purity [%]	Test compound	Test water	pH	T [°C]	Hardness [mg $CaCO_3$/l]	Exp. time	Criterion	Test endpoint	Value [mg/l]	Notes	Reference
Ambystoma maculatum	larvae	N	S		$BeSO_4$	nw			400	96 h	LC50	mortality	22		Slonim and Ray, 1975
Ambystoma maculatum	larvae	N	S		$BeSO_4$	nw			20-25	96 h	LC50	mortality	6		Slonim and Ray, 1975

Notes
1. LC50 was reported as minimum and maximum of a range; reported is the geometric mean of these values.
2. Results obtained from different laboratories.
3. Linear interpolation between the EC10 at 100 µg/l and the EC60 at 150 µg/l gives an EC50 of 140 µg/l.
4. Linear interpolation between the highest concentration without effect (50 µg/l) and the next higer concentration (the EC80 at 100 µg/l) gives an EC50 of 81 µg/l.

Table A2. 2. Acute toxicity of vanadium to freshwater organisms.

Species	Species properties	A	Test type	Purity [%]	Test compound	Test water	pH	T [°C]	Hardness [mg $CaCO_3$/l]	Exposure time	Criterion	Test endpoint	Value [mg/l]	Notes	Reference
Protozoa															
Tetrahymena pyriformis		N	S	ag	$VOSO_4$	am		28		9 h	EC50	doubling time	18		Sauvant et al., 1997
Tetrahymena pyriformis	1e4 cells/ml			≥99	$VOSO_4$	am				9 h	EC50	growth	18		Sauvant, et al., 1995b
Tetrahymena pyriformis	5e4 cells/ml			≥99	$VOSO_4$	am		28		36 h	EC50	growth	9.0		Sauvant, et al., 1995b
Mollusca															
Crassostrea gigas	egg	N	S		V_2O_5	am	8.1	24		48 h	EC50	hatchability	0.91	1	Fichet and Miramand, 1998
Annelida															
Pristina leidyi		Y	S		Na_3VO_4	tw	7.9		105	48 h	LC50	mortality	31	2	Smith et al., 1991
Crustacea															
Crangonyx pseudogracilis	adult	N	S		$NaVO_3$	tw	6.7-6.8		45-55	96 h	EC50		12		Martin and Holdich, 1986
Daphnia magna	24 h	N	S		$VOSO_4$	am		20	250	24 h	EC50	immobilisation	1.8		Knie et al., 1983
Daphnia magna	<24 h	Y	S	>98%	$NaVO_3$	rw	8.2-8.4	19	136	48 h	EC50		3.5	3	Beusen and Neven, 1987
Echinodermata															
Paracentrotus lividus	egg	N	S		V_2O_5	am	8.1	24		48 h	EC50	hatchability	1.08	1	Fichet and Miramand, 1998
Pisces															
Brachydanio rerio		Y	R	>98%	$NaVO_3$	rw	7.7-8.5	23	136	96 h	LC50	mortality	4.0	4	Beusen and Neven, 1987
Carassius auratus	3-5 cm; 0.3-2.9 g	N	S		V_2O_5	fw	6-6.5	22.5	35	6 d	LC50	mortality	8.1	5	Knudtson, 1979
Carassius auratus	3-5 cm; 0.3-2.9 g	N	S		$VOSO_4$	fw	6-6.5	22.5	35	6 d	LC50	mortality	3.0	5	Knudtson, 1979
Carassius auratus	3-5 cm; 0.3-2.9 g	N	S		NH_4VO_3	fw	6-6.5	22.5	35	6 d	LC50	mortality	3.8	5	Knudtson, 1979
Carassius auratus	3-5 cm; 0.3-2.9 g	N	S		$NaVO_3$	fw	6-6.5	22.5	35	6 d	LC50	mortality	2.5	5	Knudtson, 1979
Colisa fasciatus	ad, 48-55 mm, 2.9-3.2 g	N	R	ag	$VOSO_4$	am	6.8-7.6	23	68	120 h	LC50	mortality	5.0		Srivastava and Tyagi, 1984
Catostomus latipinnis	larvae; 12-13 d	N	S	rg	NaVO3	rw	7.9	25	144	96 h	LC50	mortality	12		Hamilton and Buhl, 1997b
Jordanella floridae	adult	N	S		V_2O_5	nw	8.2		275	96 h	LC50	mortality	11		Holdway and Sprague, 1979
Nuria danrica	ad, 5.1 cm			rg	NH4VO3	fw	6.2-6.5		4-5.5	96 h	LC50	mortality	2.6		Abbasi et al., 1993
Oncorhynchus mykiss	juv, 3.03 g	Y	CF	rg	V_2O_5	fw	5.51	15	101	7 d	LC50	mortality	4.7		Stendahl and Sprague, 1982

Species	Species properties	A	Test type	Purity [%]	Test compound	Test water	pH	T [°C]	Hardness [mg $CaCO_3$/l]	Exposure time	Criterion	Test endpoint	Value [mg/l]	Notes	Reference
Oncorhynchus mykiss	juv, 3.03 g	Y	CF	rg	V_2O_5	fw	5.51	15	101	7 d	LC50	mortality	4.8		Stendahl and Sprague, 1982
Oncorhynchus mykiss	juv, 11.74 g	Y	CF	rg	V_2O_5	fw	7.69	15	99	7 d	LC50	mortality	2.0		Stendahl and Sprague, 1982
Oncorhynchus mykiss	juv, 6.21 g	Y	CF	rg	V_2O_5	fw	7.66	15	98	7 d	LC50	mortality	2.5		Stendahl and Sprague, 1982
Oncorhynchus mykiss	juv, 2.45 g	Y	CF	rg	V_2O_5	fw	7.71	15	101	7 d	LC50	mortality	3.8		Stendahl and Sprague, 1982
Oncorhynchus mykiss	juv, 2.44 g	Y	CF	rg	V_2O_5	fw	7.72	15	103	7 d	LC50	mortality	3.0		Stendahl and Sprague, 1982
Oncorhynchus mykiss	juv, 2.11 g	Y	CF	rg	V_2O_5	fw	7.7	15	100	7 d	LC50	mortality	3.4		Stendahl and Sprague, 1982
Oncorhynchus mykiss	juv, 1.47 g	Y	CF	rg	V_2O_5	fw	7.7	15	100	7 d	LC50	mortality	4.6		Stendahl and Sprague, 1982
Oncorhynchus mykiss	juv	Y	CF	rg	V_2O_5	fw	6.61	15	368	7 d	LC50	mortality	3.6		Stendahl and Sprague, 1982
Oncorhynchus mykiss	juv, 1.55 g	Y	CF	rg	V_2O_5	fw	5.51	15	30	7 d	LC50	mortality	3.0		Stendahl and Sprague, 1982
Oncorhynchus mykiss	juv, 2.12 g	Y	CF	rg	V_2O_5	fw	6.6	15	31	7 d	LC50	mortality	2.5		Stendahl and Sprague, 1982
Oncorhynchus mykiss	juv, 1.35 g	Y	CF	rg	V_2O_5	fw	7.7	15	30	7 d	LC50	mortality	2.4		Stendahl and Sprague, 1982
Oncorhynchus mykiss	juv, 1.68 g	Y	CF	rg	V_2O_5	fw	8.8	15	29	7 d	LC50	mortality	2.4		Stendahl and Sprague, 1982
Oncorhynchus mykiss	juv, 3.90 g	Y	CF	rg	V_2O_5	fw	6.66	15	105	7 d	LC50	mortality	3.7		Stendahl and Sprague, 1982
Oncorhynchus mykiss	juv, 1.20 g	Y	CF	rg	V_2O_5	fw	8.78	15	101	7 d	LC50	mortality	5.4		Stendahl and Sprague, 1982
Oncorhynchus mykiss	juv	Y	CF	rg	V_2O_5	fw	5.5	15	357	7 d	LC50	mortality	5.6		Stendahl and Sprague, 1982
Oncorhynchus mykiss	juv	Y	CF	rg	V_2O_5	fw	7.7	15	355	7 d	LC50	mortality	2.9		Stendahl and Sprague, 1982
Oncorhynchus mykiss	juv	Y	CF	rg	V_2O_5	fw	8.75	15	335	7 d	LC50	mortality	4.2		Stendahl and Sprague, 1982
Oncorhynchus tshawytscha	fry, 0.5 g				Na_3VO_4	fw	7-8.3	12	211	96 h	LC50	mortality	17		Hamilton and Buhl, 1990b
Oncorhynchus tshawytscha	fry, 1.98 g				Na_3VO_4	fw	6.7-8.4	12	343	96 h	LC50	mortality	17		Hamilton and Buhl, 1990b
Poecilia reticulata	1.5-2.5 cm; 0.1-0.5 g	N	S		$VOSO_4$	fw	6-6.5	22.5	35	6 d	LC50	mortality	1.1	5	Knudtson, 1979
Poecilia reticulata	1.5-2.5 cm; 0.1-0.5 g	N	S		V_2O_5	fw	6-6.5	22.5	35	6 d	LC50	mortality	0.37	5	Knudtson, 1979
Poecilia reticulata	1.5-2.5 cm; 0.1-0.5 g	N	S		NH_4VO_3	fw	6-6.5	22.5	35	6 d	LC50	mortality	1.5	5	Knudtson, 1979
Poecilia reticulata	1.5-2.5 cm; 0.1-0.5 g	N	S		$NaVO_3$	fw	6-6.5	22.5	35	6 d	LC50	mortality	0.49	5	Knudtson, 1979
Poecilia reticulata		Y	R	>98%	$NaVO_3$	rw	7.7-8.5	23	136	96 h	LC50	mortality	7.9	6	Beusen and Neven, 1987
Salvelinus fontinalis	yearling	Y	CF	rg	V_2O_5	tw	6.5-8	17	35.4	3.5 d	LC50	mortality	7.0	7	Ernst and Garside, 1987
Salvelinus fontinalis	alevin	Y	S	rg	V_2O_5	tw	6.5-7.9	9	37	96 h	LC50	mortality	24	8	Ernst and Garside, 1987

Notes
1. Figure was scanned, digitised, and a logistic dose-effect relationship was fitted through the obtained dataset using nonlinear regression; EC50 determined from this relationship. EC50 slightly extrapolated, highest test concentration was 0.75 mg/l.
2. Based on measured concentrations.
3. Geometric mean of 5 test results.
4. Geometric mean of 3 test results.
5. Background V concentration 0.94 µg/l.

6. Geometric mean of 2 test results.
7. The LC50 was also 7.0 mg V/l at 4 d, and 5 d of exposure.
8. LC50 declines to 2.0 mg/l at 720 h of (static) exposure in identical set up.

Table A2. 3. Acute toxicity of cobalt to freshwater organisms.

Species	Species properties	A	Test type	Purity [%]	Test compound	Test water	pH	T [°C]	Hardness [mg $CaCO_3$/l]	Exp. time	Criterion	Test endpoint	Value [mg/l]	Notes	Reference
Bacteria															
Pseudomonas putida		N	S		$CoCl_2$	am		20		16 h	EC50	growth	0.98	1	Schmitz et al., 1998
Protozoa															
Philodina acuticornis		N	S		$CoCl_2$	am	7.4-7.9		25	24 h	EC50	immobility	28		Buikema et al., 1974
Spirostomum ambiguum		N	S	ag	$Co(NO_3)_2$	am	7.4	25	2.8	48 h	EC50	mortality	11		Nalecz-Jawecki and Sawicki, 1997
Tetrahymena pyriformis		N	S	ag	$CoCl_2$	am		28		9 h	EC50	doubling time	50		Sauvant et al., 1997
Tetrahymena pyriformis		N	S	>98	$CoCl_2$	am				9 h	IC50	growth	56		Sauvant et al., 1995c
Tetrahymena pyriformis	1e4 cells/ml	N	S	>99	$CoCl_2$	am		28		9 h	IC50	growth	50		Sauvant et al., 1995b
Tetrahymena pyriformis	5e4 cells/ml	N	S	>99	$CoCl_2$	am		28		36 h	IC50	growth	24		Sauvant et al., 1995b
Algae															
Chlorella vulgaris		N	S		$CoCl_2$	am	6.5			4 d	EC50	population growth	0.52		Rachlin and Grosso, 1993
Chlorella pyrenoidosa	algae in exponential growth phase (2 d)	N	S		$CoCl_2$	am		20		6 h	EC50	O_2 release	95	2	Plekhanov et al., 2003
Macrophyta															
Azolla pinnata	fronds	N	S	ag	$CoCl_2$	am	7	25		96 h	EC50	growth (fw)	0.24		Gaur et al., 1994
Spirodela polyrhiza	fronds	N	S	ag	$CoCl_2$	am	7	25		96 h	EC50	growth (fw)	0.14		Gaur et al., 1994
Platyhelminthes															
Dugesia tigrina	11-12 mm, 18-24 d, cut individuals	N	S		$Co(NO_3)_2$	ISO		20	105	10 d	EC50	mortality	1.12		Solski and Piontek, 1987
Dugesia tigrina	20 d, cut individuals	N	S	ag	$Co(NO_3)_2$	ISO	7.2-8.2	18-22	105	10 d	LC50	mortality	3.5		Piontek, 1999
Dugesia tigrina	20 d, 11-12 mm long, whole individuals	N	S	ag	$Co(NO_3)_2$	ISO	7.2-8.2	18-22	105	96 h	LC50	mortality	16.6		Piontek, 1999
Nematoda															
Caenorhabditis elegans	ad	Y	S		$Co(NO_3)_2$	am		20		24 h	LC50	mortality	1273		Tatara et al., 1998
Rotifera															
Philodina acuticornis		N	S		$CoCl_2$	am	7.4-7.9	20	25	24 h	EC50	immobilization	28		Buikema et al., 1974

Species	Species properties	A	Test type	Purity [%]	Test compound	Test water	pH	T [°C]	Hardness [mg $CaCO_3$/l]	Exp. time	Criterion	Test endpoint	Value [mg/l]	Notes	Reference
Annelida															
Branchiura sowerbyi		N	S	ag	$CoCl_2$					96 h	LC50	mortality	133	3	Das and Kaviraj, 1994
Tubifex tubifex		N	S	rg	$CoCl_2$	am	7.5	15	226-255	96 h	LC50	mortality	239		Rathore and Khangarot, 2002
Tubifex tubifex		N	S	rg	$CoCl_2$	am	7.5	20	226-255	96 h	LC50	mortality	180		Rathore and Khangarot, 2002
Tubifex tubifex		N	S		$CoCl_2$	nw	7.6		245	96 h	EC50	immobility	140		Khangarot, 1991
Tubifex tubifex		N	S	rg	$CoCl_2$	am	7.8	20	160-184	96 h	LC50	mortality	326		Rathore and Khangarot, 2003
Crustacea															
Austropotamobius pallipes	19-32 mm	Y			$CoCl_2$	nw	7	16		96 h	LC50	mortality	8.8		Boutet and Chaisemartin, 1973
Ceriodaphnia dubia	<24 h	Y	R	rg	$CoCl_3$	nw		20	57.2	24 h	EC50	immobility	2.3	4	Diamond et al., 1992
Ceriodaphnia dubia	<24 h	Y	R	rg	$CoCl_3$	nw		20	256	24 h	EC50	immobility	4.6	4	Diamond et al., 1992
Ceriodaphnia dubia	<24 h	Y	R	rg	$CoCl_3$	nw		20	477	24 h	EC50	immobility	4.2	4	Diamond et al., 1992
Crangonyx pseudogracilis	ad, 4 mm	N	S		$CoCl_2$	tw	6.7-6.8		45-55	96 h	EC50		39		Martin and Holdich, 1986
Cyclops abyssorum	< 24 h	N	S		$CoCl_2$	nw	7.2		31	48 h	EC50		16		Baudouin and Scoppa, 1974
Daphnia hyalina	< 24 h	N	S		$CoCl_2$	nw	7.2		31	48 h	EC50		1.3		Baudouin and Scoppa, 1974
Daphnia magna	12+12 h	N	S	rg	$CoCl_2$	nw	7.4-8.2		44-53	48 h	LC50		1.1		Biesinger and Christensen, 1972
Daphnia magna	< 24 h	N	S		$CoCl_2$	nw	7.5		204	48 h	EC50	immobility	5.0		Bringmann and Kühn, 1959
Daphnia magna		N	S		$CoCl_2$	nw	7.2-7.8		235-260	48 h	EC50	immobility	1.5		Khangarot and Ray, 1989a
Diaptomus forbesi		N	S	ag	$CoCl_2$					96 h	LC50	mortality	3.4	3	Das and Kaviraj, 1994
Eudiaptomus padanus	< 24 h	N	S		$CoCl_2$	nw	7.2		31	48 h	EC50		4		Baudouin and Scoppa, 1974
Orconectes limosus	19-32 mm	Y			$CoCl_2$	nw	7	16		96 h	LC50	mortality	10		Boutet and Chaisemartin, 1973
Insecta															
Chironomus tentans		N	S		$CoCl_2$	nw	6.1-6.6		18-35	48 h	LC50	immobility	57		Khangarot and Ray, 1989b
Acroneuria lycorias	field collected	Y	S		$CoSO_4$	lw	7.2	18.5	50	8 d	LC50	mortality	32		Warnick and Bell, 1969
Hydropsyche betteni	field collected	Y	S		$CoSO_4$	lw	7	18.5	46	7 d	LC50	mortality	32		Warnick and Bell, 1969
Ephemerella subvaria	field collected	Y	S		$CoSO_4$	lw	6.9	18.5	50	96 h	LC50	mortality	16		Warnick and Bell, 1969
Pisces															
Colisa fasciata	ad. female; 4.56 g	N	S		$CoCl_2$	tw	7.3	25	120	96 h	LC50	mortality	102		Srivastava and Agrawal, 1979
Cyprinus carpio	0.0271-0.0329 m; Fry; 0.2-0.4 g	N	S	ag	$CoCl_2$					96 h	LC50	mortality	333	3	Das and Kaviraj, 1994

Species	Species properties	A	Test type	Purity [%]	Test compound	Test water	pH	T [°C]	Hardness [mg $CaCO_3$/l]	Exp. time	Criterion	Test endpoint	Value [mg/l]	Notes	Reference
Lepidocephalichthyes guntea	avg. 6.18 cm, 1.27 g, field collected	N	R		$CoCl_2$	tw	7.35	22-26	60-70	96 h	LC50	mortality	344		Shivaraj et al, 1985
Oncorhynchus mykiss	29-32 mm; fry	Y	CF	rg	$CoCl_2$	fw	7.5	9.9	24.9	14 d	LC50	mortality	0.35	5	Marr et al., 1998
Oryzias latipes	8 d fry	N	S		$CoCl_2$	tw	6.9		11	24 h	LC50	mortality	4.8		Hiraoka et al., 1985
Amphibia															
Rana hexadactyla	20 mm; tadpole; 500 mg	N	R	rg	$CoCl_2$	fw	6.1	15	20	96 h	LC50	mortality	18		Khangarot et al., 1985
Xenopus laevis	embryos	N	S	100	$CoCl_2$	fw	6.8	23	111	101 h	EC50	malformations	1.5	6	Plowman et al., 1991
Xenopus laevis	embryos	N	S	100	$CoCl_2$	fw	6.8	23	111	101 h	LC50	mortality	613	6	Plowman et al., 1991

Notes
1. Tested in 96 well microplates; Integral of curve used to determine EC50.
2. Endpoint is rate of photoinduced oxygen release.
3. Test organisms collected from unpolluted natural source; test method followed APHA (1975) guidelines.
4. Test water is filtered pond water of which a 5th part is 20:80 Perrier®:distilled water.
5. Result is incipient LC50, test water is mixture of deionised, filtrated well water and deionised water.
6. FETAX test; test medium was an artificial pond water.

Table A2. 4. Acute toxicity of selenium to freshwater organisms.

Species	Species properties	A	Test type	Purity [%]	Test compound	Test water	pH	T [°C]	Hardness [mg $CaCO_3$/l]	Exp. time	Criterion	Test endpoint	Value [mg/l]	Notes	Reference
Bacteria															
Pseudomonas fluorescens	early exponential phase	N	S	rg	Na_2SeO_3	am		33		2 h	EC50	growth	52		Paran et al., 1990
Pseudomonas putida		N	S		Na_2SeO_3	am		20		16 h	EC50	growth	23.5	1	Schmitz et al., 1999b
Pseudomonas putida		N	S		SeO_2	am		20		16 h	EC50	growth	12.1	1	Schmitz et al., 1999b
Cyanobacteria															
Anabaena flos-aquae	$2x10^4$ cells/ml	N			SeO_2	am		20		3 d	EC50	biomass	4.8		Abdel-Hamid and Skulberg, 1995
Anabaena flos-aquae	$2x10^4$ cells/ml	N			Na_2SeO_3	am		20		3 d	EC50	biomass	5.0		Abdel-Hamid and Skulberg, 1995
Microcystis aeruginosa	$2x10^4$ cells/ml	N			SeO_2	am		20		3 d	EC50	biomass	7.2		Abdel-Hamid and Skulberg, 1995
Microcystis aeruginosa	$2x10^4$ cells/ml	N			Na_2SeO_3	am		20		3 d	EC50	biomass	6.4		Abdel-Hamid and Skulberg, 1995
Oscillatoria agardhii	$2x10^4$ cells/ml	N			SeO_2	am		20		3 d	EC50	biomass	1.5		Abdel-Hamid and Skulberg, 1995
Oscillatoria agardhii	$2x10^4$ cells/ml	N			Na_2SeO_3	am		20		3 d	EC50	biomass	1.1		Abdel-Hamid and Skulberg, 1995
Protozoa															
Spirostomum ambiguum		N	S	ag	Na_2SeO_3	am	7.4	25	2.8	48 h	EC50	mortality	52		Naleçz-Jawecki and Sawicki, 1997
Algae															
Chlorella sp.	$2x10^4$ cells/ml	N			Na_2SeO_3	am		20		3 d	EC50	biomass	0.80		Abdel-Hamid and Skulberg, 1995
Chlorella sp.	$2x10^4$ cells/ml	N			SeO_2	am		20		3 d	EC50	biomass	0.80		Abdel-Hamid and Skulberg, 1995
Monoraphidium contortum		N			Na_2SeO_3	am		20		3 d	EC50	biomass	2.9		Abdel-Hamid and Skulberg, 1995
Monoraphidium contortum		N			SeO_2	am		20		3 d	EC50	biomass	0.90		Abdel-Hamid and Skulberg, 1995
Monoraphidium convolutum		N			Na_2SeO_3	am		20		3 d	EC50	biomass	3.8		Abdel-Hamid and Skulberg, 1995
Monoraphidium convolutum		N			SeO_2	am		20		3 d	EC50	biomass	0.30		Abdel-Hamid and Skulberg, 1995
Monoraphidium griffithii	$2x10^4$ cells/ml	N			Na_2SeO_3	am		20		3 d	EC50	biomass	0.69		Abdel-Hamid and Skulberg, 1995
Monoraphidium griffithii	$2x10^4$ cells/ml	N			SeO_2	am		20		3 d	EC50	biomass	0.56		Abdel-Hamid and Skulberg, 1995
Scenedesmus obliquus	$2x10^4$ cells/ml	N			Na_2SeO_3	am		20		3 d	EC50	biomass	0.080		Abdel-Hamid and Skulberg, 1995
Scenedesmus obliquus	$2x10^4$ cells/ml	N			SeO_2	am		20		3 d	EC50	biomass	0.10		Abdel-Hamid and Skulberg, 1995
Selenastrum capricornutum	$2x10^4$ cells/ml	N			Na_2SeO_3	am		20		3 d	EC50	biomass	3.3		Abdel-Hamid and Skulberg, 1995
Selenastrum capricornutum	$2x10^4$ cells/ml	N			SeO_2	am		20		3 d	EC50	biomass	1.2		Abdel-Hamid and Skulberg, 1995

Species	Species properties	A	Test type	Purity [%]	Test compound	Test water	pH	T [°C]	Hardness [mg $CaCO_3$/l]	Exp. time	Criterion	Test endpoint	Value [mg/l]	Notes	Reference
Macrophyta															
Lemna minor		N	S		Se^{4+}	rw	7.5			96 h	EC50	growth	2.4		Wang, 1986b
Rotifera															
Brachionus calyciflorus		N	S		Se	am	7.5	25	85	1 d	EC50	mortality	16		Snell et al., 1991b
Crustacea															
Ceriodaphnia affinis	<24 h	Y	S		Na_2SeO_3	tw	7.9		101	48 h	EC50		0.60		Owsley and McCauley, 1986
Ceriodaphnia affinis		Y	S		Na_2SeO_3	tw	7.9		101	48 h	EC50		0.35	2	Owsley and McCauley, 1986
Ceriodaphnia dubia	<24 h	Y	S	rg	Na_2SeO_4	syn w	7.8	20	52	48 h	LC50		1.9	3	Brix et al., 2001
Ceriodaphnia dubia	<24 h	Y	S	rg	Na_2SeO_4	syn w	7.8	20	52	48 h	LC50		2.0	3	Brix et al., 2001
Daphnia magna	<24 h	N	S		Na_2SeO_3	tw	7.6-7.7		286	24 h	EC50		10		Bringmann and Kühn, 1977a
Daphnia magna	<24 h	N	S		Na_2SeO_3	tw	8.0±0.2		250	24 h	EC50		3.9		Bringmann and Kühn, 1982
Daphnia magna	<24 h	N	S	n.r.	Na_2SeO_3	rw	8.2-8.4		130	48 h	EC50		1.1		Dunbar et al., 1983
Daphnia magna	<24 h	N	S		Na_2SeO_3	rw	7.8		46	48 h	EC50		0.70		Ingersoll et al., 1990
Daphnia magna	<24 h	N	S		Na_2SeO_3	rw	8.2		136	48 h	EC50		3.0		Ingersoll et al., 1990
Daphnia magna		Y	S		Na_2SeO_3	rec	8.2		85	48 h	LC50		0.55	4	Maier et al., 1993
Daphnia magna	adult	N	S		Na_2SeO_3					48 h	EC50		0.25		Nassos et al. 1980
Daphnia magna	middle instar	Y	CF		Na_2SeO_3/O_4	nw	7.3	25	329	48 h	LC50		0.71	5	Halter et al., 1980
Daphnia magna	middle instar	Y	CF		Na_2SeO_3/O_4	nw	7.3	25	329	96 h	LC50		0.43	5	Halter et al., 1980
Daphnia magna	<24 h	N	S		Na_2SeO_3/O_4	rw	7.8		46	48 h	EC50		1.8	6	Ingersoll et al., 1990
Daphnia magna	<24 h	N	S		Na_2SeO_3/O_4	rw	8.2		136	48 h	EC50		2.6	6	Ingersoll et al., 1990
Daphnia magna	<24 h	N	S	n.r.	Na_2SeO_4	rw	8.2-8.4		130	48 h	EC50		5.3		Dunbar et al., 1983
Daphnia magna	<24 h	N	S		Na_2SeO_4	rw	7.8		46	48 h	EC50		2.6		Ingersoll et al., 1990
Daphnia magna	<24 h	N	S		Na_2SeO_4	rw	8.2		136	48 h	EC50		4.1		Ingersoll et al., 1990
Daphnia magna	egg	N	SS		Na_2SeO_4		8.4			72 h	EC50		1.4		Johnston, 1987
Daphnia magna	6-18 h	N	SS		Na_2SeO_4		8.4			48 h	EC50		0.55		Johnston, 1987
Daphnia magna		Y	S		Na_2SeO_4	rec	8.2		85	48 h	LC50		2.5	4	Maier et al., 1993
Daphnia magna	<24 h	N	S		Na_2SeO_3	nw	7.5		204	48 h	EC50		2.5		Bringmann and Kühn, 1959
Daphnia magna	≤24 h	N	S		SeO_2	am	7.9		250	48 h	LC50	mortality	4.8		Weltens et al., 2000
Daphnia pulex	12-36 h	N	S		Na_2SeO_3	rw	7.4		46	48 h	EC50		3.9		Reading and Buikema, 1983
Daphnia pulex	ad, unfed	N	S		Na_2SeO_3	fw	7.4	20		96 h	EC50	mortality	0.071		Schultz et al., 1980

Species	Species properties	A	Test type	Purity [%]	Test compound	Test water	pH	T [°C]	Hardness [mg $CaCO_3$/l]	Exp. time	Criterion	Test endpoint	Value [mg/l]	Notes	Reference
Daphnia pulex	juv, fed	N	S		Na_2SeO_3	fw	7.4	20		96 h	EC50	mortality	0.13		Schultz et al., 1980
Daphnia pulex	ad, fed	N	S		Na_2SeO_3	fw	7.4	20		96 h	EC50	mortality	0.50		Schultz et al., 1980
Daphnia pulex	<24 h	Y	S	rg	Na_2SeO_4	syn w	7.7	20	52	48 h	LC50		10	3	Brix et al., 2001
Daphnia pulex	<24 h	Y	S	rg	Na_2SeO_4	syn w	7.7	20	52	48 h	LC50		8.1	3	Brix et al., 2001
Gammarus lacustris	0.008-0.012 m; sub-ad	Y	S	rg	Na_2SeO_4	syn w	7.6	15	116	96 h	EC50	mortality	3.1		Brix et al., 2001
Gammarus pseudolimnaeus	0.005-0.01 m; juv	Y	S	rg	Na_2SeO_4	Mixed	7.6	18	140		EC50	mortality	2.5		Brix et al., 2001
Gammarus pseudolimnaeus	ad	Y	S	rg	Na_2SeO_4	lw	7.8	17.8	139	96 h	EC50	mortality	1.2		Brix et al., 2001
Hyalella azteca	60 d; 2 mm	Y	R	rg	Na_2SeO_3	ww	8.6		133	96 h	EC50	mortality	0.68		Brasher and Ogle, 1993
Hyalella azteca	adult	Y	CF		Na_2SeO_3/O_4	nw	7.3	25	329	96 h	LC50	mortality	0.34	5	Halter et al., 1980
Hyalella azteca	60 d; 2 mm	Y	R	rg	Na_2SeO_4	ww	8.6		133	96 h	EC50	mortality	1.9		Brasher and Ogle, 1993
Hyalella azteca	17-22 d	Y	S	rg	Na_2SeO_4	syn w	7.4	18.2	143	96 h	EC50	mortality	2.5		Brix et al., 2001
Hyalella azteca	7-10 d	Y	S	rg	Na_2SeO_4	syn w	7.8	20	52	96 h	EC50	mortality	1.4	7	Brix et al., 2001
Insecta															
Chironomus decorus	4th instar	Y	S		Na_2SeO_3	rec	8.1-8.3	20	85	48 h	EC50	mortality	48	8	Maier and Knight, 1993
Chironomus decorus	4th instar	Y	S		Na_2SeO_4	rec	8.1-8.3	20	85	48 h	EC50	mortality	24	7	Maier and Knight, 1993
Chironomus riparius	larvae	Y	R		Na_2SeO_3	nw				120 h	LC50	mortality	6.7	9	Beaty and Hendricks, 2001
Chironomus riparius	larvae	Y	R		Na_2SeO_3	nw				120 h	LC50	mortality	4.1	9	Beaty and Hendricks, 2001
Chironomus thummi	<24 h	N	S		Na_2SeO_3	river w	8.16	22	136	48 h	EC50	immobilization	0.70		Ingersoll et al., 1990
Chironomus thummi	<24 h	N	S		Na_2SeO_3	syn w	7.82	22	46	48 h	EC50	immobilization	15		Ingersoll et al., 1990
Chironomus thummi	<24 h	N	S		Na_2SeO_4	river w	8.16	22	136	48 h	EC50	immobilization	16		Ingersoll et al., 1990
Chironomus thummi	<24 h	N	S		Na_2SeO_4	syn w	7.82	22	46	48 h	EC50	immobilization	11		Ingersoll et al., 1990
Chironomus thummi	<24 h	N	S		Se	river w	8.16	22	136	48 h	EC50	mortality	1.8	6	Ingersoll et al., 1990
Chironomus thummi	<24 h	N	S		Se	fw	7.82	22	46	48 h	EC50	mortality	14	6	Ingersoll et al., 1990
Culex fatigans	larvae	N	S		Na_2SeO_3					48 h	LC50	mortality	3.1		Nassos et al., 1980
Annelida															
Tubifex tubifex		N	S		$NaHSeO_3$	nw	7.6		245	96 h	EC50	immobility	7.7		Khangarot, 1991
Pisces															
Carassius auratus	4-8 cm	N	S		SeO_2	de-ion w	6-6.9	19-25	125	2 d	LC50	mortality	12	10	Weir and Hine, 1970
Catostomus commersoni	adult	Y	CF		Na_2SeO_3	nw	6.4		18	96 h	LC50	mortality	31		Duncan et al., 1983

Species	Species properties	A	Test type	Purity [%]	Test compound	Test water	pH	T [°C]	Hardness [mg $CaCO_3$/l]	Exp. time	Criterion	Test endpoint	Value [mg/l]	Notes	Reference
Catostomus commersoni	juvenile	Y	IF		Na_2SeO_3	nw	6.4		10	96 h	LC50	mortality	29		Klaverkamp et al., 1983
Catostomus latipinnis	12-12 d; larvae	N		rg	Na_2SeO_3	rec	7.4-7.9	25	144	96 h	LC50	mortality	12		Hamilton and Buhl, 1997b
Catostomus latipinnis	12-12 d; larvae	N		rg	Na_2SeO_4	rec	7.4-7.9	25	144	96 h	LC50	mortality	15		Hamilton and Buhl, 1997b
Colisa fasciatus	ad, 48-55 mm, 2.9-3.2 g	N	R	ag	SeO_2	am	6.8-7.6	23	68	120 h	LC50	mortality	2.3		Srivastava and Tyagi, 1984
Danio rerio	larvae; 0.25 mg	Y			K_2SeO_3	fw		26		96 h	LC50	mortality	15		Niimi and LaHam, 1976
Danio rerio	larvae; 0.25 mg	Y			K_2SeO_4	fw		26		96 h	LC50	mortality	81		Niimi and LaHam, 1976
Danio rerio	larvae; 0.25 mg	Y			Na_2SeO_3	fw		26		96 h	LC50	mortality	23		Niimi and LaHam, 1976
Danio rerio	larvae; 0.25 mg	Y			Na_2SeO_4	fw		26		96 h	LC50	mortality	82		Niimi and LaHam, 1976
Danio rerio	larvae; 0.25 mg	Y			SeO_2	fw		26		96 h	LC50	mortality	20		Niimi and LaHam, 1976
Esox lucius	juvenile	Y	IF		Na_2SeO_3	nw	6.4		10	72 h	LC50	mortality	11		Klaverkamp et al., 1983
Etroplus maculatus	8.2-8.3 cm; field collected	N	S		SeO_2	tw	7.2	29	28.4	96 h	LC50	mortality	7.6		Gaikwad, 1989
Etroplus maculatus	field collected	N	R		SeO_2	tw	6.8	28		96 h	LC50	mortality	4.6		Veena et al., 1997
Gila elegans	4-19 d; 0.7-1.4 cm; larvae; 2-13 mg	N	S	rg; ≥99	Na_2SeO_3	rec	7.6-8.6	25	199	96 h	LC50	mortality	23		Buhl and Hamilton, 1996
Gila elegans	100-110 d; 3.9-4.1 cm; juv; 0.378-0.45 g	N	S	rg; ≥99	Na_2SeO_3	rec	7.6-8.6	25	199	96 h	LC50	mortality	21		Buhl and Hamilton, 1996
Gila elegans	11-18 d; fry	N	S		Na_2SeO_3	rec	7-8.5	25	182-201	96 h	LC50	mortality	19		Hamilton, 1995
Gila elegans	138-145 h; juv; 1.1 g	N	S		Na_2SeO_3	rec	7-8.5	25	182-201	96 h	LC50	mortality	17		Hamilton, 1995
Gila elegans	220-234 d; juv; 2.6 g	N	S		Na_2SeO_3	rec	7-8.5	25	182-201	96 h	LC50	mortality	15		Hamilton, 1995
Gila elegans	4-19 d; 0.7-1.4 cm; larvae; 2-13 mg	N	S	rg; ≥99	Na_2SeO_4	rec	7.9	25	199	96 h	LC50	mortality	26		Buhl and Hamilton, 1996
Gila elegans	100-110 d; 3.9-4.1 cm; juv; 0.378-0.45 g	N	S	rg; ≥99	Na_2SeO_4	rec	7.9	25	199	96 h	LC50	mortality	44		Buhl and Hamilton, 1996
Gila elegans	11-18 d; fry	N	S		Na_2SeO_4	rec	7-8.5	25	182-201	96 h	LC50	mortality	55		Hamilton, 1995
Gila elegans	138-145 h; juv; 1.1 g	N	S		Na_2SeO_4	rec	7-8.5	25	182-201	96 h	LC50	mortality	246		Hamilton, 1995
Gila elegans	220-234 d; juv; 2.6 g	N	S		Na_2SeO_4	rec	7-8.5	25	182-201	96 h	LC50	mortality	217		Hamilton, 1995
Gila elegans	juvenile	Y	IF		SeO_2		7.9		140	96 h	LC50	mortality	13		Cardwell et al., 1976
Jordanella floridae	juvenile	Y	IF		SeO_2		7.9		152	96 h	LC50	mortality	6.5	5	Cardwell et al., 1976
Leuciscus idus melanotus		N	S		Na_2SeO_3	tw	7-8		255	48 h	LC50	mortality	110		Juhnke and Lüdemann, 1978
Notemigonus crysoleucas	fish	Y	CF	rg	Na_2SeO_3	tw	7.5		72.2	96 h	LC50	mortality	11		Hartwell et al., 1989
Oncorhynchus kisutch	29.8 mm; alevin; 0.24 g	N			Na_2SeO_3	fw	<=9.6	12	41	96 h	LC50	mortality	80		Buhl and Hamilton, 1991
Oncorhynchus kisutch	41.6 mm; juv; 0.47 g	N			Na_2SeO_3	fw	<=9.6	12	41	96 h	LC50	mortality	7.8		Buhl and Hamilton, 1991
Oncorhynchus kisutch	fry, 0.5 g, 8-12 wk	N	S		Na_2SeO_3	fw	7.8	12	211	96 h	LC50	mortality	7.8		Hamilton and Buhl, 1990a
Oncorhynchus kisutch	29.8 mm; alevin; 0.24 g	N			Na_2SeO_4	fw	6.1-7.9	12	41	96 h	LC50	mortality	379		Buhl and Hamilton, 1991
Oncorhynchus kisutch	41.6 mm; juv; 0.47 g	N			Na_2SeO_4	fw	6.1-7.9	12	41	96 h	LC50	mortality	74		Buhl and Hamilton, 1991

Species	Species properties	A	Test type	Purity [%]	Test compound	Test water	pH	T [°C]	Hardness [mg $CaCO_3$/l]	Exp. time	Criterion	Test endpoint	Value [mg/l]	Notes	Reference
Oncorhynchus kisutch	fry, 0.5 g, 8-12 wk	N	S		Na_2SeO_4	fw	7.8	12	211	96 h	LC50	mortality	33		Hamilton and Buhl, 1990a
Oncorhynchus mykiss	20.8 mm; alevin; 0.1 g	N			Na_2SeO_3	fw	<=9.6	12	41	96 h	LC50	mortality	118		Buhl and Hamilton, 1991
Oncorhynchus mykiss	49.6 mm; juv; 1.04 g	N			Na_2SeO_3	fw	<=9.6	12	41	96 h	LC50	mortality	9.0		Buhl and Hamilton, 1991
Oncorhynchus mykiss	adult				Na_2SeO_3	nw	7.2		40	96 h	LC50	mortality	1.8		Hunn et al., 1987
Oncorhynchus mykiss	20.8 mm; alevin; 0.1 g	N			Na_2SeO_4	fw	6.1-7.9	12	41	96 h	LC50	mortality	470		Buhl and Hamilton, 1991
Oncorhynchus mykiss	49.6 mm; juv; 1.04 g	N			Na_2SeO_4	fw	6.1-7.9	12	41	96 h	LC50	mortality	32		Buhl and Hamilton, 1991
Oncorhynchus mykiss	fish, 125 mm	N	S				6.7-7.3	12	36	96 h	LC50	mortality	13		Goettl et al., 1976
Oncorhynchus mykiss	fish, 60 mm	N	S				6.7-7.3	9	30	96 h	LC50	mortality	12		Goettl et al., 1976
Oncorhynchus tshawytscha	alevin				Na_2SeO_3	fw	7.6	12	41.7	96 h	LC50	mortality	104		Hamilton and Buhl, 1990a
Oncorhynchus tshawytscha	fry, 0.31 g				Na_2SeO_3	fw	7.6	12	41.7	96 h	LC50	mortality	27		Hamilton and Buhl, 1990a
Oncorhynchus tshawytscha	fry, 0.46 g				Na_2SeO_3	fw	7.6	12	41.7	96 h	LC50	mortality	13		Hamilton and Buhl, 1990a
Oncorhynchus tshawytscha	8-12 wk; 0.5-0.7 g	N	S		Na_2SeO_3	nw	7.8		211	96 h	LC50	mortality	14	11	Hamilton and Buhl, 1990a
Oncorhynchus tshawytscha	fry, 0.31 g				Na_2SeO_4	fw	7.6	12	41.7	96 h	LC50	mortality	114		Hamilton and Buhl, 1990a
Oncorhynchus tshawytscha	8-12 wk; 0.5-0.7 g	N	S		Na_2SeO_4	nw	7.8		211	96 h	LC50	mortality	115	11	Hamilton and Buhl, 1990a
Oryzias latipes	8 d fry	N	S		Na_2SeO_3	tw	6.9		11	24 h	LC50	mortality	16	5	Hiraoka et al., 1985
Pimephales promelas	fry, 25-35 d, 0.03 g, 17 mm	Y	CF		Na_2SeO_3/O_4	nw	7.3	25	329	96 h	LC50	mortality	1.0		Halter et al., 1980
Pimephales promelas	1 d fry	Y	IF		SeO_2		7.8		151	96 h	LC50	mortality	2.1		Cardwell et al., 1976
Ptychocheilus lucius	8-8 d; 0.9-1.1 cm; larvae; 0.004-0.007 g	N	S	rg; ≥99	Na_2SeO_3	rec	7.9	25	199	96 h	LC50	mortality	13		Buhl and Hamilton, 1996
Ptychocheilus lucius	155-186 d; 4.2-4.7 cm; juv; 0.433-0.574 g	N	S	rg; ≥99	Na_2SeO_3	rec	7.9	25	199	96 h	LC50	mortality	28		Buhl and Hamilton, 1996
Ptychocheilus lucius	40 d; 20 mm; posthatch larvae; 47 mg	N			Na_2SeO_3	rec river w	8.06	25	144	96 h	LC50	mortality	21		Hamilton and Buhl, 1997a
Ptychocheilus lucius	99-115 d; juv; 0.4-1.1 g	N	S		Na_2SeO_3	rec	7-8.5	25	182-201	96 h	LC50	mortality	36		Hamilton, 1995
Ptychocheilus lucius	17-31 d; fry	N	S		Na_2SeO_3	rec	7-8.5	25	182-201	96 h	LC50	mortality	14		Hamilton, 1995
Ptychocheilus lucius	193-207 d; juv; 1.7 g	N	S		Na_2SeO_3	rec	7-8.5	25	182-201	96 h	LC50	mortality	32		Hamilton, 1995
Ptychocheilus lucius	155-186 d; 4.2-4.7 cm; juv; 0.433-0.574 g	N		rg; ≥99	Na_2SeO_4	rec	7.9	25	199	96 h	LC50	mortality	78		Buhl and Hamilton, 1996
Ptychocheilus lucius	8-15 d; 0.9-1.1 cm; larvae; 0.004-0.007 g	N	S	rg; ≥99	Na_2SeO_4	rec	7.9	25	199	96 h	LC50	mortality	25		Buhl and Hamilton, 1996
Ptychocheilus lucius	40 d; 20 mm; posthatch larvae; 47 mg	N			Na_2SeO_4	rec river w	8.06	25	144	96 h	LC50	mortality	88		Hamilton and Buhl, 1997a
Ptychocheilus lucius	99-115 d; juv; 0.4-1.1 g	N	S		Na_2SeO_4	rec	7-8.5	25	182-201	96 h	LC50	mortality	286		Hamilton, 1995
Ptychocheilus lucius	17-31 d; fry	N	S		Na_2SeO_4	rec	7-8.5	25	182-201	96 h	LC50	mortality	66		Hamilton, 1995
Ptychocheilus lucius	193-207 d; juv; 1.7 g	N	S		Na_2SeO_4	rec	7-8.5	25	182-201	96 h	LC50	mortality	331		Hamilton, 1995
Savelinus fontinalis	adult	Y	IF		SeO_2		7.8		148	96 h	LC50	mortality	10		Cardwell et al., 1976

Species	Species properties	A	Test type	Purity [%]	Test compound	Test water	pH	T [°C]	Hardness [mg $CaCO_3$/l]	Exp. time	Criterion	Test endpoint	Value [mg/l]	Notes	Reference
Stizostedion vitreum	66.7 mm; fingerling	Y	CF	rg	Na_2SeO_3		7.8		380	96 h	LC50	mortality	12		Mauk and Brown, 1999
Thymallus arcticus	15 mm; alevin; 0.02 g	N			Na_2SeO_3	fw	<=9.6	12	41	96 h	LC50	mortality	76		Buhl and Hamilton, 1991
Thymallus arcticus	51.5 mm; juv; 0.81 g	N			Na_2SeO_3	fw	<=9.6	12	41	96 h	LC50	mortality	34		Buhl and Hamilton, 1991
Thymallus arcticus	14.3 mm; alevin; 0.01 g	N			Na_2SeO_4	fw	6.1-7.9	12	41	96 h	LC50	mortality	100		Buhl and Hamilton, 1991
Thymallus arcticus	62.4 mm; juv; 1.44 g	N			Na_2SeO_4	fw	6.1-7.9	12	41	96 h	LC50	mortality	180		Buhl and Hamilton, 1991
Tilapia mossambica	4.5-9 cm; field collected sp.	N	S		Na_2SeO_4					96 h	LC50	mortality	6.4		Chidambaram and Sastry, 1991
Xyrauchen texanus	7-29 d; 1.1-2.5 cm; larvae; 0.004-0.107 g	N	S	rg	Na_2SeO_3	rec	7.9	25	199	96 h	LC50	mortality	17		Buhl and Hamilton, 1996
Xyrauchen texanus	102-102 d; 3.3-3.8 cm; juv; 0.351-0.58 g	Y	S	rg	Na_2SeO_3	rec	7.9	25	199	96 h	LC50	mortality	14		Buhl and Hamilton, 1996
Xyrauchen texanus	23 d; 20 mm; posthatch larvae; 42 mg	N			Na_2SeO_3	rec river w	8.06	25	144	96 h	LC50	mortality	11		Hamilton and Buhl, 1997a
Xyrauchen texanus	176-186 d; juv; 2 g	N	S		Na_2SeO_3	rec	7-8.5	25	182-201	96 h	LC50	mortality	16		Hamilton, 1995
Xyrauchen texanus	133-139 d; juv; 0.9 g	N	S		Na_2SeO_3	rec	7-8.5	25	182-201	96 h	LC50	mortality	9		Hamilton, 1995
Xyrauchen texanus	10-17 d; fry	N	S		Na_2SeO_3	rec	7-8.5	25	182-201	96 h	LC50	mortality	15		Hamilton, 1995
Xyrauchen texanus	102-116 d; 3.3-3.8 cm; juv; 0.351-0.58 g	Y	S	rg	Na_2SeO_4	rec	7.9	25	199	96 h	LC50	mortality	14		Buhl and Hamilton, 1996
Xyrauchen texanus	7-29 d; 1.1-2.5 cm; larvae; 0.004-0.107 g	N	S	rg	Na_2SeO_4	rec	7.9	25	199	96 h	LC50	mortality	25		Buhl and Hamilton, 1996
Xyrauchen texanus	23 d; 20 mm; posthatch larvae; 42 mg	N			Na_2SeO_4	rec river w	8.06	25	144	96 h	LC50	mortality	16		Hamilton and Buhl, 1997a
Xyrauchen texanus	176-186 d; juv; 2 g	N	S		Na_2SeO_4	rec	7-8.5	25	182-201	96 h	LC50	mortality	25		Hamilton, 1995
Xyrauchen texanus	133-139 d; juv; 0.9 g	N	S		Na_2SeO_4	rec	7-8.5	25	182-201	96 h	LC50	mortality	36		Hamilton, 1995
Xyrauchen texanus	10-17 d; fry	N	S		Na_2SeO_4	rec	7-8.5	25	182-201	96 h	LC50	mortality	48		Hamilton, 1995
Amphibia															
Xenopus laevis	embryo to tadpole	N	R		Na_2SeO_3	de-ion w		23		7 d	EC50	mortality	0.7		Browne and Dumont, 1979
Xenopus laevis		N	R		Na_2SeO_4	am	7-8	24			EC50	mortality	21	12	DeYoung et al., 1991
Xenopus laevis		N	R		Na_2SeO_4	am	7-8	24			EC50	teratogenesis	7.2	12	DeYoung et al., 1991

Notes
1. Integral of growth curve used to determine EC50.
2. F1-animals of which the parents were exposed to 18-360 mg Se/l during 18-19 days.
3.Test performed in duplicate, both results have been entered.
4. Sulfate concentration in testwater 81.5 mg/l
5. EC50 and LC50 calculated according to Spearman and Karber.
6. 6:1 selenate:selenite mixture.
7. 2-3 mm silica sand (without organic C) was placed at the bottom of the test chambers
8. Sulfate concentration of testwater 27.2 mg/l
9. Test results obtained with two control cultures; experiment contained a series of Se acclimated cultures.

10. 50 mg/l $CaCO_3$ was added to the water; organisms exposed for 48 h; mortality scored 7 days thereafter.
11. Reported here is the pooled value of two experiments.
12. Result is the geometric mean of three replicate tests.

Table A2. 5. Acute toxicity of molybdenum to freshwater organisms.

Species	Species properties	A	Test type	Purity [%]	Test compound	Test water	pH	T [°C]	Hardness [mg $CaCO_3$/l]	Exp. time	Criterion	Test endpoint	Value [mg/l]	Notes	Reference
Annelida															
Tubifex tubifex		N	S		Na_2MoO_4	nw	7.6		245	96 h	EC50	immobility	29		Khangarot, 1991
Crustacea															
Crangonyx pseudogracilis		N	S		Na_2MoO_4	tw	6.7-6.8		45-55	96 h	LC50	mortality	2700		Martin and Holdich, 1986
Pisces															
Catostomus latipinnis	larvae; 12-13 d	N	S	rg	Na_2MoO_4	rw	7.9	25	144	96 h	LC50	mortality	1940		Hamilton and Buhl, 1997
Nemacheilus botia	3.5 g, 5.8 cm	N	S		$(NH_4)_6Mo_7O_{24}$		8.0-8.5	20	36-60	96 h	LC50	mortality	211	1	Pundir, 1989
Oncorhynchus mykiss	fish, 55 mm	Y	S		Na_2MoO_4	tw	6.9-7.2	12	14-32	96 h	LC50	mortality	1320		McConnell, 1977
Oncorhynchus mykiss	fish, 20 mm	Y	S		Na_2MoO_4	tw	6.9-7.2	8	14-32	96 h	LC50	mortality	800		McConnell, 1977
Puntius ticto	field collected	N	S		$(NH_4)_6Mo_7O_{24}$		8.0	16	53	96 h	LC50	mortality	550		Pundir and Saxena, 1990

Notes
1. Hardness was 36 mg $CaCO_3$/l at the start and 60 mg/l at the end of the test.

Table A2. 6. Acute toxicity of tin to freshwater organisms.

Species	Species properties	A	Test type	Purity [%]	Test compound	Test water	pH	T [°C]	Hardness [mg $CaCO_3$/l]	Exp. time	Criterion	Test endpoint	Value [mg/l]	Notes	Reference
Cyanobacteria															
Anabaena doliolum		N	S		$SnCl_2$	am	7.5	26		2 h	EC50	CO2 uptake	52	1	Dubey and Rai, 1990a
Protozoa															
Tetrahymena pyriformis	$1x10^4$ cells/ml	N	S	>98	$SnCl_2$	am				9 h	IC50	growth	90		Sauvant et al., 1995c
Tetrahymena pyriformis	$1x10^4$ cells/ml	N	S	>99	$SnCl_4$	am		28		9 h	IC50	growth	54		Sauvant et al., 1995b
Algae															
Scenedesmus quadricauda	$7x10^5$ cells/ml	N	S		$SnCl_4$	nw	8	20		4 h	EC50	primary prod.	50	2	Wong et al., 1982
Ankistrodesmus falcatus	$7x10^5$ cells/ml	N	S		$SnCl_2$	nw	8	20		4 h	EC50	primary prod.	14	2	Wong et al., 1982
Ankistrodesmus falcatus	$7x10^5$ cells/ml	N	S		$SnCl_4$	nw	8	20		4 h	EC50	primary prod.	12	2	Wong et al., 1982
Annelida															
Tubifex tubifex	20 mm	N	S		$SnCl_2$	am	6.67	20	10	96 h	EC50	mortality	30	3	Fargašová, 1994
Tubifex tubifex	field collected mature worms, 20 mm	N	S	a.g.	$SnCl_2$	tw	7.8	20	311	96 h	LC50	mortality	30	3	Fargašová, 1999b
Tubifex tubifex					$SnCl_2$	fw				96 h	EC50	immobilization	21		Khangarot, 1991
Tubifex tubifex	field collected mature worms, 20 mm	N	S	a.g.	Na_2SnO_3	tw	7.8	20	311	96 h	LC50	mortality	27.5		Fargašová, 1999b
Crustacea															
Crangonyx pseudogracilis	ad, 4 mm, 0.2 mg	N	S		$SnCl_2$	tw	6.7-6.8	13	45-55	96 h	LC50	mortality	50		Martin and Holdich, 1986
Daphnia magna		N	S		$SnCl_2$	nw	7.2-7.8		235-260	48 h	EC50	immobilization	22		Khangarot and Ray, 1989a
Daphnia magna	12 h				$SnCl_2$	fw	7.74	18	45	48 h	EC50	immobilization	55		Biesinger and Christensen, 1972
Insecta															
Chironomus plumosus		N	S		SnCl2	am	6.67	20	10	96 h	LC50	mortality	3.6		Fargašová, 1994
Pisces															
Cyprinus carpio communis	fertilised eggs				SnCl2	fw	7.51	16	360		LC50	mortality	295		Kapur and Yadav, 1982

Notes

1. Figure was scanned, digitised, and a logistic dose-effect relationship was fitted through the obtained dataset using nonlinear regression; EC50 determined from this relationship.
2. primary production measured as uptake of 14C-bicarbonate.
3. Although LC50 values are identical, pH and hardness differ. Therefore these tests are considered independent test results.

Table A2. 7. Acute toxicity of antimony to freshwater organisms.

Species	Species properties	A	Test type	Purity [%]	Test compound	Test water	pH	T [°C]	Hardness [mg $CaCO_3$/l]	Exp. time	Criterion	Test endpoint	Value [mg/l]	Notes	Reference
Protozoa															
Tetrahymena pyriformis		N	S	ag	$SbCl_3$	am		28		9 h	EC50	doubling time	16		Sauvant et al., 1997
Tetrahymena pyriformis	1e4 cells/ml	N	S	>98	$SbCl_3$	am				9 h	IC50	growth	20		Sauvant et al., 1995c
Tetrahymena pyriformis	1e4 cells/ml	N	S	≥ 99	$SbCl_3$	am		28		9 h	IC50	growth	16		Sauvant et al., 1995b
Tetrahymena pyriformis	5e4 cells/ml	N	S	≥ 99	$SbCl_3$	am		28		36 h	IC50	growth	6		Sauvant et al., 1995b
Crustacea															
Daphnia magna	<24 h	Y	S		$K_2(C_4H_2O_6Sb)_2$		7.8 ± 0.2	20	31	48 h	LC50	mortality	5		Doe et al., 1987
Daphnia magna	<24 h	Y	S		$K_2(C_4H_2O_6Sb)_2$		7.8 ± 0.2	20	45	48 h	LC50	mortality	5		Doe et al., 1987
Daphnia magna	<24 h	Y	S		$K_2(C_4H_2O_6Sb)_2$		7.8 ± 0.2	20	92	48 h	LC50	mortality	5		Doe et al., 1987
Daphnia magna	<24 h	Y	S		$K_2(C_4H_2O_6Sb)_2$		7.8 ± 0.2	20	220	48 h	LC50	mortality	6.7		Doe et al., 1987
Daphnia magna	<24 h	N	S		$K_2(C_4H_2O_6Sb)_2$	nw	7.5		67	48 h	EC50	immobility	9.0		Bringmann and Kühn, 1959
Daphnia magna	24 h	N	S		$K_2(C_4H_2O_6Sb)_2$	am		20	250	24 h	EC50	immobility	55		Knie et al., 1983
Pisces															
Leuciscus idus melanotus		N	S		$KSb(OH)_6$	tw	7-8	20	255	48 h	LC50	mortality	1100		Juhnke and Lüdemann, 1978
Oncorhynchus mykiss	mean weight 1.2 g	Y	S		$K_2(C_4H_2O_6Sb)_2$		6.7-7.3	15	25	96 h	LC50	mortality	37		Doe et al., 1987
Tilapia mossambica	larvae, 3 d	N	S	99.99	$SbCl_3$	fw		26-29		96 h	LC50	mortality	36	1	Lin and Hwang, 1998

Notes
1. Duration was 48 h, but all mortality occured within 48 h, therefore 96 h LC50=48 h LC50.

Table A2. 8. Acute toxicity of barium to freshwater organisms.

Species	Species properties	A	Test type	Purity [%]	Test compound	Test water	pH	T [°C]	Hardness [mg $CaCO_3$/l]	Exp. time	Criterion	Test endpoint	Value [mg/l]	Notes	Reference
Protozoa															
Tetrahymena pyriformis		N	S	ag	$BaCl_2$	am		28		9 h	EC50	doubling time	350		Sauvant et al., 1997
Tetrahymena pyriformis	1e4 cells/ml	N	S	ag	$BaCl_2$	am				9 h	EC50	growth	330		Sauvant et al., 1995c
Tetrahymena pyriformis	1e4 cells/ml	N	S	>99	$BaCl_2$	fw		28		9 h	EC50	growth	350		Sauvant et al., 1995b
Macrophyta															
Lemna minor	40 fronds	Y	S	rg	$BaCl_2$	nw	8.0-8.1	25-28	245-320	96 h	EC50	growth	314	1	Wang, 1988
Lemna minor	40 fronds	Y	S	rg	$BaCl_2$	nw	8.1-8.3	25-28	290-318	96 h	EC50	growth	229	2	Wang, 1988
Lemna minor	40 fronds	Y	S	rg	$BaCl_2$	nw	6.3-7.3	25-28	37-38	96 h	EC50	growth	97	3	Wang, 1988
Lemna minor	40 fronds	Y	S	rg	$BaCl_2$	nw	6.9-7.6	25-28	54-78	96 h	EC50	growth	95	4	Wang, 1988
Lemna minor	40 fronds	Y	S	rg	$BaCl_2$	nw	8.0-8.1	25-28	140-146	96 h	EC50	growth	119	5	Wang, 1988
Lemna minor	40 fronds	Y	S	rg	$BaCl_2$	nw	7.3-7.8	25-28	84-87	96 h	EC50	growth	174	6	Wang, 1988
Lemna minor	40 fronds	Y	S	rg	$BaCl_2$	nw	8.1-8.3	25-28	237-242	96 h	EC50	growth	136	7	Wang, 1988
Lemna minor	40 fronds	Y	S	rg	$BaCl_2$	nw	7.9-8.2	25-28	308-311	96 h	EC50	growth	354	8	Wang, 1988
Lemna minor	40 fronds	Y	S	rg	$BaCl_2$	nw	7.6-8.1	25-28	82-256	96 h	EC50	growth	111	9	Wang, 1988
Lemna minor	40 fronds	Y	S	rg	$BaCl_2$	nw	8.1-8.3	25-28	160-310	96 h	EC50	growth	133	10	Wang, 1988
Lemna minor	40 fronds	Y	S	rg	$BaCl_2$	nw	7.3-8.0	25-28	80-129	96 h	EC50	growth	97	11	Wang, 1988
Lemna minor	40 fronds	Y	S	rg	$BaCl_2$	nw	7.5-8.3	25-28	126-314	96 h	EC50	growth	193	12	Wang, 1988
Lemna minor	40 fronds	Y	S	rg	$BaCl_2$	nw	7.8-8.3	25-28	244-325	96 h	EC50	growth	259	13	Wang, 1988
Platyhelminthes															
Dugesia tigrina	20 d, 11-12 mm long, whole individuals	N	S	ag	$Ba(NO_3)_2$	ISO	7.2-8.2	18-22	105	96 h	LC50	mortality	97		Piontek, 1999
Dugesia tigrina	20 d, cut individuals	N	S	ag	$Ba(NO_3)_2$	ISO	7.2-8.2	18-22	105	10 d	LC50	mortality	15		Piontek, 1999
Nematoda															
Caenorhabditis elegans					$Ba(NO_3)_2$	fw		20		24 h	LC50	mortality	385		Tatara et al., 1998
Rotifera															
Brachionus calyciflorus	larvae	N	S	>97	$Ba(NO_3)_2$	syn w		25	85	24 h	LC50	mortality	372		Calleja et al., 1994

Species	Species properties	A	Test type	Purity [%]	Test compound	Test water	pH	T [°C]	Hardness [mg $CaCO_3$/l]	Exp. time	Criterion	Test endpoint	Value [mg/l]	Notes	Reference
Crustacea															
Austropotamobius pallipes	19-32 mm	Y			$BaCl_2$		7	16		96 h	LC50	mortality	46		Boutet and Chaisemartin, 1973
Daphnia	< 24 h	N	S		$BaCl_2$	nw	7.5		67	48 h	EC50	immobility	170		Bringmann and Kühn, 1959
Daphnia magna	12+12 h	N	S	rg	$BaCl_2$	nw	7.4-8.2		44-53	48 h	LC50	mortality	15		Biesinger and Christensen, 1972
Daphnia magna	<24 h	N	S	>97	$Ba(NO_3)_2$	syn w				24 h	EC50	immobilization	110		Calleja et al., 1994
Daphnia magna		N	S		$BaSO_4$	nw	7.2-7.8		235-260	48 h	EC50	immobility	32		Khangarot and Ray, 1989a
Daphnia magna	<24 h; neonate	N	S	rg	$Ba(NO_3)_2$	fw	7.6	21	200	24 h	EC50	immobilization	70		Lilius et al., 1994
Echinogammarus berilloni	10-20 mm; ad	N			$BaCl_2$	fw	7.7	19	277	96 h	LC50	mortality	122		Vincent et al., 1986
Echinogammarus berilloni	10-20 mm; ad	N			$BaCl_2$	fw	7.7	19	27	96 h	LC50	mortality	129		Vincent et al., 1986
Gammarus pulex	10-20 mm; ad	N			$BaCl_2$	fw	7.7	19	277	96 h	LC50	mortality	238		Vincent et al., 1986
Gammarus pulex	10-20 mm; ad	N			$BaCl_2$	fw	7.7	19	27	96 h	LC50	mortality	227		Vincent et al., 1986
Orconectes limosus	19-32 mm	Y			$BaCl_2$		7	16		96 h	LC50	mortality	78		Boutet and Chaisemartin, 1973
Streptocephalus proboscideus	2nd+3rd instar	N	S	>97	$Ba(NO_3)_2$	syn w		25	85	24 h	LC50	mortality	372		Calleja et al., 1994
Pisces															
Leuciscus idus melanotus		N	S		$BaCl_2$	tw	7--8		255	48 h	LC50	mortality	570		Juhnke and Lüdemann, 1978
Salmo trutta	yearling	N	S		$BaCl_2$	fw	7.6-8	15	100	48 h	LC50	mortality	150		Woodiwiss and Fretwell, 1974

Notes

1. Natural water from Embarras River at Camargo enriched with algal growth medium; EC50 is geometric mean of 2 values, obtained with river water sampled at different dates.
2. Natural water from Fox River at Algonquin enriched with algal growth medium; EC50 is geometric mean of 2 values, obtained with river water sampled at different dates.
3. Natural water from Hayes Creek at Glendale enriched with algal growth medium; EC50 is geometric mean of 2 values, obtained with river water sampled at different dates.
4. Natural water from Horseshoe Lake at Miller City enriched with algal growth medium; EC50 is geometric mean of 2 values, obtained with river water sampled at different dates.
5. Natural water from Lake Michigan at Glencoe enriched with algal growth medium; EC50 is geometric mean of 4 values, obtained with river water sampled at different dates.
6. Natural water from Rend Lake at Ina enriched with algal growth medium; EC50 is geometric mean of 3 values, obtained with river water sampled at different dates.
7. Natural water from Lake Geneva At Williams Bay, WI enriched with algal growth medium; EC50 is geometric mean of 3 values, obtained with river water sampled at different dates.
8. Natural water from Kankakee River at Schneider, IN enriched with algal growth medium; EC50 is geometric mean of 3 values, obtained with river water sampled at different dates.
9. Natural water from Mississippi River at Fort Madison, IA enriched with algal growth medium; EC50 is geometric mean of 3 values, obtained with river water sampled at different dates.
10. Natural water from Rock River at Janesville, WI enriched with algal growth medium; EC50 is geometric mean of 2 values, obtained with river water sampled at different dates.
11. Natural water from Salt River at Rte. 79, MO enriched with algal growth medium; EC50 is geometric mean of 3 values, obtained with river water sampled at different dates.
12. Natural water from Skunk River at Rte. 61, IA enriched with algal growth medium; EC50 is geometric mean of 2 values, obtained with river water sampled at different dates.
13. Natural water from Wabash River at Perryville, IN enriched with algal growth medium; EC50 is geometric mean of 3 values, obtained with river water sampled at different dates.

Table A2. 9. Acute toxicity of thallium to freshwater organisms.

Species	Species properties	A	Test type	Purity [%]	Test compound	Test water	pH	T [°C]	Hardness [mg $CaCO_3$/l]	Exp. time	Criterion	Test endpoint	Value [mg/l]	Notes	Reference
Algae															
Chlamydomonas reinhardtii		N	S				7.0			15 min	EC50	photosynthesis assimilation	3.0	1	Overnell, 1975
Chlorococcales					$TlNO_3$	fw				24 h	EC50	efficiency	0.43		Krebs, 1991
Fungi															
Geotrichum candidum		N			Tl_2SO_4	fw	6.5	28		4 h	EC50	glucose uptake	155		Jacobsen, 1995
Macrophyta															
Elodea canadensis	0.5-1.0 g				Tl_2SO_4		6.7	24		24 h	EC50	photosynthesis	1.4		Brown and Rattigan, 1979
Nematoda															
Caenorhabditis elegans	ad. 3-4 d	N	S	rg	Tl	am		20		96 h	LC50	mortality	123	2	Williams and Dusenbery, 1990
Rotifera															
Brachionus calyciflorus	larvae	N	S	>97	Tl_2SO_4	syn w		25	85	24 h	LC50	mortality	7.7		Calleja et al., 1994
Crustacea															
Daphnia magna	<24 h	N	S		$TlNO_3$	tw	7.6-7.7		286	24 h	EC50		1.6		Bringmann and Kühn, 1977a
Daphnia magna	<24 h	N	S		$TlNO_3$	tw	8.0±0.2		250.2	24 h	EC50		0.11		Bringmann and Kühn, 1982
Daphnia magna	<24 h	N	S	>97	Tl_2SO_4	syn w				24 h	EC50	immobilization	3.4	3	Calleja et al., 1994
Daphnia magna	<24 h	N	S	rg	Tl_2SO_4	fw	7.6	21	200	24 h	EC50	immobilization	6.5		Lilius et al., 1994
Daphnia magna	<24 h	N	S		Tl_2SO_4	syn w	7.6		200	24 h	EC50	immobilization	3.3		Lilius et al., 1995
Daphnia pulex	<24 h	N	S		Tl_2SO_4	syn w	7.6	20	200	24 h	EC50	immobilization	3.8		Lilius et al., 1995
Hyalella azteca	0-7 d	Y	S		$TlNO_3$	tw	7.9-8.6	25	130	7 d	LC50	mortality	0.052	4	Borgmann et al., 1998
Hyalella azteca	0-7 d	Y	S		$TlNO_3$	am		25	125	7 d	LC50	mortality	0.086	5	Borgmann et al., 1998
Hyalella azteca	0-7 d	Y	S		$TlNO_3$	am		25	12.5	7 d	LC50	mortality	0.10	6	Borgmann et al., 1998
Streptocephalus proboscideus	2nd+3rd instar	N	S	>97	Tl_2SO_4	syn w		25	85	24 h	LC50	mortality	0.33		Calleja et al., 1994
Pisces															
Lepomis macrochirus	young; 0.32-1.2 g	N		>80	Tl_2SO_4	fw	6.7-7.8	21-23	32-34	96 h	LC50	mortality	120		Buccafusco et al., 1981

Species	Species properties	A	Test type	Purity [%]	Test compound	Test water	pH	T [°C]	Hardness [mg $CaCO_3$/l]	Exp. time	Criterion	Test endpoint	Value [mg/l]	Notes	Reference
Leuciscus idus melanotus		N	S		$TlNO_3$	tw	7-8		255	48 h	LC50		140		Juhnke and Lüdemann, 1978
Pimephales promelas		N	S		Tl_2SO_4	nw	6.7-7.1		28-40	96 h	LC50		0.86		LeBlanc and Dean, 1984

Notes
1. Compound added unknown, but EC50 based on Tl+.
2. Elemental Tl used in test.
3. Test conducted following OECD (1984) guidance.
4. Test result is geometric mean of five values: 190, 200, 290, 300 and 310 (nmol/l), tested at 1.56 mg K/l.
5. Artificial medium contained 1.8 mg K/l.
6. Mean of two test results: 380 and 600 (nmol/l), 10x diluted medium, with 1.8 mg K/l.

Table A2. 10. Chronic toxicity of beryllium to freshwater organisms.

Species	Species properties	A	Test type	Purity [%]	Test compound	Test water	pH	T [°C]	Hardness [mg $CaCO_3$/l]	Exp. time	Criterion	Test endpoint	Value [mg/l]	Notes	Reference
Bacteria															
Pseudomonas putida		N	S		$Be(NO_3)_2$	am	7.0		81.2	16 h	NOEC	growth	0.020	1	Bringmann and Kühn, 1977b
Cyanobacteria															
Microcystis aeruginosa		N	S		$Be(NO_3)_2$	am	7.0		55	8 d	NOEC	growth	0.43	1	Bringmann and Kühn, 1976
Protozoa															
Chilomonas paramaecium E.		N	S		$Be(NO_3)_2$	am	6.9		74.6	48 h	NOEC	growth	0.51	1	Bringmann et al., 1980
Entosiphon sulcatum S.		N	S		$Be(NO_3)_2$	am	6.9		75.1	72 h	NOEC	growth	0.0040	1	Bringmann, 1978
Uronema parduczi C.		N	S		$Be(NO_3)_2$	am	6.9		75.1	20 h	NOEC	growth	0.017	1	Bringmann and Kühn, 1980
Algae															
Scenedesmus quadricauda		N	S		$Be(NO_3)_2$	am	7.0		55	8 d	NOEC	growth	0.030	1	Bringmann and Kühn, 1977b
Pisces															
Cyprinus carpio	eggs	Y	SS		$Be(NO_3)_2$	nw				3 d	NOEC	reproduction	0.080	2	Hildebrand and Cushman, 1978

Notes
1. NOEC set equal to TGK (Toxische Grenzkonzentration or toxicity threshold).
2. based on measured concentrations.
3. NOEC was calculated as MATC=NOEC/≤√2.

Table A2. 11. Chronic toxicity of vanadium to freshwater organisms.

Species	Species properties	A	Test type	Purity [%]	Test compound	Test water	pH	T [°C]	Hardness [mg $CaCO_3$/l]	Exp. time	Criterion	Test endpoint	Value [mg/l]	Notes	Reference
Crustacea															
Daphnia magna	<24 h	N	SS		$NaVO_3$	rw	8.2-8.9		136	23 d	NOEC	mortality	1.6		Beusen and Neven, 1987
Daphnia magna	10 d	N	CF		$NaVO_3$	nw	8.1		197	97 d	NOEC	mortality	1.0		Van der Hoeven, 1990
Daphnia magna	<24 h	N	SS		$NaVO_3$	rw	8.2-8.9		136	23 d	NOEC	reproduction	1.9		Beusen and Neven, 1987
Daphnia magna	0-24 h old	Y	IF	99	$NaVO_3$	nw	8.1	20	225	21 d	EC10	reproduction	0.03	1	Van Leeuwen et al., 1987
Pisces															
Jordanella floridae	eggs	N	CF		V_2O_5	rw	8.2		347	34 d	NOEC	growth	0.041	2	Holdway and Sprague, 1979

Notes
1. Lake water (IJsselmeer); endpoint is effect on population yield (mean number of daphnids).
2. F1 eggs from P-generation which was exposed for 96 days to similar concentrations of V_2O_5.

Table A2. 12. Chronic toxicity of cobalt to freshwater organisms.

Species	Species properties	A	Test type	Purity [%]	Test compound	Test water	pH	T [°C]	Hardness [mg $CaCO_3$/l]	Exp. time	Criterion	Test endpoint	Value [mg/l]	Notes	Reference
Cyanobacteria															
Spirulina platensis		N	S		$CoCl_2$	am				7 d	NOEC	growth	0.50		Sharma et al., 1987
Algae															
Scenedesmus sp.		N	S		$CoCl_2$	am				96 h	NOEC	growth	1.0	1	Bringmann and Kühn, 1959
Macrophyta															
Lemna minor	fronds; 32-50 mg	Y	S	ag	$CoCl_2$	am	6.3-6.4	25-28		7 d	EC10	growth	0.47	2	Dirilgen and Inel, 1994
Lemna minor		N	S	rg	$CoCl_2$		6.0	25-27		7 d	EC10	growth	0.33	2	Ince et al., 1999
Platyhelminthes															
Dugesia tigrina	11-12 mm, 18-24 d, cut individuals	N	R		$Co(NO_3)_2$	fw		20	105	80 d	EC10	mortality	0.024	3	Solski and Piontek, 1987
Crustacea															
Daphnia magna	12+12 h	N	SS	rg	$CoCl_2$	nw	7.4-8.2		44-53	21 d	NOEC	reproduction	0.0050	4	Biesinger and Christensen, 1972
Pisces															
Brachydanio rerio	2-4 h; early life-stages (sub-chronic)	N	R	ag	$CoCl_2$	fw	7.5-7.7	25-26	100	13 d	NOEC	mortality	0.060	5	Dave and Xiu, 1991
Cyprinus carpio	eggs	N	S		$CoCl_2$		7.5		360		NOEC	reproduction	1.1	6	Kapur and Yadav, 1982
Pimephales promelas	<24 h; larvae	Y	R	rg	$CoCl_2$	fw		25	46-74	7 d	NOEC	mortality	1.2		Diamond et al., 1992
Pimephales promelas	<24 h; larvae	Y	R	rg	$CoCl_2$	fw		25	400	7 d	NOEC	mortality	1.9		Diamond et al., 1992
Pimephales promelas	<24 h; larvae	Y	R	rg	$CoCl_2$	fw		25	200	7 d	NOEC	mortality	1.8		Diamond et al., 1992
Amphibia															
Xenopus laevis	embryos - blastula stage	N	S	>99.9	$CoCl_2$	am	6.8	23	111	101 h	LC10	mortality	394.9		Sunderman, 1992
Xenopus laevis	embryos - blastula stage	N	S	>99.9	$CoCl_2$	am	6.8	23	111	101 h	EC10	malformations	0.94		Sunderman, 1992

Notes
1. NOEC set equal to TGK (Toxische Grenzkonzentration or toxicity treshold).
2. EC10 calculated by fitting a logistic dose response model through data reported by author.
3. Mortality for the fourth generation of animals, each of which was created by cutting individuals after 20 days.

4. NOEC calculated as EC16:2.
5. 2-4 h old eggs (blastula stage) were tested.
6. NOEC obtained by extrapolation of concentration-effects relationship.

Table A2. 13. Chronic toxicity of selenium to freshwater organisms.

Species	Species properties	A	Test type	Purity [%]	Test compound	Test water	pH	T [°C]	Hardness [mg $CaCO_3$/l]	Exp. time	Criterion	Test endpoint	Value [mg/l]	Notes	Reference
Bacteria															
Pseudomonas putida		N	S		Na_2SeO_3	am	7.0		81.2	16 h	NOEC	growth	11	1	Bringmann and Kühn, 1977b
Cyanobacteria															
Anabaena flos-aquae		Y	S	rg	Na_2SeO_3	am				10 d	NOEC	growth (Chl a)	1.0		Kiffney and Knight, 1990
Anabaena flos-aquae		Y	S	rg	Na_2SeO_4	am				10 d	NOEC	growth (Chl a)	1.0		Kiffney and Knight, 1990
Microcoleus vaginatus		N	S		Na_2SeO_4	am	7.3			14 d	NOEC	growth	5.0		Vocke et al., 1980
Microcystis aeruginosa		N	S		Na_2SeO_3	am	7.0		55	8 d	NOEC	growth	9.4	1	Bringmann and Kühn, 1976
Phormidium luridum		N	S		Na_2SeO_3	am				8 d	NOEC	growth, photosyn	0.079		Sielicki and Burnham, 1973
Protozoa															
Chilomonas paramaecium		N	S		Na_2SeO_3	am	6.9		74.6	48 h	NOEC	growth	0.062	1	Bringmann et al., 1980
Entosiphon sulcatum		N	S		Na_2SeO_3	am	6.9		75.1	72 h	NOEC	growth	0.0018	1	Bringmann, 1978
Uronema parduczi		N	S		Na_2SeO_3	am	6.9		75.1	20 h	NOEC	growth	0.118	1	Bringmann and Kühn, 1980
Algae															
Ankistrodesmus falcatus		N	S		Na_2SeO_4	am	7.30			14 d	NOEC	growth	0.0050		Vocke et al., 1980
Chlorella vulgaris					Na_2SeO_4	fw	8.38	25	122	7 d	NOEC	biomass	0.0091		Dobbs et al., 1996
Scenedesmus sp.		N	S		Na_2SeO_3	am				4 d	NOEC	growth	2.5	1	Bringmann and Kühn, 1959
Scenedesmus obliquus		N	S		Na_2SeO_4	am	7.3			14 d	NOEC	growth	0.05		Vocke et al., 1980
Scenedesmus quadricauda		N	S		Na_2SeO_3	am	7.0		55	8 d	NOEC	growth	0.52	1	Bringmann and Kühn, 1977b
Selenastrum capricornutum		N	S		Na_2SeO_4	am	7.3			14 d	NOEC	growth	0.20		Vocke et al., 1980
Macrophyta															
Lemna minor	fronds	Y	S		Na_2SeO_3	am	5		313	14 d	NOEC	surface coverage	0.080		Jenner and Janssen-Mommen, 1993
Lemna minor	fronds	Y	S		Na_2SeO_3	am	5		313	14 d	NOEC	multiplication rate	0.80		Jenner and Janssen-Mommen, 1993
Lemna minor	fronds	Y	S		SeO_2	am	5		313	14 d	NOEC	surface coverage	0.80		Jenner and Janssen-Mommen, 1993
Lemna minor	fronds	Y	S		SeO_2	am	5		313	14 d	NOEC	multiplication rate	0.80		Jenner and Janssen-Mommen, 1993
Lemna minor	fronds	Y	S		SeO_4^{2-}	am	5		313	14 d	NOEC	surface coverage	0.80		Jenner and Janssen-Mommen, 1993

Species	Species properties	A	Test type	Purity [%]	Test compound	Test water	pH	T [°C]	Hardness [mg $CaCO_3$/l]	Exp. time	Criterion	Test endpoint	Value [mg/l]	Notes	Reference
Crustacea															
Ceriodaphnia affinis		N	SS		Na_2SeO_3	rw	7.9		101	8 d	NOEC	reproduction	0.20	2	Owsley and McCauley, 1986
Ceriodaphnia affinis		N	SS		Na_2SeO_3	rw	7.9		101	8 d	NOEC	reproduction	0.050	3	Owsley and McCauley, 1986
Ceriodaphnia affinis		N	SS		Na_2SeO_3	rw	7.9		101	8 d	NOEC	reproduction	0.10	4	Owsley and McCauley, 1986
Ceriodaphnia dubia	<24 h	Y	R		Na_2SeO_4	rec	7.9	25.8	119.4	8 d	EC10	reproduction	0.46	5	Naddy et al., 1995
Daphnia magna	<24 h	N	SS		Na_2SeO_4	rw	8.2-8.4		130	32 d	NOEC	growth	1.0		Dunbar et al., 1983
Daphnia magna	6-18 h	N	SS		Na_2SeO_4	am	8.4			15 d	NOEC	growth	0.050		Johnston, 1987
Daphnia magna	<24 h	Y	CF		Na_2SeO_3/O_4	rw	7.9		138	21 d	NOEC	growth	0.085	6	Ingersoll et al., 1990
Daphnia magna	<24 h	Y	CF		Na_2SeO_3/O_4	rw	7.9		138	21 d	NOEC	reproduction	0.16	6	Ingersoll et al., 1990
Daphnia magna	<24 h	N	SS		Na_2SeO_4	rw	8.2-8.4		130	32 d	NOEC	reproduction	1.5		Dunbar et al., 1983
Daphnia magna	6-18 h	N	SS		Na_2SeO_4	am	8.4			15 d	NOEC	reproduction	0.025		Johnston, 1987
Daphnia pulex	12-36 h	N	SS		Na_2SeO_3	rw	7.2		42	28 d	NOEC	reproduction	0.20		Reading and Buikema, 1983
Hyalella azteca	60 d; 2 mm	Y	R	rg	Na_2SeO_3	ww	8.6		133	24 d	NOEC	reproduction	0.10	7	Brasher and Ogle, 1993
Hyalella azteca	adult	Y	CF		Na_2SeO_3/O_4	nw	7.3		329	21 d	NOEC	mortality	0.030		Halter et al., 1980
Insecta															
Chironomus thummi	<24 h	Y	CF		Na_2SeO_3/O_4	fw	7.98	22	138	30 d	NOEC	emergence	0.30	6	Ingersoll et al., 1990
Pisces															
Lepomis macrochirus	3-4 years; 171 mm; 96 g	Y		rg	Na_2SeO_3	river w	8		179	356 d	EC11	reproduction	0.010	7	Hermanutz et al., 1992
Lepomis macrochirus	5 mo; juv; 0.3 g	Y		95	Se	Mixed	7.9-8.3	25	137-143	60 d	NOEC	mortality	0.33-0.64	8	Cleveland et al., 1993
Oncorhynchus mykiss	eyed eggs	Y	CF		Na_2SeO_3	rw	7.9		135	44 w	NOEC	mortality	0.015	6	Hodson et al., 1980
Oncorhynchus mykiss	eggs	Y	CF		Na_2SeO_3	rw	7.2		40	90 d	NOEC	mortality, growth	0.021	6	Hunn et al., 1987
Oncorhynchus mykiss	eggs		CF				6.7-7.3	11	30	12 mo	NOEC	mortality	0.040		Goettl et al., 1976

Notes
1. NOEC set equal to TGK (Toxische Grenzkonzentration or toxicity threshold).
2. Total number of young in the first three broods of the P-generation.
3.Total number of young in the first three broods of the F1-generation.
4. Total number of young in the first three broods of the F2 and F3-generations.
5. EC10 was calculated after fitting a logistic model through the reported EC12.5, EC25 and EC50 with measured concentrations.
6. Based on measured concentrations.
7. Test result applies to F2 generation in test

8. Outdoor experimental stream, endpoint is the number of embryos that were collected. EC11 will be used as a NOEC.
9. A NOEC=0.33 mg/l will be used. This concentration is statistically determined to be the NOEC (by the authors) and gives 12.5% higher mortality compared to the control.

Table A2. 14. Chronic toxicity of molybdenum to freshwater organisms.

Species	Species properties	A	Test type	Purity [%]	Test compound	Test water	pH	T [°C]	Hardness [mg $CaCO_3$/l]	Exp. time	Criterion	Test endpoint	Value [mg/l]	Notes	Reference
Algae															
Scenedesmus sp.		N	S		$(NH_4)_6Mo_7O_{24}$	am		24		96 h	NOEC	growth	54	1	Bringmann and Kühn, 1959

Notes
1. NOEC set equal to TGK (Toxische Grenzkonzentration or toxicity threshold).

Table A2. 15. Chronic toxicity of tin to freshwater organisms.

Species	Species properties	A	Test type	Purity [%]	Test compound	Test water	pH	T [°C]	Hardness [mg $CaCO_3$/l]	Exp. time	Criterion	Test endpoint	Value [mg/l]	Notes	Reference
Cyanobacteria															
Anabaena doliolum		N	S		$SnCl_2$	am	7.5	26		9 d	EC10	growth rate	25	1	Dubey and Rai, 1990a
Synechocystis aquatilis		N	S		$SnCl_2$	am	7.2	23	35	96 h	EC10	growth rate	0.030	2	Pawlik-Skowronska et al., 1997
Algae															
Ankistrodesmus falcatus		N	S		$SnCl_2$	am	8	20		8 d	NOEC	growth	14	3	Wong et al., 1982
Ankistrodesmus falcatus		N	S		$SnCl_4$	am	8	20		8 d	NOEC	growth	0.053	4	Wong et al., 1982
Crustacea															
Daphnia magna	12+12 h	N	SS	rg	$SnCl_2$	nw	7.4-8.2		44-53	21 d	NOEC	reproduction	0.18	5	Biesinger and Christensen, 1972
Pisces															
Cyprinus carpio	eggs	N	S		$SnCl_2$		7.5		360		NOEC	reproduction	7.8	6	Kapur and Yadav, 1982
Oncorhynchus mykiss	fertilised eggs	Y	R		Sn	rec	7.7	12.5	102	27 d	EC10	mortality	0.076	7	Birge et al., 1981

Notes
1. Figure was scanned, digitised, and a logistic dose-effect relationship was fitted through the obtained dataset using nonlinear regression; EC10 determined from this relationship; EC10 determined over the period of logarithmic growth (9 d) of A. doliolum.
2. Growth rates were calculated from growth data plotted in graphs.
3. EC10 determined by linear interpolation of EC1 and EC97 after digitising graph from author. The steepness of the dose-effect relationship allows for linear approximation.
4. Figure was scanned, digitised, and a logistic dose-effect relationship was fitted through the obtained dataset using nonlinear regression; EC10 determined from this relationship.
5. NOEC calculated as EC16:2.
6. NOEC obtained by extrapolation of concentration-effects relationship.
7. Test duration: reported as until 4 days post-hatching. The duration in the table is estimated since posthatching of rainbow trout at 12°C is approx. 23 days.

Table A2. 16. Chronic toxicity of antimony to freshwater organisms.

Species	Species properties	A	Test type	Purity [%]	Test compound	Test water	pH	T [°C]	Hardness [mg $CaCO_3$/l]	Exp. time	Criterion	Test endpoint	Value [mg/l]	Notes	Reference
Cyanobacteria															
Microcystis aeruginosa		N	S		$KSb(OH)_6$	am	7.0		55	8 d	NOEC	growth	33	1	Bringmann et al., 1978
Protozoa															
Entosiphon sulcatum S.		N	S		$KSb(OH)_6$	am	6.9		75.1	72 h	NOEC	growth	121	1	Bringmann, 1978
Algae															
Scenedesmus quadricauda		N	S		$KSb(OH)_6$	am	7.0		55	8 d	NOEC	growth	>2000	2	Bringmann and Kühn, 1977b
Crustacea															
Daphnia magna	<24 h	Y	R		$K_2(C_4H_2O_6Sb)_2$		7.8	20	250 ± 25	30 d	NOEC	reproduction	1.7	3	Doe et al., 1987
Daphnia magna	<24 h	Y	R		$K_2(C_4H_2O_6Sb)_2$		7.8	20	250 ± 25	33 d	NOEC	growth	0.8	3	Doe et al., 1987
Pisces															
Oreochromis mossambicus	larvae, 30 d	N	R	99.99	$SbCl_3$	fw				16 d	NOEC	growth	4.8	4	Lin and Hwang, 1998

Notes
1. NOEC set equal to TGK (Toxische Grenzkonzentration or toxicity treshold); concentration Sb was calculated from SbO_4^{3-}.
2. NOEC set equal to TGK (Toxische Grenzkonzentration or toxicity treshold).
3. Result based on nominal Sb concentrations.
4. NOEC calculated as NOEC=LOEC/2. The LOEC showed 15% growth inhibition (significantly different from the control) and was the lowest tested concentration.

Table A2. 17. Chronic toxicity of barium to freshwater organisms.

Species	Species properties	A	Test type	Purity [%]	Test compound	Test water	pH	T [°C]	Hardness [mg $CaCO_3$/l]	Exp. time	Criterion	Test endpoint	Value [mg/l]	Notes	Reference
Cyanobacteria															
Anacystis nidulans		N	S		$BaCl_2$	am	7.9			7 d	EC10	growth rate	47	3	Lee and Lustigman, 1996
Algae															
Scenedesmus sp.		N	S		$BaCl_2$	am				96 h	NOEC	growth	34	1	Bringmann and Kühn, 1959
Bryophyta															
Scapania undulata	field collected	N	S		$BaCl_2$	nw		14		16 d	EC10	mortality	182	7	Samecka-Cymerman, 1988
Scapania undulata	field collected	N	S		$BaCl_2$	nw		14		16 d	EC10	growth plant	77	8	Samecka-Cymerman, 1988
Scapania undulata	field collected	N	S		$BaCl_2$	nw		14		16 d	EC10	growth branches	68	8,9	Samecka-Cymerman, 1988
Scapania undulata	field collected	N	S		$BaCl_2$	nw		14		16 d	EC10	growth branches	44	8,10	Samecka-Cymerman, 1988
Macrophyta															
Lemna minor	40 fronds	Y	S	rg	$BaCl_2$	am		25-28		96 h	EC10	growth	6.2	5	Wang, 1988
Lemna minor	40 fronds	Y	S	rg	$BaCl_2$	de-ion		25-28		96 h	EC10	growth	5.5	6	Wang, 1986a
Myriophyllum spicatum	apices	N	S		Ba	tw		20	96	32 d	EC10	root growth	17	4	Stanley, 1974
Crustacea															
Daphnia magna	12+12 h	N	SS	rg	$BaCl_2$	nw	7.4-8.2		44-53	21 d	NOEC	reproduction	2.9	2	Biesinger and Christensen, 1972

Notes

1. NOEC set equal to TGK (Toxische Grenzkonzentration or toxicity treshold).
2. NOEC calculated as EC16:2.
3. EC10 determined from a logistic dose-response relationship, which was fitted through the data obtained after digitizing a graph. EC10 expressed as mg Ba/l.
4. Apices were derived from Dutch field collected plant species; EC10 calculated from reported EC50 and ratio of EC90 and EC10 using EC10=0.5*log(EC90/EC10), since ec50 lies exactly in the middle of EC10 and EC90. Apices were planted in 30 cc soil, Ba was added to the water (200 ml). Test compound unknown.
5. Testwater was double strength algal growth medium; EC10 determined by fitting a non linear sigmodial dose effect relationship through the data after digitising published graph to obtain data points.
6. Testwater was de-ionised water; EC10 determined by fitting a non linear sigmodial dose effect relationship through the data after digitising published graph to obtain data points.
7. Geometric mean of 9 tests with S. undulata collected at various sites and tested in water from original habitat, with Ba added in concentration range (10 concentrations); EC10 determined by fitting a sigmodial dose response relationship through reported data.
8. Geometric mean of 9 tests with S. undulata collected at various sites and tested in water from original habitat, with Ba added in concentration range (10 concentrations); EC10 determined by fitting a sigmodial dose response relationship through reported data; controls were omitted from dose-response relationships, since controls showed a response pattern inconsistent with the rest of the concentration range (10 concentrations).
9. Endpoint is growth of I range lateral branches.

10.Endpoint is the number of I range lateral branches.

Table A2. 18. Chronic toxicity of thallium to freshwater organisms.

Species	Species properties	A	Test type	Purity [%]	Test compound	Test water	pH	T [°C]	Hardness [mg $CaCO_3$/l]	Exp. time	Criterion	Test endpoint	Value [mg/l]	Notes	Reference
Algae															
Chlorella sp.		N	S		$Tl(NO_3)_3$	am	7.3	20-23		96 h	EC10	growth rate	0.0048	1	Ralph and Twiss, 2002
Macrophyta															
Lemna minor		N	S	Analar g	Tl CH_3COO	am	6		41	10 d	EC10	multiplication rate	0.0076	2	Kwan and Smith, 1988
Crusctacea															
Hyalella azteca	0-7 d	Y	R		$TlNO_3$	tw	7.9-8.6	25	130	28 d	LC10	mortality	0.0095	3	Borgmann et al., 1998
Hyalella azteca	0-7 d	Y	R		$TlNO_3$	tw	7.9-8.6	25	130	42 d	EC10	growth	0.0051	3,4	Borgmann et al., 1998
Hyalella azteca	0-7 d	Y	R		$TlNO_3$	tw	7.9-8.6	25	130	70 d	EC10	reproduction	0.0016	3,5	Borgmann et al., 1998
Pisces															
Pimephales promelas	larvae	N	CF		Tl_2SO_4	nw	6.7-7.1		28-40	30 d	NOEC	survival	0.16	6	LeBlanc and Dean, 1984
Pimephales promelas	larvae	N	CF		Tl_2SO_4	nw	6.7-7.1		28-40	30 d	NOEC	growth	0.030	6	LeBlanc and Dean, 1984
Pimephales promelas	larvae	N	CF		Tl_2SO_4	nw	6.7-7.1		28-40	30 d	NOEC	reproduction	0.10	6	LeBlanc and Dean, 1984

Notes
1. Figure was scanned, digitised, and a logistic dose-effect relationship was fitted through the obtained dataset using nonlinear regression; EC10 determined from this relationship. Concentrations used were total dissolved, NOTcalculated (speciation) concentrations by the authors.
2. Graphical data from author were used to fit logistic dose effect relationship. EC10 values determined for three other growth parameters (frond area, frond no, fresh weight) were similar, only the lowest value is presented here.
3. Figure was scanned, digitised, and a logistic dose-effect relationship was fitted through the obtained dataset using nonlinear regression; LC10 determined from this relationship.
4. Test result is geometric mean of four values: 7.0, 4.4, 3.6 and 6.1 (µg/l), tested at 1.56 mg K/l.
5. Test result is the mean of three values: 0.2, 5.9 and 3.8 (µg/l), tested at 1.56 mg K/l..
6. Exposure was for 30 d post hatch.

Table A2. 19. Acute toxicity of beryllium to marine organisms.

Species	Species properties	A	Test type	Purity [%]	Test compound	Test water	pH	T [°C]	Salintiy [‰]	Exp. time	Criterion	Test endpoint	Value [mg/l]	Notes	Reference
Bacteria															
Vibrio fisheri		Y	S		$Be(NO_3)_2$	am	6.9-7.2	27	35	22 h	EC50	luminescence	0.0014	1	Hsieh et al., 2004

Notes
1. EC50 is the mean of three replicate experiments (not individually reported); standard deviation was 0.00018 mg/l.

Table A2. 20. Acute toxicity of vanadium to marine organisms.

Species	Species properties	A	Test type	Purity [%]	Test compound	Test water	pH	T [°C]	Salinity [‰]	Exp. time	Criterion	Test endpoint	Value [mg/l]	Notes	Reference
Coelenterata															
Cordylophora caspia		N	S		NH_4VO_3	nsw				9 d	EC50	growth rate	4.5	1	Ringelband, 2001
Cordylophora caspia					NH_4VO_3	salt w	8	20		10 d	LC50	mortality	5.8		Ringelband and Karbe, 1996
Mollusca															
Mytilus galloprovincialis	ad	N	R		$NaVO_3$	nw		14	38	9 d	LC50	mortality	64	2	Miramand and Unsal, 1978
Annelida															
Nereis diversicolor	ad	N	R		$NaVO_3$	nw		14	38	9 d	LC50	mortality	11	2	Miramand and Unsal, 1978
Crustacea															
Artemia salina	egg	N	S		V_2O_5	am	8.1	20		8 d	LC50	mortality	0.37	3	Fichet and Miramand, 1998
Carcinus maenas	ad	N	R		$NaVO_3$	nw		14	38	9 d	LC50	mortality	35	2	Miramand and Unsal, 1978
Pisces															
Limanda limanda	7-13.2 cm, 5.6-30.8 g	Y	CF	Analar	NH_4VO_3	nw	7.7	12	34.6	96 h	LC50	mortality	28	4	Taylor et al., 1985
Therapon jarbua	juv, 2.4-3.6 cm, 0.2-0.7 g				V_2O_5	salt w				96 h	LC50	mortality	0.62		Krishnakumari et al., 1983

Notes
1. The seawater used was diluted, aged and filtered before use. Control growth rate was optimal at 10 ppt salinity.
2. Figure was scanned, digitised, and a logistic dose-effect relationship was fitted through the obtained dataset using nonlinear regression; EC50 determined from this relationship.
3. Test was started with eggs, but mortality refers to nauplii larvae after first moulting. Data from graph were converted to dose response relationship, through which a logistic curve was fitted using nonlinear regression to obtain the EC50.
4. Test performed with field collected animals; purity = "analar grade".

Table A2. 21. Acute toxicity of cobalt to marine organisms.

Species	Species properties	A	Test type	Purity [%]	Test compound	Test water	pH	T [°C]	Salinity [‰]	Exp. time	Criterion	Test endpoint	Value [mg/l]	Notes	Reference
Bacteria															
Vibrio fisheri		N	S		Co	salt w		15		0.5 h	EC50	luminescence	29	1	Kafka et al., 1997
Vibrio fisheri		N	S		$Co(NO_3)_2$	am	5.81	15		15 min	EC50	luminescence	52	2	McCloskey et al., 1996
Vibrio fisheri		N	S	rg	$CoCl_2$	am		15		15 min	EC50	luminescence	33		Ince et al., 1999
Vibrio fisheri		N	S		$CoCl_2$	am		15		0.5 h	EC50	luminescence	856	3	Schmitz et al., 1999b
Vibrio fisheri		N	S		$CoCl_2$	am		15		0.5 h	EC50	luminescence	577	4	Schmitz et al., 1999b
Vibrio fisheri	direct assay	N	S		$CoCl_2$	am	7.4	23	30	1 h	EC50	luminescence	1.7	5	Thomulka et al., 1993b
Vibrio fisheri		N	S		$CoCl_2$	am		20		7 h	EC50	growth	3.3	3	Schmitz et al., 1998
Vibrio harveyi	direct assay	N	S		$CoCl_2$	am	7.0	23	25	1 h	EC50	luminescence	0.021		Thomulka et al., 1993a
Vibrio harveyi	growth test	N	S		$CoCl_2$	am	7.0	23	25	5 h	EC50	luminescence	0.41		Thomulka et al., 1993a
Algae															
Nitzschia closterium		N	S		$CoSO_4$	am	6.7-6.9		24-37	96 h	EC50	growth	24		Rosko and Rachlin, 1975
Ditylum brightwelli		N	S		$CoCl_2$	am	8.0		18.8	5 d	EC50	growth	0.30		Canterford and Canterford, 1980
Mollusca															
Perna perna	60-80 mm; field collected		S		$CoCl_2$	salt w				1 h	EC50	filtration rate	1.7		Watling and Watling, 1982
Annelida															
Monhystera disjuncta	4.5 d; J2 larvae	N	S	ag	$CoCl_2$	salt w	7.5-8	17	30	96 h	EC50	mortality	179	6	Vranken et al., 1991
Crustacea															
Artemia salina	nauplii, 3 d	N	S		$Co(NO_3)_2$	nw		24		48 h	LC50	mortality	172		Kissa et al., 1984
Artemia salina	eggs	N	S		$Co(NO_3)_2$	nw		24		48 h	EC50	hatching rate	10		Kissa et al., 1984
Nitocra spinipes		N	S		$CoCl_2$	nw	8.0		7	96 h	LC50	mortality	4.5		Bengtsson, 1978
Tisbe holothuriae	field collected from polluted area	N	S		$CoCl_2$	asw		19	38	48 h	LC50	mortality	3.5		Miliou et al., 2000
Tisbe holothuriae	field collected from non polluted area	N	S		$CoCl_2$	asw		19	38	48 h	LC50	mortality	2.5		Miliou et al., 2000
Tisbe holothuriae	1^{st} gen lab., parents from polluted area	N	S		$CoCl_2$	asw		19	38	48 h	LC50	mortality	2.5		Miliou et al., 2000
Tisbe holothuriae	Stock culture from polluted area	N	S		$CoCl_2$	asw		16	38	48 h	LC50	mortality	6.1		Miliou et al., 2000
Tisbe holothuriae	Stock culture from polluted area	N	S		$CoCl_2$	asw		19	38	48 h	LC50	mortality	3.6		Miliou et al., 2000

Species	Species properties	A	Test type	Purity [%]	Test compound	Test water	pH	T [°C]	Salinity [‰]	Exp. time	Criterion	Test endpoint	Value [mg/l]	Notes	Reference
Tisbe holothuriae	Stock culture from polluted area	N	S		$CoCl_2$	asw		22	38	48 h	LC50	mortality	3.1		Miliou et al., 2000
Tisbe holothuriae	Stock culture from unpolluted area	N	S		$CoCl_2$	asw		16	38	48 h	LC50	mortality	5.1		Miliou et al., 2000
Tisbe holothuriae	Stock culture from unpolluted area	N	S		$CoCl_2$	asw		19	38	48 h	LC50	mortality	3.1		Miliou et al., 2000
Tisbe holothuriae	Stock culture from unpolluted area	N	S		$CoCl_2$	asw		22	38	48 h	LC50	mortality	2.4		Miliou et al., 2000
Pisces															
Therapon jarbua	3.6 cm; juv; 0.7 g	N	S		$CoSO_4$	salt w			36	96 h	EC50	mortality	53		Krishnakumari et al., 1983

Notes
1 Test water is 2% NaCl solution.
2. Tested in 3.02% w/v/ $NaNO_3$ solution instead of 2% w/v NaCl.
3. Tested in 96 well microplates; Integral of curve used to determine EC50.
4. Tested in cuvettes.
5. Test species is called *Photobacterium phosphoreum* in publication.
6. EC50 calculated by fitting a logistic dose response model through data reported by author.

Table A2. 22. Acute toxicity of selenium to marine organisms.

Species	Species properties	A	Test type	Purity [%]	Test compound	Test water	pH	T [°C]	Salinity [‰]	Exp. time	Criterion	Test endpoint	Value [mg/l]	Notes	Reference
Bacteria															
Vibrio fisheri		N	S		Na_2SeO_3	am		15		0.5 h	EC50	luminescence	10653	1,2	Schmitz et al., 1999b
Vibrio fisheri		N	S		Na_2SeO_3	am		15		0.5 h	EC50	luminescence	10387	3	Schmitz et al., 1999b
Vibrio fisheri		N	S		Na_2SeO_3	am	7	15		5 min	EC50	luminescence	110		Yu et al., 1997
Vibrio fisheri		Y	S		SeO_2	am	6.9-7.2	27	35	22 h	EC50	luminescence	0.11	4	Hsieh et al., 2004
Vibrio fisheri		N	S		Na_2SeO_4	am	7	15		5 min	EC50	luminescence	7725		Yu et al., 1997
Vibrio fisheri		N	S		Na_2SeO_4	am	7	15		10 min	EC50	luminescence	5762		Yu et al., 1997
Vibrio fisheri		N	S		Na_2SeO_4	am	7	15		15 min	EC50	luminescence	5669		Yu et al., 1997
Vibrio fisheri		N	S		Na_2SeO_3	am		20		7 h	EC50	growth	11.4	2	Schmitz et al., 1999b
Vibrio fisheri		N	S		SeO_2	am		20		7 h	EC50	growth	3.2	2	Schmitz et al., 1999b
Rotifera															
Brachionus plicatilis		N	S		Se	syn salt w	8	25	15	24 h	LC50	mortality	17	5	Snell et al., 1991a
Crustacea															
Allorchestes compressa		Y	CF		$NaSeO_3$	nw	7.5		34.8	96 h	LC50	mortality	4.8		Ahsanullah et al., 1980
Callinectus sapidus		N	S		$NaSeO_3$	nw			30	96 h	LC50	mortality	4.6		Ward et al., 1981
Cancer magister	1st stage zoeae	Y	S	ag	SeO_2	n salt w	8.1	15		96 h	LC50	mortality	1.0		Glickstein, N., 1978
Cyclaspis usitata		Y	CF		$NaSeO_3$	nw	8.1		35.4	96 h	LC50	mortality	6.1		Ahsanullah et al., 1980
Mysidopsis bahia		Y	IF		H_2SeO_3	nw			30	96 h	LC50	mortality	1.5		Ward et al., 1981
Penaeus aztecus		N	S		$NaSeO_3$	nw			30	96 h	LC50	mortality	1.2		Ward et al., 1981
Scylla serrata	7-9 cm; intermoult; 60-95 g	N	S		Se	nw				96 h	LC50	mortality	39	6	Savant and Nilkanth, 1991
Scylla serrata		N	SS		SeO_2	am	7-7.2			96 h	LC50	mortality	33		Krishnaja et al., 1987
Mollusca															
Argopecten irradians		N	SS		SeO_2	nw	6.9-7.5		25	96 h	LC50	mortality	0.26		Nelson et al., 1988
Notacallista sp.		Y	CF		$NaSeO_3$	nw	8		35.6	96 h	LC50	mortality	2.9		Ahsanullah et al., 1980
Spisula solidissima		N	SS		SeO_2	nw	6.9-7.5		25	96 h	LC50	mortality	1.9		Nelson et al., 1988
Pisces															

Species	Species properties	A	Test type	Purity [%]	Test compound	Test water	pH	T [°C]	Salinity [‰]	Exp. time	Criterion	Test endpoint	Value [mg/l]	Notes	Reference
Cyprinodon variegatus		Y	IF		$NaSeO_3$	nw			30	96 h	LC50	mortality	7.4		Ward et al., 1981
Lagodon rhomboides		N	S		$NaSeO_3$	nw			30	96 h	LC50	mortality	4.4		Ward et al., 1981
Morone saxatilis	24 d; posthatch larvae	Y			Na_2SeO_3	salt w		17	5	96 h	LC50	mortality	3.4		Chapman, 1992
Morone saxatilis	25 d; posthatch larvae	Y			Na_2SeO_3	salt w		17	5	96 h	LC50	mortality	3.3		Chapman, 1992
Morone saxatilis	31 d; posthatch larvae	Y			Na_2SeO_3	salt w		17	5	96 h	LC50	mortality	3.8		Chapman, 1992
Morone saxatilis	32 d; posthatch larvae	Y			Na_2SeO_3	salt w		17	5	96 h	LC50	mortality	3.9		Chapman, 1992
Morone saxatilis		N	S		Na_2SeO_3	am	7.9		1	96 h	LC50	mortality	1.6		Palawski et al., 1985
Morone saxatilis	24 d; posthatch larvae	Y			Na_2SeO_4	salt w		17	5	96 h	LC50	mortality	26		Chapman, 1992
Morone saxatilis	25 d; posthatch larvae	Y			Na_2SeO_4	salt w		17	5	96 h	LC50	mortality	24		Chapman, 1992
Morone saxatilis	31 d; posthatch larvae	Y			Na_2SeO_4	salt w		17	5	96 h	LC50	mortality	26		Chapman, 1992
Morone saxatilis	32 d; posthatch larvae	Y			Na_2SeO_4	salt w		17	5	96 h	LC50	mortality	29		Chapman, 1992
Oncorhynchus kisutch	fry, 2.6 g				Na_2SeO_3	salt w	7.8	12		96 h	LC50	mortality	14		Hamilton and Buhl, 1990a
Oncorhynchus kisutch	fry, 1.7 g				Na_2SeO_4	salt w	7.8	12		96 h	LC50	mortality	39		Hamilton and Buhl, 1990a
Oncorhynchus tshawytscha	1.6 g, fry				Na_2SeO_3	salt w	7.8	12		96 h	LC50	mortality	23	7	Hamilton and Buhl, 1990a
Oncorhynchus tshawytscha	1.6 g, fry				Na_2SeO_4	salt w	7.8	12		96 h	LC50	mortality	149	7	Hamilton and Buhl, 1990a
Pagrus major	3 mo	Y	S	ag	Na_2SeO_3	nsw	7.8-8.1	20		96 h	LC50	mortality	12	8	Takayanagi, 2001
Pagrus major	3 mo	Y	S	ag	Na_2SeO_4	nsw	7.8-8.1	20		96 h	LC50	mortality	76	8	Takayanagi, 2001

Notes
1. Tested in 96 well microplates.
2. Integral of growth curve used to determine EC50.
3. Tested in cuvettes.
4. EC50 is the mean of three replicate experiments (not individually reported); standard deviation was 0.021 mg/l.
5. No information on Se salt that was used.
6. Se species not mentioned. Results is expressed as ppm Se (metal).
7. Reported here is the pooled value of two experiments.
8. Seawater was sand and activated coal filtered.

Table A2. 23. Acute toxicity of molybdenum to marine organisms.

Species	Species properties	A	Test type	Purity [%]	Test compound	Test water	pH	T [°C]	Salinity [‰]	Exp. time	Criterion	Test endpoint	Value [mg/l]	Notes	Reference
Mollusca															
Mytilus edulis	larvae	Y	S		$(NH_4)_6Mo_7O_{24}$	nw	8.4		26	48 h	EC50	reproduction	150		Morgan et al., 1986
Crassostrea virginica		Y	SS		$NaMoO_4$	am			20	96 h	EC50	growth	1900		Knothe et al., 1988
Crustacea															
Penaeus duorarum		Y	S		$NaMoO_4$	am			25	96 h	LC50	mortality	1900		Knothe et al., 1988
Mysidopsis bahia		Y	S		$NaMoO_4$	nw			27	96 h	LC50	mortality	1100		Knothe et al., 1988
Allorchestes compressa		Y	CF		$(NH_4)_6Mo_7O_{24}$	nw	5.0-5.4	16	34.8	96 h	LC50	mortality	247		Ahsannulah, 1982
Pisces															
Cyprinodon variegatus		Y	S	AR	$NaMoO_4$	am			25	96 h	LC50	mortality	2600		Knothe et al., 1988

Table A2. 24. Acute toxicity of tin to marine organisms.

Species	Species properties	A	Test type	Purity [%]	Test compound	Test water	pH	T [°C]	Salinity [‰]	Exp. time	Criterion	Test endpoint	Value [mg/l]	Notes	Reference
Bacteria															
Vibrio harveyi	direct assay	N	S		$SnCl_4$	am	7.0	23	25	1 h	EC50	luminescence	1.64	1	Thomulka et al., 1993a
Algae															
Skeletonema costatum	2500 cells/ml	Y	S		$SnCl_2$	syn salt w	8.1	20	30	72 h	EC50	growth	0.21		Walsh et al., 1985
Thalassiosira pseudonana	2500 cells/ml	Y	S		$SnCl_2$	syn salt w	8.1	20	30	72 h	EC50	growth	0.20		Walsh et al., 1985
Crustacea															
Idotea balthica	6-8 mm	Y	S	ag	$SnCl_2$	nsw	8			106 h	EC50	mortality	95	2	El-Nady and Atta, 1996

Notes
1. Author does not report chemical identity of substances used in the study; presumably $SnCl_4$ is used.
2. EC50 calculated by fitting a logistic dose response model through data reported by author.

Table A2. 25. Acute toxicity of antimony to marine organisms.

Species	Species properties	A	Test type	Purity [%]	Test compound	Test water	pH	T [°C]	Salinity [‰]	Exp. time	Criterion	Test endpoint	Value [mg/l]	Notes	Reference
Bacteria															
Vibrio fisheri		Y	S		$SbCl_3$	am	6.9-7.2	27	35	22 h	EC50	luminescence	0.64	1	Hsieh et al., 2004
Pisces															
Cyprinodon variegatus	14-28 d; 8-15 mm	N		>80		nsw		25-31	10-31	96 h	LC50		6.2-8.3	2	Heitmuller et al., 1981
Pagrus major	3 mo	Y	S	ag	$SbCl_5$	nsw	7.8-8.1	20		96 h	EC50	mortality	0.93	3	Takayanagi, K, 2001
Pagrus major	3 mo	Y	S	ag	$SbCl_3$	nsw	4.9-7.8	20		96 h	EC50	mortality	12	4	Takayanagi, K, 2001

Notes
1. EC50 is the mean of three replicate experiments (not individually reported); standard deviation was 0.043 mg/l.
2. Sb species unknown; 6.2 mg/l was slected for risk assessment.
3. Seawater was sand and activated coal filtered.
4. Seawater was sand and activated coal filtered. The low pH was also tested in controls with HCl adjusted seawater, in which no mortality occured.

Table A2. 26. Acute toxicity of barium to marine organisms.

Species	Species properties	A	Test type	Purity [%]	Test compound	Test water	pH	T [°C]	Salinity [‰]	Exp. time	Criterion	Test endpoint	Value [mg/l]	Notes	Reference
Bacteria															
Vibrio fisheri		N	S		$Ba(NO_3)_2$	am	5.65	15		15 min	EC50	bioluminescence	13	1	McCloskey et al., 1996
Mollusca															
Mytilus californianus	embryo	Y	S		$Ba(CH_3COOH)_2$	salt w	7.8	15		2 d	EC50	development	0.19	2	Spangenberg and Cherr, 1996
Crustacea															
Artemia salina	2nd+3rd instar	N	S	>97	$Ba(NO_3)_2$	syn w			35	24 h	LC50	mortality	4738		Calleja et al., 1994

Notes
1. Tested in 3.02% w/v/ $NaNO_3$ solution instead of 2% w/v NaCl.
2. Test water is natural seawater, 0.45 µm filtered.

Table A2. 27. Acute toxicity of thallium to marine organisms.

Species	Species properties	A	Test type	Purity [%]	Test compound	Test water	pH	T [°C]	Salinity [‰]	Exp. time	Criterion	Test endpoint	Value [mg/l]	Notes	Reference
Bacteria															
Vibrio fisheri		N	S	>97	Tl_2SO_4	syn salt w				15 min	EC50	luminescence	3601		Calleja et al., 1994
Vibrio fisheri		Y	S		$TlNO_3$	am	6.9-7.2	27	35	22 h	EC50	luminescence	6.3	1	Hsieh et al., 2004
Algae															
Ditylum brightwelli		N	S		TlCl	am	8.0		18.8	5 d	EC50	growth	0.34	2	Canterford and Canterford, 1980
Crustacea															
Artemia salina	2nd+3rd instar	N	S	>97	Tl_2SO_4	syn salt w			35	24 h	LC50	mortality	32		Calleja et al., 1994
Pisces															
Cyprinodon variegatus		N			Tl	nw			10-31	96 h	LC50	mortality	21		Heitmuller et al., 1981

Notes
1. EC50 is the mean of three replicate experiments (not individually reported); standard deviation was 0.321 mg/l.
2. Three tests were performed, which resulted in EC50 values of 330, 340 and 350 µg/l. The (geo)mean value is reported here. Endpoint=number of cells counted at day 5 (end of test).

Table A2. 28. Chronic toxicity of vanadium to marine organisms.

Species	Species properties	A	Test type	Purity [%]	Test compound	Test water	pH	T [°C]	Salinity [‰]	Exp. time	Criterion	Test endpoint	Value [mg/l]	Notes	Reference
Algae															
Dunaliella marina		N	S		$NaVO_3$	nw			38	15 d	EC10	mortality	0.34	1	Miramand and Unsal, 1978
Asterionella japonica		N	S		$NaVO_3$	nw			38	15 d	EC10	mortality	0.050	1,2	Miramand and Unsal, 1978
Prorocentrum micans		N	S		$NaVO_3$	nw			38	15 d	EC10	mortality	0.054	1,2	Miramand and Unsal, 1978

Notes
1. Figure was scanned, digitised, and a logistic dose-effect relationship was fitted through the obtained dataset using nonlinear regression; EC10 determined from this relationship.
2. EC10 was extrapolated a factor of 2 below the lowest test concentration (0.1 mg/l); r2 of nonlinear dose response regression fit >0.98).

Table A2. 29. Chronic toxicity of cobalt to marine organisms.

Species	Species properties	A	Test type	Purity [%]	Test compound	Test water	pH	T [°C]	Salinity [‰]	Exp. time	Criterion	Test endpoint	Value [mg/l]	Notes	Reference
Algae															
Chlorella vulgaris	isolated from marine bay water	N	S	ag	$CoCl_2$	sw+		24	7.6	9 d	EC10	cell number	0.58	1	Latała and Surosz, 1999
Oocystis submarina	isolated from marine bay water	N	S	ag	$CoCl_2$	sw+		24	7.6	9 d	EC10	cell number	0.73	1	Latała and Surosz, 1999
Stichococcus bacillaris	isolated from marine bay water	N	S	ag	$CoCl_2$	sw+		24	7.6	9 d	EC10	cell number	1.67	1	Latała and Surosz, 1999
Cyclotella meneghiniana	isolated from marine bay water	N	S	ag	$CoCl_2$	sw+		24	7.6	9 d	EC10	cell number	2.49	1	Latała and Surosz, 1999
Crustacea															
Carcinus maenas	adult	N	S		$CoCl_2$	nw	7.4-7.8			10 d	NOEC	survival	110		Amiard, 1976
Homarus vulgaris	3 stage larvae	N	S		$CoCl_2$	nw	7.4-7.8			9 d	NOEC	survival	0.45		Amiard, 1976
Pisces															
Blennius pholis	adult	N	S		$CoCl_2$	nw	7.4-7.8			15 d	NOEC	survival	45		Amiard, 1976

Notes
1. Growth medium sw+ = seawater+nutrients; medium contained 2.5 µg/l Co; author states algae to be in exponential growth phase at day 9.

Table A2. 30. Chronic toxicity of selenium to marine organisms.

Species	Species properties	A	Test type	Purity [%]	Test compound	Test water	pH	T [°C]	Salinity [‰]	Exp. time	Criterion	Test endpoint	Value [mg/l]	Notes	Reference
Cyanobacteria															
Agmenellum quadruplicatum		N	S		Na_2SeO_3	am		18		60 d	NOEC	growth rate	6.2	1	Wong et al., 1991
Agmenellum quadruplicatum		N	S		Na_2SeO_4	am		18		60 d	NOEC	growth rate	51	1	Wong et al., 1991
Algae															
Amphidinium carterae		N	S		Na_2SeO_3	am		18		60 d	NOEC	growth rate	1.0	1	Wong et al., 1991
Amphidinium carterae		N	S		Na_2SeO_4	am		18		60 d	NOEC	growth rate	5.4	1	Wong et al., 1991
Chaetoceros vixvisibilis		N	S		Na_2SeO_3	am		18		60 d	NOEC	growth rate	6.5	1	Wong et al., 1991
Chaetoceros vixvisibilis		N	S		Na_2SeO_4	am		18		60 d	NOEC	growth rate	6.8	1	Wong et al., 1991
Chlorella sp.		N	S		Na_2SeO_3	am			32	14 d	NOEC	growth	10		Wheeler et al., 1982
Dunaliella primolecta		N	S		Na_2SeO_4	am			32	14 d	NOEC	growth	0.10		Wheeler et al., 1982
Dunaliella tertiolecta		N	S		Na_2SeO_3	am		18		60 d	NOEC	growth rate	0.19	1	Wong et al., 1991
Dunaliella tertiolecta		N	S		Na_2SeO_4	am		18		60 d	NOEC	maximum yield	75	2	Wong et al., 1991
Isochrysis galbana		N	S		Na_2SeO_3	am		18		60 d	NOEC	growth rate	1.8	1	Wong et al., 1991
Isochrysis galbana		N	S		Na_2SeO_4	am		18		60 d	NOEC	growth rate	68	1	Wong et al., 1991
Nannochloropsis oculata		N	S		Na_2SeO_4	am		18		60 d	NOEC	growth rate	7.9	1	Wong et al., 1991
Pavlova lutheri		N	S		Na_2SeO_3	am		18		60 d	NOEC	growth rate	0.28	1	Wong et al., 1991
Pavlova lutheri		N	S		Na_2SeO_4	am		18		60 d	NOEC	growth rate	31	1	Wong et al., 1991
Platymonas subcordiformis		N	S		Na_2SeO_4	am			32	14 d	NOEC	growth	0.010		Wheeler et al., 1982
Crustacea															
Allorchestes compressa	juv, 1st instar		CF	lg	Na_2SeO_3	salt w		20	32-35	4 w	NOEC	growth	0.044		Ahsanullah and Brand, 1985
Mysidopsis bahia		Y	IF		H_2SeO_3	nw			26		NOEC	reproduction	0.14	3	Ward et al., 1981
Pisces															
Cyprinodon variegatus		Y	IF		Na_2SeO_3	nw			27		NOEC	reproduction	0.47	3	Ward et al., 1981

Notes

1. A logistic dose response model was fitted trough reported data to obtain the EC10. The reported exponential growth rates used to construct dose response relationships were obtained from that part of the experiment where algae were multiplicating at maximum speed. The exposure duration mentioned in the table reflects the total experiment rather than the period over which exponential growth was observed.

2. A logistic dose response model was fitted trough reported data to obtain the EC10. Maximum yield was used here because the dose-effect relationship of the parameter growth rate was too steep to be fitted and cell yield showed an identical sensitivity. The exposure duration mentioned in the table reflects the total experiment rather than the period over which exponential growth was observed.
3. calculated from MATC of an ELS test.

Table A2. 31. Chronic toxicity of barium to marine organisms.

Species	Species properties	A	Test type	Purity [%]	Test compound	Test water	pH	T [°C]	Salinity [‰]	Exp. time	Criterion	Test endpoint	Value [mg/l]	Notes	Reference
Crustacea															
Cancer anthonyi	embryos, 4-lobed stage	N	R		$BaCl_2$	sw	7.8	20	34	7 d	EC10	mortality	8.9	1	Macdonald et al., 1988
Cancer anthonyi	embryos, 4-lobed stage	N	R		$BaCl_2$	sw	7.8	20	34	7 d	EC10	hatching	14.7	1	Macdonald et al., 1988

Notes
1. EC10 calculated by fitting a logistic dose response model through data reported by author.

Table A2. 32. Toxicity of beryllium to aquatic organisms, data not used.

Species	Species properties	A	Test type	Purity [%]	Test compound	Test water	pH	T [°C]	Hardness [mg $CaCO_3$/l]	Exp. time	Criterion	Test endpoint	Value [mg/l]	Notes	Reference
Crustacea															
Daphnia magna	neonate, ad.			rg	$BeSO_4$	fw	8.36	20.5		28 d	EC50	mortality	0.034	1	Kimball, 1978
Daphnia magna	neonate, ad.			rg	$BeSO_4$	fw	8.36	20.5		28 d	NOEC	progeny	0.0038	1	Kimball, 1978
Daphnia magna	neonate, 12 h			rg	$BeSO_4$	fw	7.83	20		48 h	EC50	mortality	3.07	1,2	Kimball, 1978
Daphnia magna	neonate, 12 h			rg	$BeSO_4$	fw	7.83	20		48 h	EC50	mortality	2.41	1,3	Kimball, 1978
Daphnia magna	neonate, 12 h			rg	$BeSO_4$	fw	7.83	20		96 h	EC50	mortality	0.82	1,2	Kimball, 1978
Daphnia magna	neonate, 12 h			rg	$BeSO_4$	fw	7.83	20		48 h	EC50	mortality	3.46	2	Kimball, 1978
Daphnia magna	neonate, 12 h			rg	$BeSO_4$	fw	7.83	20		96 h	EC50	mortality	1.25	2	Kimball, 1978
Pimephales promelas	8-10 mm			rg	$BeSO_4$	fw	7.6	25.1		96 h	EC50	mortality	17.9	1	Kimball, 1978
Pisces															
Carassius auratus		Y	CF		$BeSO_4$		7.6		147	10 d	LC50	mortality	6.5		Cardwell et al., 1976
Fundulus heteroclitus		N			$BeSO_4$	nw		20	5.2	96 h	LC50	mortality	17.5	4	Dorfman, 1977
Fundulus heteroclitus		N			$BeSO_4$	nw		20	21.8	96 h	LC50	mortality	4.7	4	Dorfman, 1977
Oncorhynchus mykiss	egg				$BeCl_2$	fw	6.9-7.8	12-13	92-110	28 d	EC50	mortality	0.38		Birge et al., 1980
Pimpephales promelas		Y	CF		$BeSO_4$		8.0		140	14 d	LC50	mortality	4.0		Cardwell et al., 1976

Notes
1. Precipitate formed.
2. Fed.
3. Not fed.
4. Author states that pH was probable cause of mortality; pH was <4 at the end of test.

Table A2. 33. Toxicity of vanadium to aquatic organisms, data not used.

Species	Species properties	A	Test type	Purity [%]	Test compound	Test water	pH	T [°C]	Hardness [mg $CaCO_3$/l] Salinity [‰]	Exp. time	Criterion	Test endpoint	Value [mg/l]	Notes	Reference
Algae															
Scenedesmus quadricauda		N	S		V_2O_5	am					EC50	growth	2.2	1	Fargašová, 1999a
Scenedesmus quadricauda		N	S		V_2O_5	am					EC50	growth	2.3	1	Fargašová, 2001
Annelida															
Tubifex tubifex	field collected mature worms, 20 mm	N	S	ag	V_2O_5	tw	7.8	20	311	96 h	LC50	mortality	0.21	2,3	Fargašová, 1999b
Insecta															
Chironomus plumosus	25 mm	N	S		V_2O_5	tw	7.7	20		96 h	LC53.3	mortality	0.24	4	Fargašová, 1997
Chironomus plumosus	larvae 25 mm	N	S		V_2O_5	tw	7.8	20	80	96 h	LC50	mortality	0.22	3	Fargašová, 1998a
Pisces															
Brachydanio rerio	juv/ad	Y	SS		$NaVO_3$	nw	7.7-8.5		136	7 d	LC50		2.30		Beusen and Neven, 1987
Carassius auratus	3-5 cm	N	S		V_2O_5	rw	6.0-6.5		35	6 d	LC50		8.10		Knudtson, 1979
Carassius auratus	3-5 cm	N	S		$VOSO_4$	rw	6.0-6.5		35	6 d	LC50		3.00		Knudtson, 1979
Carassius auratus	3-5 cm	N	S		NH_4VO_3	rw	6.0-6.5		35	6 d	LC50		3.80		Knudtson, 1979
Carassius auratus	3-5 cm	N	S		$NaVO_3$	rw	6.0-6.5		35	6 d	LC50		2.50		Knudtson, 1979
Fundulus heteroclitus		N			NH_4VO_3	nw		20	6.0	96 h	LC50	mortality	13.5	5	Dorfman, 1977
Fundulus heteroclitus		N			NH_4VO_3	nw		20	21.6	96 h	LC50	mortality	17.5	5	Dorfman, 1977
Jordanella floridae	1 wk	N	CF		V_2O_5	rw	8.2		347	96 d	LC50		1.10		Holdway and Sprague, 1979
Jordanella floridae	eggs	N	CF		V_2O_5	rw	8.2		347	34 d	LC50		0.69	6	Holdway and Sprague, 1979
Lebistes reticulatus	1.5-2.5 cm	N	S		V_2O_5	rw	6.0-6.5		35	6 d	LC50		1.10		Knudtson, 1979
Lebistes reticulatus	1.5-2.5 cm	N	S		$VOSO_4$	rw	6.0-6.5		35	6 d	LC50		0.37		Knudtson, 1979
Lebistes reticulatus	1.5-2.5 cm	N	S		NH_4VO_3	rw	6.0-6.5		35	6 d	LC50		1.50		Knudtson, 1979
Lebistes reticulatus	1.5-2.5 cm	N	S		$NaVO_3$	rw	6.0-6.5		35	6 d	LC50		0.49		Knudtson, 1979
Oncorhynchus mykiss	juv, 3.03 g	Y	CF	rg	V_2O_5	fw	5.51	15	101	96 h	EC50	mortality	11.7		Stendahl and Sprague, 1982
Oncorhynchus mykiss	juv, 3.03 g	Y	CF	rg	V_2O_5	fw	5.51	15	101	5 d	EC50	mortality	8.1		Stendahl and Sprague, 1982
Oncorhynchus mykiss	juv, 3.03 g	Y	CF	rg	V_2O_5	fw	5.51	15	101	8 d	EC50	mortality	2.7		Stendahl and Sprague, 1982
Oncorhynchus mykiss	juv, 11.74 g	Y	CF	rg	V_2O_5	fw	7.69	15	99	96 h	EC50	mortality	6.4		Stendahl and Sprague, 1982
Oncorhynchus mykiss	juv, 11.74 g	Y	CF	rg	V_2O_5	fw	7.69	15	99	5 d	EC50	mortality	2.2		Stendahl and Sprague, 1982

Species	Species properties	A	Test type	Purity [%]	Test compound	Test water	pH	T [°C]	Hardness [mg $CaCO_3$/l] Salinity [‰]	Exp. time	Criterion	Test endpoint	Value [mg/l]	Notes	Reference
Oncorhynchus mykiss	juv, 6.21 g	Y	CF	rg	V_2O_5	fw	7.66	15	98	96 h	EC50	mortality	5.2		Stendahl and Sprague, 1982
Oncorhynchus mykiss	juv, 6.21 g	Y	CF	rg	V_2O_5	fw	7.66	15	98	5 d	EC50	mortality	3.3		Stendahl and Sprague, 1982
Oncorhynchus mykiss	juv, 2.45 g	Y	CF	rg	V_2O_5	fw	7.71	15	101	96 h	EC50	mortality	10		Stendahl and Sprague, 1982
Oncorhynchus mykiss	juv, 2.45 g	Y	CF	rg	V_2O_5	fw	7.71	15	101	5 d	EC50	mortality	6.3		Stendahl and Sprague, 1982
Oncorhynchus mykiss	juv, 2.45 g	Y	CF	rg	V_2O_5	fw	7.71	15	101	8 d	EC50	mortality	3.3		Stendahl and Sprague, 1982
Oncorhynchus mykiss	juv, 2.44 g	Y	CF	rg	V_2O_5	fw	7.72	15	103	96 h	EC50	mortality	6.2		Stendahl and Sprague, 1982
Oncorhynchus mykiss	juv, 2.44 g	Y	CF	rg	V_2O_5	fw	7.72	15	103	5 d	EC50	mortality	5.1		Stendahl and Sprague, 1982
Oncorhynchus mykiss	juv, 2.44 g	Y	CF	rg	V_2O_5	fw	7.72	15	103	11 d	EC50	mortality	2		Stendahl and Sprague, 1982
Oncorhynchus mykiss	juv, 2.44 g	Y	CF	rg	V_2O_5	fw	7.72	15	103	8 d	EC50	mortality	2.9		Stendahl and Sprague, 1982
Oncorhynchus mykiss	juv, 2.44 g	Y	CF	rg	V_2O_5	fw	7.72	15	103	9 d	EC50	mortality	2.7		Stendahl and Sprague, 1982
Oncorhynchus mykiss	juv, 2.44 g	Y	CF	rg	V_2O_5	fw	7.72	15	103	10 d	EC50	mortality	2.4		Stendahl and Sprague, 1982
Oncorhynchus mykiss	juv, 2.11 g	Y	CF	rg	V_2O_5	fw	7.7	15	100	96 h	EC50	mortality	6.1		Stendahl and Sprague, 1982
Oncorhynchus mykiss	juv, 2.11 g	Y	CF	rg	V_2O_5	fw	7.7	15	100	5 d	EC50	mortality	4.6		Stendahl and Sprague, 1982
Oncorhynchus mykiss	juv, 2.44 g	Y	CF	rg	V_2O_5	fw	7.72	15	103	9 d	EC50	mortality	2.6		Stendahl and Sprague, 1982
Oncorhynchus mykiss	juv, 2.11 g	Y	CF	rg	V_2O_5	fw	7.7	15	100	8 d	EC50	mortality	2.6		Stendahl and Sprague, 1982
Oncorhynchus mykiss	juv, 2.44 g	Y	CF	rg	V_2O_5	fw	7.72	15	103	10 d	EC50	mortality	<=2		Stendahl and Sprague, 1982
Oncorhynchus mykiss	juv, 1.47 g	Y	CF	rg	V_2O_5	fw	7.7	15	100	96 h	EC50	mortality	8		Stendahl and Sprague, 1982
Oncorhynchus mykiss	juv, 1.47 g	Y	CF	rg	V_2O_5	fw	7.7	15	100	5 d	EC50	mortality	7.4		Stendahl and Sprague, 1982
Oncorhynchus mykiss	juv, 1.47 g	Y	CF	rg	V_2O_5	fw	7.7	15	100	8 d	EC50	mortality	4.3		Stendahl and Sprague, 1982
Oncorhynchus mykiss	juv, 1.47 g	Y	CF	rg	V_2O_5	fw	7.7	15	100	9 d	EC50	mortality	4.1		Stendahl and Sprague, 1982
Oncorhynchus mykiss	juv, 1.47 g	Y	CF	rg	V_2O_5	fw	7.7	15	100	10 d	EC50	mortality	3.7		Stendahl and Sprague, 1982
Oncorhynchus mykiss	juv, 1.47 g	Y	CF	rg	V_2O_5	fw	7.7	15	100	11 d	EC50	mortality	3.5		Stendahl and Sprague, 1982
Oncorhynchus mykiss	juv, 1.47 g	Y	CF	rg	V_2O_5	fw	7.7	15	100	12 d	EC50	mortality	2.7		Stendahl and Sprague, 1982
Oncorhynchus mykiss	juv	Y	CF	rg	V_2O_5	fw	7.7	15	100	13-20 d	EC50	mortality	2.5		Stendahl and Sprague, 1982
Oncorhynchus mykiss	juv	Y	CF	rg	V_2O_5	fw	6.61	15	368	96 h	EC50	mortality	13.2		Stendahl and Sprague, 1982
Oncorhynchus mykiss	juv	Y	CF	rg	V_2O_5	fw	6.61	15	368	5 d	EC50	mortality	5.5		Stendahl and Sprague, 1982
Oncorhynchus mykiss	juv	Y	CF	rg	V_2O_5	fw	6.61	15	368	8 d	EC50	mortality	3.4		Stendahl and Sprague, 1982
Oncorhynchus tshawytscha	fry, 0.5 g				Na_3VO_4	fw	7-8.3	12	211	24 h	EC50	mortality	39.2		Hamilton and Buhl, 1990b
Oncorhynchus tshawytscha	fry, 1.98 g				Na_3VO_4	fw	6.7-8.4	12	343	24 h	EC50	mortality	46.5		Hamilton and Buhl, 1990b
Poecilia reticulata	juv/ad	Y	SS		$NaVO_3$	rw	7.7-8.5		136	7 d	LC50		3.30		Beusen and Neven, 1987

Notes
1. Cells counted only at termination of test and test incubated too long (12 d).
2. Same study result also reported in Fargasova (1998) with a hardness of 80 mg $CaCO_3$/l.
3. Rejected because results for Mo and Cu published in this study were extremely deviant compared to the species sensitivity distribution.
4. One concentration tested.
5. Author states that pH is the probable cause of death for other compounds tested; pH was not reported in this study.
6. F1 eggs from P-generation which was exposed for 96 days to similar concentrations of V_2O_5.

Table A2. 34. Toxicity of cobalt to aquatic organisms, data not used.

Species	Species properties	A	Test type	Purity [%]	Test compound	Test water	pH	T [°C]	Hardness/ [mg $CaCO_3$/l] Salinity [‰]	Exp. time	Criterion	Test endpoint	Value [mg/l]	Notes	Reference
Bacteria															
Vibrio fisheri		N	S		$CoCl_2$	am		20		0.5 h	EC50	luminescence	112		Schmitz et al., 1999a
Vibrio harveyi	direct assay	N	S		$CoCl_2$	am	7.0	23	2.5‰	1 h	EC20	luminescence	44	1	Thomulka et al., 1997
Vibrio harveyi	direct assay	N	S		$CoCl_2$	am					EC50	luminescence	>4.5		Thomulka et al., 1997
Vibrio harveyi	direct assay+ 3 g seashore sand	N	S		$CoCl_2$	am	7.0	23	30	1 h	EC50	luminescence	34		Thomulka and Lange, 1994
Algae															
Euglena viridis		N			$Co(NO_3)_2$	am				21 d	EC50	growth	1.3	2	Coleman et al., 1971
Annelida															
Tubifex tubifex		N	S	rg	$CoCl_2$	am	6.6	20	10-15	96 h	LC50	mortality	129	3	Rathore and Khangarot, 2003
Tubifex tubifex		N	S	rg	$CoCl_2$	am	7.3	20	38-50	96 h	LC50	mortality	164	3	Rathore and Khangarot, 2003
Tubifex tubifex		N	S	rg	$CoCl_2$	am	7.8	20	275-330	96 h	LC50	mortality	566	3	Rathore and Khangarot, 2003
Tubifex tubifex		N	S	rg	$CoCl_2$	am	7.5	25	226-255	96 h	LC50	mortality	247	4	Rathore and Khangarot, 2002
Tubifex tubifex		N	S	rg	$CoCl_2$	am	7.5	30	226-255	96 h	LC50	mortality	95	4	Rathore and Khangarot, 2002
Crustacea															
Austropotamobius pallipes	19-32 mm	Y			$CoCl_2$	nw	7	16		30 d	EC50	mortality	0.77		Boutet and Chaisemartin, 1973
Orconectes limosus	19-32 mm	Y			$CoCl_2$	nw	7	16		30 d	EC50	mortality	0.79		Boutet and Chaisemartin, 1973
Ceriodaphnia dubia	<24 h	Y	R	rg	$CoCl_2$	fw			432-580 mg/l	7 d	NOEC	mortality	0.05	5	Diamond et al., 1992
Ceriodaphnia dubia	<24 h	Y	R	rg	$CoCl_3$	nw		20	882 mg/l	24 h	EC50	immobility	>5.3	6	Diamond et al., 1992
Pisces															
Fundulus heteroclitus		N			$CoCO_3$	nw		20	7.9 mg/l	96 h	LC50	mortality	>1000		Dorfman, 1977
Fundulus heteroclitus		N			$CoCO_3$	nw		20	18.8 mg/l	96 h	LC50	mortality	>1000		Dorfman, 1977
Fundulus heteroclitus		N			$CoCl_2$	nw		20	5 mg/l	96 h	LC50	mortality	275	7	Dorfman, 1977
Fundulus heteroclitus		N			$CoCl_2$	nw		20	25.3 mg/l	96 h	LC50	mortality	275	7	Dorfman, 1977

Notes
1. This value is reported to be cited from Thomulka *et al*., (1993), but is not and can not be brought in accordance with the cited source.
2. EC50 derived from data presented by the author; effect possibly underestimated because growth was measured as dry weight.

3. Test result obtained at a hardness representative for surface water of major water in the Netherlands was selected.
4. Test results obtained at more relevant temperature for surface water of major water in the Netherlands was selected.
5. Authors state that data can not be used to derive chronic endpoints for *C. dubia* due to survival and reproduction problems caused by the medium. Other 7 d NOECs are reported for different hardness values but also rejected.
6. Test water is filtered pond water of which a 5th part is 20:80 Perrier®:distilled water.
7. Author states that pH is the probable cause of death for other compounds tested; pH was not reported in this study.

Table A2. 35. Toxicity of selenium to aquatic organisms, data not used.

Species	Species properties	A	Test type	Purity [%]	Test compound	Test water	pH	T [°C]	Hardness [mg $CaCO_3$/l]	Exp. time	Criterion	Test endpoint	Value [mg/l]	Notes	Reference
Bacteria															
Vibrio fischeri		N	S	rg	Na_2SeO_3	am				15 min.	EC50	luminescence	33.4	1	Paran et al., 1990
Vibrio harveyi	direct assay	N	S		SeO_2	am	7.0	23	2.5‰	1 h	EC50	luminescence	0.7	2	Thomulka et al., 1997
Cyanobacteria															
Anabaena constricta	$5x10^5$ hormogonia/ml	N	S		Na_2SeO_3	am		25		3 d	EC50	biomass	120	3	Shabana et al., 1994
Algae															
Chlorella vulgaris					Na_2SeO_4	fw	8.21	25	120	24 d	NOEC	biomass	0.40		Dobbs et al., 1996
Chlorella ellipsoida	$20x10^5$ cells/ml	N	S		Na_2SeO_3	am		25		3 d	EC50	biomass	126	3	Shabana et al., 1994
Nannochloropsis oculata		N	S		Na_2SeO_3	am		18		60 d	NOEC	growth rate	>79	4	Wong et al., 1991
Selenastrum capricornutum	1.5e6 cells/ml	N	S	ag	Na_2SeO_3/O_4	am	7.5	24		4 d	EC50	growth	96	5	Ibrahim and Spacie, 1990
Macrophyta															
Hydrilla verticillata	plants with 7-10 cm shoot length	N	S		SeO_2	am	6	25	70	5 d	NOEC	growth	≥ 10		Byl et al., 1994
Lemna minor	fronds	Y	S		SeO_4^{2-}	am	5		313	14 d	NOEC	multiplication rate	>2400		Jenner and Janssen-Mommen, 1993
Rotifera															
Brachionus calyciflorus	female with eggs	Y	CF		Na_2SeO_4	rec	8.21	25	120	24 d	LOEC	biomass	0.11	6	Dobbs et al., 1996
Mollusca															
Crassostrea gigas	embryo to larvae	Y	S	ag	Na_2SeO_3	n salt w	8.1	20	33.8‰	48 h	EC50	development	>10		Glickstein, 1978
Crassostrea gigas	embryo to larvae	Y	S	ag	SeO_2	n salt w	8.1	20	33.8‰	48 h	EC50	development	>10		Glickstein, 1978
Crustacea															
Corophium sp.	juveniles	Y	R		Na_2SeO_3	n salt w		23	30‰	96 h	NOEC	mortality	0.058		Hyne et al., 2002
Corophium sp.	juveniles	Y	R		Na_2SeO_4	n salt w		23	30‰	96 h	NOEC	mortality	0.12		Hyne et al., 2002
Daphnia magna	2 d	Y	CF		Na_2SeO_3/O_4	nw	7.3		329	21 d	NOEC	mortality	≥280		Halter et al., 1980
Daphnia magna	adult	N	SS		Na_2SeO_4	am	8.4			6 d	EC50		0.42	7	Johnston, 1987

Species	Species properties	A	Test type	Purity [%]	Test compound	Test water	pH	T [°C]	Hardness [mg $CaCO_3$/l]	Exp. time	Criterion	Test endpoint	Value [mg/l]	Notes	Reference
Daphnia magna	adult	N	SS		Na_2SeO_3	am	8.4			7 d	EC50		0.32	7	Johnston, 1987
Hyalella azteca	60 d; 2 mm	Y	R	rg	Na_2SeO_4	ww	8.6		133	24 d	NOEC	reproduction	>0.7	8	Brasher and Ogle, 1993
Pisces															
Carassius auratus	adult	Y	IF		SeO_2		7.6		148	14 d	LC50	mortality	6.30		Cardwell et al., 1976
Lepidocephalichthyes thermalis	field collected	N			Se uknown species		7.2	27	1.2	96 h	LC50	mortality	3.2		Manoharan and Prabakaran, 1994
Lepomis macrochirus	adult	Y	IF		SeO_2		7.9		140	14 d	LC50	mortality	13		Cardwell et al., 1976
Oncorhynchus mykiss	juvenile	Y	CF		Na_2SeO_3	rw	7.9		135	9 d	LC50	mortality	6.4		Hodson et al., 1980
Oncorhynchus tshawytscha	eyed egg				Na_2SeO_3	fw	7.6	12	41.7	96 h	LC50	mortality	>560		Hamilton and Buhl, 1990a
Oncorhynchus tshawytscha	alevin				Na_2SeO_4	fw	7.6	12	41.7	96 h	LC50	mortality	>320		Hamilton and Buhl, 1990a
Oncorhynchus tshawytscha	eyed egg				Na_2SeO_4	fw	7.6	12	41.7	96 h	LC50	mortality	>1000		Hamilton and Buhl, 1990a
Perca flavescens	juvenile	Y	IF		Na_2SeO_3	nw	6.4		10	10 d	LC50	mortality	4.8	9	Klaverkamp et al., 1983
Pimephales promelas	juvenile	Y	IF		SeO_2		7.8		151	9 d	LC50	mortality	2.1		Cardwell et al., 1976
Pimephales promelas	12-24 h; larvae	Y	CF		Na_2SeO_4	rec	8.21	25	120	25 d	LOEC	growth	0.11	10	Dobbs et al., 1996
Pimephales promelas	juvenile	N	CF		Na_2SeO_3/O_4	nw	7.3		329	17 d	LC50	mortality	0.60		Halter et al., 1980

Notes

1. Temperature unkown; T is known to influence the outcome of the test.
2. This value is reported to be cited from Thomulka et al., (1993), but is not in accordance with the cited source.
3. Control treatment was not growing exponentially; result unclear since authors report the concentration range both in µg/l and mg/l.
4. A logistic dose response model was fitted trough reported data to obtain the EC10. The reported exponential growth rates used to construct dose response relationships were obtained from that part of the experiment where algae were multiplicating at maximum speed. The exposure duration mentioned in the table reflects the total experiment rather than the period over which exponential growth was observed.
5. Test inoculated with 1.5×10^6 cells/ml, which is too high: growth of control was not exponential as shown in presented graphs.
6. LOEC=54%effect at t=24 days. Calculated mean percentage effect over 9 time points during 24 d exposure to this treatment, is 20%; however the effect of this treatment (relative to the control) increases significantly when plotted versus time (P=0.016).
7. EC50 calculated according to Spearman and Karber.
8. Test result applies to F2 generation in test. No significant effect at the highest concentration tested. NOEC>=700 µg/l.
9. Based on measured concentrations.
10. LOEC=52%effect at t=24 days. The effect of this treatment (relative to the control) increases significantly when plotted versus time (P=0.004).

Table A2. 36. Toxicity of molybdenum to aquatic organisms, data not used.

Species	Species properties	A	Test type	Purity [%]	Test compound	Test water	pH	T [°C]	Hardness [mg $CaCO_3$/l] or salinity [‰]	Exp. time	Criterion	Test endpoint	Value [mg/l]	Notes	Reference
Annelida															
Tubifex tubifex	field collected mature worms, 20 mm	N	S	ag	$(NH_4)_6Mo_7O_{24}$	tw	7.8	20	311	96 h	LC50	mortality	4.6	1	Fargašová, 1999b
Crustacea															
Carcinus maenas					MoO_4^{2-}		5	12-14	33.2‰	48 h	LC50	mortality	1018	2	Abbott, 1977
Insecta															
Chironomus plumosus	25 mm	N	S		$(NH_4)_6Mo_7O_{24}$	tw	7.7	20		96 h	LC50	mortality	0.36	1,3	Fargašová, 1997
Chironomus plumosus	larvae 25 mm	N	S		$(NH_4)_6Mo_7O_{24}$	tw	7.8	20	80	96 h	LC50	mortality	0.46		Fargašová, 1998a
Pisces															
Fundulus heteroclitus		N			MoO_3	nw		20	7.9	96 h	LC50	mortality	230	4	Dorfman, 1977
Fundulus heteroclitus		N			MoO_3	nw		20	18.8	96 h	LC50	mortality	315	4	Dorfman, 1977
Morone saxatilis	appr. 0.6 g	Y	S		Na_2MoO_4	am	8.27	20	21‰	96 h	LC50	mortality	>79.8	5	Dwyer et al., 1992
Oncorhynchus mykiss	eyed eggs	Y	CF	tg	Na_2MoO_4	tw	6.9-7.2	12.6	14-32	12 mo	LC50	mortality	>17	6	McConnell, 1977
Oncorhynchus nerka	20-70 g	N	S	R	Na_2MoO_4	tw	7.4-7.6	15-18	107	96 h	LC50	mortality	>2000		Reid, 2002

Notes
1. Rejected because results for Mo and Cu published in this study were extremely deviant compared to the species sensitivity distribution.
2. Test described very poorly; endpoint is reported as TLm (median tolerance limit).
3. Same study result also reported in Fargasova (1998) with a hardness of 80 mg $CaCO_3$/l.
4. Author states that pH was probable cause of mortality; pH was <4 at the end of test.
5. Exposure conc. 80% of nominal
6. Test started with eyed eggs, and lasted 12 months.

Table A2. 37. Toxicity of tin to aquatic organisms, data not used.

Species	Species properties	A	Test type	Purity [%]	Test compound	Test water	pH	T [°C]	Hardness [mg $CaCO_3$/l] Salinity [‰]	Exp. time	Criterion	Test endpoint	Value [mg/l]	Notes	Reference
Bacteria															
Vibrio harveyi	direct assay	N	S		$SnCl_2$	am	7.0	23	2.5‰	1 h	EC50	luminescence	0.84	1	Thomulka et al., 1997
Vibrio harveyi	direct assay	N	S		$SnCl_4$	am	7.0	23	2.5‰	1 h	EC50	luminescence	>100	1	Thomulka et al., 1997
Cyanobacteria															
Anabaena flos aquae	$7x10^5$ cells/ml				$SnCl_2$	fw	8	20		4 h	EC50	photosynthesis	>5		Wong et al., 1982
Algae															
Scenedesmus quadricauda		N	S		$SnCl_2$	fw	8	20		4 h	EC50	primary prod.	>50	2	Wong et al., 1982
Field population	field sample	N			$SnCl_2$	fw		20		4 h	EC50	primary prod.	>50	2,3	Wong et al., 1982
Crustacea															
Daphnia magna	4-8 h				$SnCl_4$					64 h		Immobilisation	66		Anderson, 1948
Daphnia magna	12 h				$SnCl_2$	fw	7.74	18	45 mg/l	21 d	EC50	immobilization	42		Biesinger and Christensen, 1972
Pisces															
Limanda limanda	7-13.2 cm; 5.6-30.8 g	Y	CF	Analar	$SnCl_2$	salt w	7.7	12		4 d	EC50	mortality	>0.035	4	Taylor et al., 1985

Notes
1. This value is reported to be cited from Thomulka *et al*., (1993), but is not in accordance with the cited source.
2. Primary production measured using $H[^{14}C]O^{3-}$ uptake.
3. Natural phytoplankton population from Lake Ontario water.
4. Test performed with field collected animals; purity "Analar grade".

Table A2. 38. Toxicity of antimony to aquatic organisms, data not used.

Species	Species properties	A	Test type	Purity [%]	Test compound	Test water	pH	T [°C]	Hardness [mg $CaCO_3$/l] Salinity [‰]	Exp. time	Criterion	Test endpoint	Value [mg/l]	Notes	Reference
Nematoda															
Caenorhabditis elegans	ad, 3-4 d				$SbCl_3$	fw		20		96 h	EC50	mortality	>20		Williams and Dusenbery, 1990
Annelida															
Tubifex tubifex		N	S		Sb_2O_3	nw	7.6		245	96 h	EC50	immobility	680	1	Khangarot, 1991
Crustacea															
Daphnia magna	4-8 h				$SbCl_3$					64 h		immobility	19.5		Anderson, 1948
Daphnia magna		N	S		Sb_2O_3	nw	7.2-7.8	12	235-260	48 h	EC50	immobility	423	1	Khangarot and Ray, 1989a
Pisces															
Fundulus heteroclitus		N			SbO_3	nw		20	6.0	96 h	LC50	mortality	>1000		Dorfman, 1977
Fundulus heteroclitus		N			SbO_3	nw		20	21.6	96 h	LC50	mortality	>1000		Dorfman, 1977
Lepomis macrochirus	juv, 0.32-1.2 g				Sb_2O_3	fw	6.7-7.8	21-23	32-34	96 h	EC50	mortality	>440		Buccafusco et al., 1981
Oncorhynchus mykiss	mean weight 1.2 g	Y	R		$K_2(C_4H_2O_6Sb)_2$		6.7-7.3	15	25	30 d	LC50	mortality	16		Doe et al., 1987

Notes

1. Test result >>water solubility.

Notes

1. NOEC set equal to TGK (Toxische Grenzkonzentration or toxicity threshold).

Table A2. 39. Toxicity of barium to aquatic organisms, data not used.

Species	Species properties	A	Test type	Purity [%]	Test compound	Test water	pH	T [°C]	Hardness [mg $CaCO_3$/l] Salinity [‰]	Exp. time	Criterion	Test endpoint	Value [mg/l]	Notes	Reference
Bacteria															
Vibrio fisheri		N	S	>97	$Ba(NO_3)_2$	syn w				15 min	EC50	bioluminescence	>52601		Calleja et al., 1994
Vibrio harveyi	direct assay	N	S		$BaCl_2$	am	7.0	23	2.5‰	1 h	EC50	luminescence	>100	1	Thomulka et al., 1997
Algae															
Chlorococcales					$BaCl_2$	fw				24 h	EC50	assimilation eff.	>1000		Krebs, 1991
Macrophyta															
Lemna minor	40 fronds	Y	S	rg	$BaCl_2$	nw	7.6-7.8	25-28	274-400	96 h	EC50	growth	>400	2	Wang, 1988
Lemna minor	40 fronds	Y	S	rg	$BaCl_2$	nw	7.9-8.2	25-28	232-364	96 h	EC50	growth	232- >400	3	Wang, 1988
Lemna minor	40 fronds	Y	S	rg	$BaCl_2$	nw	7.8-8.1	25-28	252-257	96 h	EC50	growth	310- >400	4	Wang, 1988
Lemna minor	40 fronds	Y	S	rg	$BaCl_2$	nw	8.0-8.1	25-28	185-298	96 h	EC50	growth	330- >400	5	Wang, 1988
Lemna minor	40 fronds	Y	S	rg	$BaCl_2$	nw	8.0-8.1	25-28	225-265	96 h	EC50	growth	33 - >400	6	Wang, 1988
Crustacea															
Daphnia magna	4-8 h				$BaCl_2$					64 h		Immobilisation	19		Anderson, 1948
Austropotamobius pallipes	19-32 mm	Y			$BaCl_2$		7	16		30 d	EC50	mortality	43		Boutet and Chaisemartin, 1973
Cancer anthonyi	embryos, 4-lobed stage	N	R		$BaSO_4$	sw	7.8	20	34	7 d	EC10	mortality	101	7	Macdonald et al., 1988
Cancer anthonyi	embryos, 4-lobed stage	N	R		$BaSO_4$	sw	7.8	20	34	7 d	EC10	hatching	164	7	Macdonald et al., 1988
Orconectes limosus	19-32 mm	Y			$BaCl_2$		7	16		30 d	EC50	mortality	61		Boutet and Chaisemartin, 1973
Pisces															
Fundulus heteroclitus		N			$BaCl_2$	nw		20	7.0	96 h	LC50	mortality	>1000		Dorfman, 1977
Fundulus heteroclitus		N			$BaCl_2$	nw		20	22.0	96 h	LC50	mortality	>1000		Dorfman, 1977
Pimephales promelas	Cells (in vitro)	N	S		$BaCl_2$	am				2 h	EC50	survival	398	8	Brandão et al., 1992
Cyprinodon variegatus	14-28 d; 8-15 mm	N		ag	Ba	nsw		25-31		4 d	EC50	mortality	>500	9	Heitmuller et al., 1981

Notes
1. This value is reported to be cited from Thomulka *et al*., (1993), but is not in accordance with the cited source.
2. Natural water from Beaucoup Creek at Route. 127.
3. Natural water from Illinois River at Peoria.

4. Natural water from LaMoine River at Colmar.
5. Natural water from Sangamon River at Oakford.
6. Natural water from Missouri River at St. Charles, MO.
7. EC10>>water solubility of $BaSO_4$, 3.1 (mg/l) @ 20°C; EC10 calculated by fitting a logistic dose response relationship through data reported by author.
8. Cell survival is measured as neutral red uptake inhibition; test duration is contact time with toxicant.
9. Ba species unknown.

Table A2. 40. Toxicity of thallium to aquatic organisms, data not used.

Species	Species properties	A	Test type	Purity [%]	Test compound	Test water	pH	T [°C]	Hardness [mg CaCO3/l]	Exp. time	Criterion	Test endpoint	Value [mg/l]	Notes	Reference
Macrophyta															
Elodea canadensis	28 d	N	S		Tl_2SO_4					28 d	EC50	phytotoxicity	2	1	Brown and Rattigan, 1979
Lemna minor	28 d	N	S		Tl_2SO_4					14 d	EC50	phytotoxicity	0.008	2	Brown and Rattigan, 1979

Notes
1. Whole plants tested; plants were grown (in 20 soil covered with 5 mm sand, submersed in water) for 28 d before onset of toxicity test of 28 d.
2. Whole plants tested; plants were grown for 28 d before onset of toxicity test of 14 d. Plants were tested free floating in water. No NOEC reported.

Appendix 3. Information on soil toxicity

Legend

$L(E)C50_{aqua\ min}$	lowest short term test result showing 50% effect or mortality
MPC	maximum permissible concentration
$MPC_{chronic}$	MPC derived using assessment factors, based solely on chronic test results
$MPC_{short\ term}$	MPC derived using assessment factors, based solely on short term test results
NOEC	no observed effect concentration
$NOEC_{aqua\ min}$	lowest no observed effect concentration
Organism	species used in the test, if available followed by age, size, weight or life stage
A	Y = test substance analyzed in test solution N = test substance not analyzed in test solution or no data
Test type	S = static, R = static with renewal, F = flow through
Test water	a.m. = artificial medium, a.s.w. = artificial seawater, n.f.s = natural filtered seawater, r.t.w. = reconsituted tap water (+additional salts)
Test substance purity	percentage active ingredient
Exposure time	h = hours, d = days, w = weeks, m = months, min. = minutes
Results	> and ≥ values = highest concentration used in the test

Contents

Table A3. 1. Acute toxicity of vanadium to soil organisms.

Species	Species properties (age, sex)	Soil type	A	Purity [%]	Test compound	pH	o.m. [%]	Clay [%]	T [°C]	Exp. time	Criterion	Test endpoint	Result test soil [mg/kg_{dw}]	Notes	Reference
Macrophyta															
Lactuca sativa	seed	Artisol	Y		V_2O_5	4.3	5.6		22	5 d	EC50	emergence	249	1	HydroQual Laboratories Ltd., 1994b
Raphanus sativus	seed	Artisol	Y		V_2O_5	4.3	5.6		22	3 d	EC50	emergence	569	1	HydroQual Laboratories Ltd., 1994c
Annelida															
Eisenia fetida	mature	Artisol	Y		V_2O_5	4.3	5.6		22	14 d	EC50	emergence	366	1	HydroQual Laboratories Ltd., 1994a

Notes
1. Results based on measured concentrations. Result is geometric mean of three replicate tests.

Table A3. 2. Acute toxicity of barium to soil organisms.

Species	Species properties (age, sex)	Soil type	A	Purity [%]	Test compound	pH	o.m. [%]	Clay [%]	T [°C]	Exp. time	Criterion	Test endpoint	Result test soil [mg/kg_{dw}]	Notes	Reference
Macrophyta															
Lactuca sativa	seed	artisol			$BaCl_2$	4.2	6.1	19		5 d	EC50	emergence	799	1	HydroQual Laboratories Ltd.1996
Raphanus sativus	seed	artisol			$BaCl_2$	4.2	6.1	19		3 d	EC50	emergence	2955	1	HydroQual Laboratories Ltd.1996
Phaseolus vulgaris		loam			$Ba(NO_3)_2$					14 d	EC50	growth	1803		Chaudry et al., 1977
Annelida															
Eisenia fetida		artisol			$BaCl_2$	4.2	6.1	19		14 d	EC50	mortality	4182	1	HydroQual Laboratories Ltd.1996

Notes
1. Test result based on nominal concentrations, result is geometric mean of 3 tests.

Table A3. 3. Acute toxicity of thallium to soil organisms.

Species	Species properties (age, sex)	Soil type	A	Purity [%]	Test compound	pH	o.m. [%]	Clay [%]	T [°C]	Exp. time	Criterion	Test endpoint	Result test soil [mg/kg_{dw}]	Notes	Reference
Macrophyta															
Lactuca sativa	seed	artisol			$TlCl_2$	4.2	6.1	19		5 d	EC50	emergence	16	1	HydroQual Laboratories Ltd., 1996
Raphanus sativus	seed	artisol			$TlCl_2$	4.2	6.1	19		3 d	EC50	emergence	266	2	HydroQual Laboratories Ltd., 1996
Annelida															
Eisenia fetida		artisol			$TlCl_2$	4.2	6.1	19		14 d	EC50	mortality	47	2	HydroQual Laboratories Ltd., 1996

Notes
1. Test result based on nominal concentrations. Result is geometric mean of 3 tests.
2. Test result based on nominal concentrations. Result is geometric mean of 4 tests.

Table A3. 4. Chronic toxicity of beryllium to soil organisms.

Species	Species properties (age, sex)	Soil type	A	Purity [%]	Test compound	pH	o.m. [%]	Clay [%]	T [°C]	Exp. time	Criterion	Test endpoint	Result test soil [mg/kg$_{dw}$]	Notes	Reference
Macrophyta															
Brassica oleracea	seeds	sand	Y		$BeSO_4$	6.5	1.1	0.06	22-33	98 d	EC10	growth	113	1	Kaplan et al., 1990
Triticum aestivum	seedling	loam				6.45	1.82			75 d	EC10	growth	318	2	Romney and Childress, 1965
Phaseolus vulgaris	seedling	loam			$BeSO_4$	6.45	1.82			35 d	EC10	growth	166	2	Romney and Childress, 1965
Trifolium repens	seedling	loam				6.45	1.82			225 d	EC10	growth	58	2	Romney and Childress, 1965
Trifolium repens	seedling	sandy clay loam				5.65	0.76			225 d	EC10	growth	71	2	Romney and Childress, 1965
Annelida															
Eisenia fetida	ad. 0.3-0.6 g	sandy loam	Y	100	$BeSO_4$	5.0	1.2	11	22	21 d	NOEC	mortality	83		Simini et al., 2002
Eisenia fetida	ad. 0.3-0.6 g	sandy loam	Y	100	$BeSO_4$	5.0	1.2	11	22	21 d	EC10	reproduction	45	3,4	Simini et al., 2002
Enchytraeus crypticus	ad	sandy loam	Y	100	$BeSO_4$	5.0	1.2	11	21	14 d	NOEC	mortality	83		Kuperman et al., 2002
Enchytraeus crypticus	ad	sandy loam	Y	100	$BeSO_4$	5.0	1.2	11	21	28 d	EC10	reproduction	42	3,5	Kuperman et al., 2002
Insecta															
Folsomia candida	juv. 10-12 d.	sandy loam	Y	100	$BeSO_4$	5.0	1.2	11	20	28 d	NOEC	mortality	18		Phillips et al., 2002
Folsomia candida	juv. 10-12 d.	sandy loam	Y	100	$BeSO_4$	5.0	1.2	11	20	28 d	EC10	reproduction	20	3,5	Phillips et al., 2002

Notes
1. EC10 calculated by fitting a logistic dose response model through data reported by author; based on nominal added Be concentrations.
2. Figure was scanned, digitised, and a logistic dose-effect relationship was fitted through the obtained dataset using nonlinear regression; EC10 determined from this relationship.
3. EC10 calculated from logistic (Gompertz) regression equation and parameters, both provided in the study report.
4. Endpoint: number of cocoons.
5. Endpoint: juvenile production.

Table A3. 5. Chronic toxicity of vanadium to soil organisms.

Species	Species properties (age, sex)	Soil type	A	Purity [%]	Test compound	pH	o.m. [%]	Clay [%]	T [°C]	Exp. time	Criterion	Test endpoint	Result test soil [mg/kg_{dw}]	Notes	Reference
Macrophyta															
Brassica oleracea	seeds	sand	Y		$VOSO_4$	6.5	1.1	6	22-33	98 d	EC10	growth	62	1	Kaplan et al., 1990
Glycine max	seed		Y		NH_4VO_3	8.2	0.72	20		45 d	EC10	growth	25	2	Wang and Liu, 1999

Notes
1. EC10 calculated by fitting a logistic dose response model through data reported by author; based on nominal added V concentrations.
2. Soil is called "Fluvo-aquic soil". Cb = 66.7 mg V/kg, extractable was 0.46 mg V/kg. Data presented in a graph were plotted as a dose-response relationship. The EC10 was determined after fitting a logistic through the data using nonlinear regression. Growth measured as dry weight yield of plant shoots.

Table A3. 6. Chronic toxicity of cobalt to soil organisms.

Species	Species properties (age, sex)	Soil type	A	Purity [%]	Test compound	pH	o.m. [%]	Clay [%]	T [°C]	Exp. time	Criterion	Test endpoint	Result [mg/kg_{dw}]	Notes	Reference
Macrophyta															
Hordeum vulgare	seed	sand	Y		$CoCl_2$	6.3	0.1	3.2	22	18 d	EC10	weight	55	1	TN&Associates Inc., 2000
Hordeum vulgare	seed	sand; artificial	Y		$CoCl_2$	5.0	5	10	22	18 d	EC10	weight	22	1	TN&Associates Inc., 2000
Medicago sativa	seed	sand	Y		$CoCl_2$	6.3	0.1	3.2	22	22 d	EC10	weight	5.6	1	TN&Associates Inc., 2000
Medicago sativa	seed	sand; artificial	Y		$CoCl_2$	5.0	5	10	22	22 d	EC10	weight	2.6	1	TN&Associates Inc., 2000
Raphanus sativus	seed	sand	Y		$CoCl_2$	6.3	0.1	3.2	22	18 d	EC10	weight	35	1	TN&Associates Inc., 2000
Raphanus sativus	seed	sand; artificial	Y		$CoCl_2$	5.0	5	10	22	18 d	EC10	weight	10	1	TN&Associates Inc., 2000
Annelida															
Eisenia fetida		manure+soil			$CoCl_2$		63	5	25	24 wk	NOEC	growth	92	2	Neuhauser et al., 1984
Eisenia fetida		manure+soil			$CoCl_2$		63	5	25	24 wk	NOEC	reproduction	92	2	Neuhauser et al., 1984

Notes
1. EC10 calculated using raw data, based on nominal concentrations.
2. Test compound added to horse manure of which 50 g was mixed with 100 g soil in the test.

Table A3. 7. Chronic toxicity of selenium to soil organisms.

Species	Species properties (age, sex)	Soil type	A	Purity [%]	Test compound	pH	o.m. [%]	Clay [%]	T [°C]	Exp. time	Criterion	Test endpoint	Result test soil [mg/kg$_{dw}$]	Notes	Reference
Macrophyta															
Brassica rapa	seed	sand	Y		Na_2SeO_4	6.3	0.1	3.2	21.4	22 d	EC10	weight	1.0	1	TN&Associates Inc., 2000
Brassica rapa	seed	aritificial; sand	Y		Na_2SeO_4	5.0	5.0	10	21.4	22 d	EC10	weight	2.2	1	TN&Associates Inc., 2000
Helianthus annuus	seedling	sand	N	ag	Na_2SeO_3	7.9	0.2			30 d	EC10	growth	5.0	2,3	Singh and Singh, 1978
Hordeum vulgare	seed	aritificial; sand	Y		Na_2SeO_4	5.0	5.0	10	21.4	19 d	EC10	weight	2.0	1	TN&Associates Inc., 2000
Medicago sativa	seed	aritificial; sand	Y		Na_2SeO_4	5.0	5.0	10	21.4	22 d	EC10	weight	2.3	1	TN&Associates Inc., 2000
Medicago sativa	seedling	sandy clay loam	Y		Na_2SeO_4	6.8	0.9	23			EC10	growth	3.0	4	Wan et al., 1988
Medicago sativa	seedling	sandy clay loam	Y		Na_2SeO_4	5.6	1.3	25			EC10	growth	1.0	5	Wan et al., 1988
Medicago sativa	seedling	sandy loam	Y		Na_2SeO_4	6.7	1.1	17			EC10	growth	0.31	6	Wan et al., 1988
Medicago sativa	seedling	sandy loam	Y		Na_2SeO_4	6.9	1.1	37			EC10	growth	0.59	7	Wan et al., 1988
Medicago sativa	seed	silty clay loam	Y		Na_2SeO_4	7.8	3.1				EC10	growth	1.4	8	Soltanpour and Workman, 1980
Medicago sativa	seed	silty clay loam	Y		Na_2SeO_4	7.7	3.7				EC10	growth	1.6	8	Soltanpour and Workman, 1980
Medicago sativa	seed	silty clay loam	Y		Na_2SeO_4	7.6	5.0				EC10	growth	2.0	9	Soltanpour and Workman, 1980
Medicago sativa	seed	silty clay loam	Y		Na_2SeO_4	7.0	6.3				EC10	growth	2.2	10	Soltanpour and Workman, 1980
Medicago sativa	seed	silty clay loam	Y		Na_2SeO_4	6.9	6.5				EC10	growth	1.8	11	Soltanpour and Workman, 1980
Sorghum vulgare	seed	sand	Y		Na_2SeO_4	4.9	11	1.9		42 d	EC10	biomass	0.29	2,12	Carlson et al., 1991
Sorghum vulgare	seed	sand	Y		Na_2SeO_4	6.5	11	1.9		42 d	EC10	biomass	0.37	2,13	Carlson et al., 1991
Sorghum vulgare	seed	sand	Y		Na_2SeO_4	5.5	18.5	4.7		42 d	EC10	biomass	0.45	2,12	Carlson et al., 1991
Sorghum vulgare	seed	sand	Y		Na_2SeO_4	6.0	18.5	4.7		42 d	EC10	biomass	0.40	2,13	Carlson et al., 1991
Sorghum vulgare	seed	sand	Y		Na_2SeO_3	4.9	11	1.9		42 d	NOEC	biomass	1	2,12	Carlson et al., 1991
Sorghum vulgare	seed	sand	Y		Na_2SeO_3	6.5	11	1.9		42 d	EC10	biomass	3.62	2,13	Carlson et al., 1991
Sorghum vulgare	seed	sand	Y		Na_2SeO_3	6.0	18.5	4.7		42 d	EC10	biomass	0.83	2,12	Carlson et al., 1991
Triticum aestivum	seed	sand	N	ag	Na_2SeO_3	7.9	0.2			135 d	EC10	growth	3.1	2,14	Singh and Singh, 1978

Notes
1. EC10 calculated using raw data, based on nominal concentrations.
2. EC10 calculated by fitting a logistic dose response model through data reported by author.
3. EC10 calculated by fitting a logistic dose response model through data reported by author.
4. Growth measured as dry weight yield. Only data from 1 st harvest were used to plot dose-effect relationships. Cb = 1.04 mg Se/kg.
5. Growth measured as dry weight yield. Only data from 1 st harvest were used to plot dose-effect relationships. Cb = 1.83 mg Se/kg.
6. Growth measured as dry weight yield. Only data from 1 st harvest were used to plot dose-effect relationships. Cb = 1.29 mg Se/kg.
7. Growth measured as dry weight yield. Only data from 1 st harvest were used to plot dose-effect relationships. Cb = 0.93 mg Se/kg.
8. Test duration not reported, but initiated with seeds, and ended at bloom stage of alfalfa plants; i.e. major part of life cycle. Soil nr. D. Growth measured as dry weight yield of whole plant. Dose-effect relationships were fitted through data reported in the article using non-linear regression and logistic model.
9. Test duration not reported, but initiated with seeds, and ended at bloom stage of alfalfa plants; i.e. major part of life cycle. Soil nr. C. Growth measured as dry weight yield of whole plant. Dose-effect relationships were fitted through data reported in the article using non-linear regression and logistic model.

10. Test duration not reported, but initiated with seeds, and ended at bloom stage of alfalfa plants; i.e. major part of life cycle. Soil nr. B. Growth measured as dry weight yield of whole plant. Dose-effect relationships were fitted through data reported in the article using non-linear regression and logistic model.
11. Test duration not reported, but initiated with seeds, and ended at bloom stage of alfalfa plants; i.e. major part of life cycle. Soil nr. A. Growth measured as dry weight yield of whole plant. Dose-effect relationships were fitted through data reported in the article using non-linear regression and logistic model.
12. Unlimed soil.
13. Limed soil.
14. EC10 was determined by fitting a logistic dose-response relationship through reported data; soil was amended with N, Zn, Fe, Mn, Cu and S. Three P treatments were employed, growth was optimal at 50 ppm P. Se data from the 50 ppm P treatment were used to determine the EC10. Test was started with seed and terminated at maturation. Growth expressed as dry matter yield of plant.

Table A3. 8. Chronic toxicity of antimony to soil organisms.

Species	Species properties (age, sex)	Soil type	A	Purity [%]	Test compound	pH	o.m. [%]	Clay [%]	T [°C]	Exp. time	Criterion	Test endpoint	Result test soil [mg/kg_{dw}]	Notes	Reference
Macrophyta															
Oryza sativa	seedling	loam	N		$K_2(C_4H_2O_6Sb)_2$	6.8	4.3			98 d	EC10	biomass growth:	56		He and Yang, 1999
Oryza sativa	seedling	loam	N		$K_2(C_4H_2O_6Sb)_2$	6.8	4.3			98 d	EC10	height	658		He and Yang, 1999
Annelida															
Eisenia fetida	ad. 0.3-0.6 g	sandy loam	Y	97	$Sb_2(SO_4)_3$	5.0	1.2	11	22	21 d	NOEC	mortality	617	1	Simini et al., 2002
Eisenia fetida	ad. 0.3-0.6 g	sandy loam	Y	97	$Sb_2(SO_4)_3$	5.0	1.2	11	22	21 d	EC10	reproduction	17	1,2,3	Simini et al., 2002
Enchytraeus crypticus	ad	sandy loam	Y	97	$Sb_2(SO_4)_3$	5.0	1.2	11	21	14 d	NOEC	mortality	384	1	Kuperman et al., 2002
Enchytraeus crypticus	ad	sandy loam	Y	97	$Sb_2(SO_4)_3$	5.0	1.2	11	21	28 d	EC10	reproduction	141	1,2,4	Kuperman et al., 2002
Insecta															
Folsomia candida	juv. 10-12 d.	sandy loam	Y	97	$Sb_2(SO_4)_3$	5.0	1.2	11	20	28 d	NOEC	mortality	100	1	Phillips et al., 2002
Folsomia candida	juv. 10-12 d.	sandy loam	Y	97	$Sb_2(SO_4)_3$	5.0	1.2	11	20	28 d	EC10	reproduction	49	1,2,4	Phillips et al., 2002

Notes
1. Results based on nominal concentrations.
2. EC10 calculated from logistic (Gompertz) regression equation and parameters, both provided in the study report.
3. Endpoint: number of cocoons.
4. Endpoint: juvenile production

Table A3. 9. Chronic toxicity of barium to soil organisms.

Species	Species properties (age, sex)	Soil type	A	Purity [%]	Test compound	pH	o.m. [%]	Clay [%]	T [°C]	Exp. time	Criterion	Test endpoint	Result test soil [mg/kg$_{dw}$]	Notes	Reference
Annelida															
Eisenia fetida	ad. 0.3-0.6 g	sandy loam	Y	97	$BaSO_4$	5.0	1.2	11	22	21 d	NOEC	mortality	1348		Simini et al., 2002
Eisenia fetida	ad. 0.3-0.6 g	sandy loam	Y	97	$BaSO_4$	5.0	1.2	11	22	21 d	EC10	reproduction	250	1,2	Simini et al., 2002
Enchytraeus crypticus	ad	sandy loam	Y	97	$BaSO_4$	5.0	1.2	11	21	14 d	NOEC	mortality	1798		Kuperman et al., 2002
Enchytraeus crypticus	ad	sandy loam	Y	97	$BaSO_4$	5.0	1.2	11	21	28 d	EC10	reproduction	425	1,3	Kuperman et al., 2002
Insecta															
Folsomia candida	juv. 10-12 d.	sandy loam	Y	97	$BaSO_4$	5.0	1.2	11	20	28 d	NOEC	mortality	375		Phillips et al., 2002
Folsomia candida	juv. 10-12 d.	sandy loam	Y	97	$BaSO_4$	5.0	1.2	11	20	28 d	EC10	reproduction	82	1,3	Phillips et al., 2002

Notes
1. EC10 calculated from logistic (Gompertz) regression equation and parameters, both provided in the study report.
2. Endpoint: number of cocoons.
3. Endpoint: juvenile production

Table A3. 10. Chronic toxicity of thallium to soil organisms.

Species	Species properties (age, sex)	Soil type	A	Purity [%]	Test compound	pH	o.m. [%]	Clay [%]	T [°C]	Exp. time	Criterion	Test endpoint	Result test soil [mg/kg_{dw}]	Notes	Reference
Macrophyta															
Lepidium sativum	seed	OECD			Tl_2CO_3	6	10	20	20	7 d	NOEC	growth (root)	10		Heim et al., 2002
Lepidium sativum	seed	OECD			Tl_2CO_3	6	10	20	20	7 d	NOEC	growth (shoot)	1		Heim et al., 2002
Mollusca															
Arianta arbustorum	hatching	OECD			Tl_2CO_3	6	10	20		28 d	NOEC	growth	10		Heim et al., 2002
Arianta arbustorum	hatching	OECD			Tl_2CO_3	6	10	20		28 d	NOEC	hatchability	1	1	Heim et al., 2002
Arianta arbustorum	hatching	OECD			Tl_2CO_3	6	10	20		28 d	NOEC	hatchability	1		Heim et al., 2002
Annelida															
Eisenia fetida	mature	OECD			Tl_2CO_3	6	10	20		28 d	NOEC	biomass	50		Heim et al., 2002
Eisenia fetida	mature	OECD			Tl_2CO_3	6	10	20		28 d	NOEC	mortality	100		Heim et al., 2002
Eisenia fetida	mature	OECD			Tl_2CO_3	6	10	20		56 d	NOEC	reproduction	1	2	Heim et al., 2002
Eisenia fetida	mature	OECD			Tl_2CO_3	6	10	20		56 d	NOEC	reproduction	10	3	Heim et al., 2002

Notes
1. Growth is shoot growth.
2. Endpoint is number of juveniles.
3. Endpoint is number of cocoons.

Table A3. 11. Toxicity of beryllium to soil microbial processes and enzyme activity.

Process/Activity	Soil type	A	Purity [%]	Test compound	pH	o.m. [%]	Clay [%]	Temp [°C]	Exp. time	Criterion	Test endpoint	Result [mg/kg$_{dw}$]	Notes	Reference
Microbial processes														
soil respiration	sandy loam	N		$BeSO_4$	8.2	4.7	11	20	9 d	EC10	inhibition	4.3	1	Lighthart et al., 1983
soil respiration	silt loam	N		$BeSO_4$	6.7	3.1	27	20	9 d	EC10	inhibition	6.0	1	Lighthart et al., 1983
soil respiration	clay	N		$BeSO_4$	7.0	5.5	51	20	9 d	EC10	inhibition	12	1	Lighthart et al., 1983
soil respiration		N		$BeSO_4$	6.2	64		20	9 d	EC10	inhibition	122	1	Lighthart et al., 1983
nitrification	sandy cambisoil	Y		Be_2SO_4	6.0	2.0	9		8-9 y	NOEC	inhibition	30	2	Wilke, 1989
nitrification	sandy cambisoil	Y		$BeSO_4$	6.0	2.0	9		8-9 y	NOEC	stimulation	80	2	Wilke, 1989

Notes
1. EC10 calculated by fitting a logistic dose response model through data reported by author.
2. NOEC is set equal to LOEC (=10% effect); field experiment.

Table A3. 12. Toxicity of vanadium to soil microbial processes and enzyme activity.

Process/Activity	Soil type	A	Purity [%]	Test compound	pH	o.m. [%]	Clay [%]	Temp [°C]	Exp. time	Criterion	Test endpoint	Result test soil [mg/kg$_{dw}$]	Notes	Reference
Microbial processes														
soil respiration	sandy loam	N		$VOSO_4$	8.2	4.7	11	20	9 d	EC10	stimulation	21	1	Lighthart et al., 1983
soil respiration	silt loam	N		$VOSO_4$	7.2	1.7	21	20	9 d	EC10	inhibition	1.6	1	Lighthart et al., 1983
soil respiration	silt loam	N		$VOSO_4$	6.7	3.1	27	20	9 d	EC10	inhibition	16	1	Lighthart et al., 1983
soil respiration	clay	N		$VOSO_4$	7.0	5.5	51	20	9 d	EC10	inhibition	1151	1	Lighthart et al., 1983
N-mineralisation	loam	N	rg		5.8	4.4	23	30	20 d	NOEC	inhibition	255	2,3	Liang and Tabatabai, 1977
N-mineralisation	clay	N	rg		6.6	5.0	45	30	20 d	NOEC	inhibition	127	3,4	Liang and Tabatabai, 1977
N-mineralisation	clay loam	N	rg		7.8	6.4	30	30	20 d	NOEC	inhibition	127	3,4	Liang and Tabatabai, 1977
N-mineralisation	silty clay	N	rg		7.4	9.3	34	30	20 d	NOEC	inhibition	127	3,4	Liang and Tabatabai, 1977
N-mineralisation	sandy cambisol	Y		V^{2+}	6.0	2.0	9	field	8-9 y	NOEC	inhibition	400	2,5	Wilke, 1989
nitrification	clay loam	N	rg		7.8	6.4	30	30	10 d	NOEC	inhibition	127	3,4	Liang and Tabatabai, 1978
nitrification	sandy cambisol	Y		V^{+}	6.0	2.0	9	field	8-9 y	NOEC	stimulation	100	2,5	Wilke, 1989
nitrification	sandy cambisol	Y		V^{2+}	6.0	2.0	9	field	8-9 y	NOEC	stimulation	200	4,5	Wilke, 1989
Enzymatic activity														
urease	clay loam	N	rg	$VOSO_4$	6.1	5.6	30	37	0.5 h	NOEC	inhibition	127	4	Tabatabai, 1977
urease	loam	N	rg	$VOSO_4$	5.8	4.4	23	37	0.5 h	NOEC	inhibition	127	4	Tabatabai, 1977
urease	clay loam	N	rg	$VOSO_4$	7.8	6.4	30	37	0.5 h	NOEC	inhibition	127	4	Tabatabai, 1977
urease	clay loam	N	rg	$VOSO_4$	7.8	6.4	30	37	0.5 h	NOEC	inhibition	25	2	Tabatabai, 1977
urease	silty clay	N	rg	$VOSO_4$	6.8	7.4	42	37	0.5 h	NOEC	inhibition	127	4	Tabatabai, 1977
urease	silty clay loam	N	rg	$VOSO_4$	7.4	9.3	34	37	0.5 h	NOEC	inhibition	13	4	Tabatabai, 1977

Notes
1. WHC 70%; 4 test concentrations: 0.05-50 mmol/kg; EC10 calculated from logistic dose response model fitted through data presented by author.
2. NOEC is set equal to LOEC (=10% effect)
3. WHC approx. 60%.
4. NOEC calculated as LOEC/2
5. Field study.

Table A3. 13. Toxicity of cobalt to soil microbial processes and enzyme activity.

Process/Activity	Soil type	A	Purity [%]	Test compound	pH	o.m. [%]	Clay [%]	Temp [°C]	Exp. time	Criterion	Test endpoint	Result test soil [mg/kg$_{dw}$]	Notes	Reference
Microbial processes														
soil respiration	sandy loam	N		$CoSO_4$	8.2	4.7	11	20	9 d	EC10	inhibition	2.3	1	Lighthart et al., 1983
soil respiration	silt loam	N		$CoSO_4$	7.2	1.7	21	20	9 d	EC10	inhibition	15	1	Lighthart et al., 1983
soil respiration	clay	N		$CoSO_4$	7.0	5.5	51	20	9 d	EC10	inhibition	36	1	Lighthart et al., 1983
soil respiration		N		$CoSO_4$	6.2	64		20	9 d	EC10	inhibition	267	1	Lighthart et al., 1983
N-mineralisation	loam	N	rg	$CoSO_4$	5.8	4.4	23	30	20 d	NOEC	inhibition	147	2	Liang and Tabatabai, 1977
N-mineralisation	clay	N	rg	$CoSO_4$	6.6	5.0	45	30	20 d	NOEC	inhibition	295	3	Liang and Tabatabai, 1977
N-mineralisation	clay loam	N	rg	$CoSO_4$	7.8	6.4	30	30	20 d	NOEC	inhibition	295	3	Liang and Tabatabai, 1977
N-mineralisation	silty clay	N	rg	$CoSO_4$	7.4	9.3	34	30	20 d	NOEC	inhibition	295	3	Liang and Tabatabai, 1977
Enzymatic activity														
acid phosphatase	clay loam	N	rg	$CoSO_4$	7.8	6.4	30	37	0.5 h	NOEC	inhibition	1473	3	Juma and Tabatabai, 1977
acid phosphatase	silty clay loam	N	rg	$CoSO_4$	7.4	9.3	34	37	0.5 h	NOEC	inhibition	1473	3	Juma and Tabatabai, 1977
acid phosphatase	loam	N	rg	$CoSO_4$	5.8	4.4	23	37	0.5 h	NOEC	inhibition	1473	3	Juma and Tabatabai, 1977
acid phosphatase	loam	N	rg	$CoSO_4$	5.8	4.4	23	37	0.5 h	NOEC	inhibition	147	3	Juma and Tabatabai, 1977
alkaline phosphatase	clay loam	N	rg	$CoSO_4$	7.8	6.4	30	37	0.5 h	NOEC	inhibition	737	2	Juma and Tabatabai, 1977
alkaline phosphatase	silty clay loam	N	rg	$CoSO_4$	7.4	9.3	34	37	0.5 h	NOEC	inhibition	1473	3	Juma and Tabatabai, 1977
alkaline phosphatase	silty clay loam	N	rg	$CoSO_4$	7.4	9.3	34	37	0.5 h	NOEC	inhibition	147	3	Juma and Tabatabai, 1977
arylsulfatase	clay loam	N	rg	$CoSO_4$	6.2	4.6	29	37	1 h	NOEC	inhibition	1473	3	Al-Khafaji and Tabatabai, 1979
arylsulfatase	clay loam	N	rg	$CoSO_4$	7.6	5.5	30	37	1 h	NOEC	inhibition	737	2	Al-Khafaji and Tabatabai, 1979
arylsulfatase	clay loam	N	rg	$CoSO_4$	7.6	5.5	30	37	1 h	NOEC	inhibition	74	2	Al-Khafaji and Tabatabai, 1979
arylsulfatase	loam	N	rg	$CoSO_4$	6.5	5.0	26	37	1 h	NOEC	inhibition	1473	3	Al-Khafaji and Tabatabai, 1979
arylsulfatase	loam	N	rg	$CoSO_4$	6.5	5.0	26	37	1 h	NOEC	inhibition	147	3	Al-Khafaji and Tabatabai, 1979
arylsulfatase	clay loam	N	rg	$CoSO_4$	7.0	9.0	34	37	1 h	NOEC	inhibition	1473	3	Al-Khafaji and Tabatabai, 1979
dehydrogenase	silt loam (loess)	Y		$CoCl_2$	7.0	1.9	15.2	21	24 h	EC10	inhibition	57		Welp, 1999
urease	clay loam	N	rg	$CoCl_2$	6.1	5.6	30	37	0.5 h	NOEC	inhibition	147	2	Tabatabai, 1977
urease	clay loam	N	rg	$CoCl_2$	7.8	6.4	30	37	0.5 h	NOEC	inhibition	16	2	Tabatabai, 1977

Notes
1. WHC=70%; 4 test concentrations: 0.05-50.0 mmol/kg; EC10 calculated from logistic dose response model fitted through data presented by author.
2. NOEC calculated as LOEC/2
3. NOEC is set equal to LOEC (=10% effect)

Table A3. 14. Toxicity of selenium to soil microbial processes and enzyme activity.

Process/Activity	Soil type	A	Purity [%]	Test compound	pH	o.m. [%]	Clay [%]	Temp [°C]	Exp. time	Criterion	Test endpoint	Result test soil [mg/kg$_{dw}$]	Notes	Reference
Microbial processes														
ammonification	mor Aeh			Na_2SeO_3	2.7	3.4		26	14 d	NOEC	inhibition	250	1,3	Wilke, 1988
soil respiration	mull Ah			Na_2SeO_3	7.9	7		26	14 d	NOEC	inhibition	125	1,3	Wilke, 1988
soil respiration	mull Ah			Na_2SeO_3	7.9	7		26	14 d	NOEC	inhibition	500	1,3	Wilke, 1988
soil respiration	mor Aeh			Na_2SeO_3	2.7	3.4		26	14 d	NOEC	stimulation	25	2,3	Wilke, 1988
soil respiration	mor Aeh			Na_2SeO_3	2.7	3.4		26	14 d	NOEC	inhibition	250	1,3	Wilke, 1988
soil respiration	silt loam	N		SeO_2	7.2	1.7	21	20	9 d	EC10	inhibition	20	4	Lighthart et al., 1983
soil respiration	silt loam	N		SeO_2	6.7	3.1	27	20	9 d	EC10	inhibition	200	4	Lighthart et al., 1983
soil respiration	clay	N		SeO_2	7	5.5	51	20	9 d	EC10	inhibition	96	4	Lighthart et al., 1983
soil respiration		N		SeO_2	6.2	64		20	9 d	EC10	inhibition	899	4	Lighthart et al., 1983
N-mineralisation	loam	N	rg	H_2SeO_3	5.8	4.4	23	30	20 d	NOEC	inhibition	395	1,5	Liang and Tabatabai, 1977
N-mineralisation	clay	N	rg	H_2SeO_3	6.6	5.0	45	30	20 d	NOEC	inhibition	395	1,5	Liang and Tabatabai, 1977
N-mineralisation	clay loam	N	rg	H_2SeO_3	7.8	6.4	30	30	20 d	NOEC	inhibition	395	1,5	Liang and Tabatabai, 1977
N-mineralisation	silty clay	N	rg	H_2SeO_3	7.4	9.3	34	30	20 d	NOEC	inhibition	395	1,5	Liang and Tabatabai, 1977
nitrification	sandy cambisol	Y		Se^{2+}	6.0	2.0	9	field	8-9 y	NOEC	stimulation	20	2	Wilke, 1989
nitrification	mull Ah	N		Na_2SeO_3	7.9	7.0		26	14 d	NOEC	stimulation	125	3	Wilke, 1988
nitrification	mor Aeh	N		Na_2SeO_3	2.7	3.4		26	14 d	NOEC	stimulation	50	3	Wilke, 1988
Enzymatic activity														
acid phosphatase	loam	N	rg	H_2SeO_3	5.8	4.4	23	37	0.5 h	NOEC	inhibition	99	2	Juma and Tabatabai, 1977
alkaline phosphatase	silty clay loam	N	rg	H_2SeO_3	7.4	9.3	34	37	0.5 h	NOEC	inhibition	99	2	Juma and Tabatabai, 1977
alkaline phosphatase	mull Ah	N		Na2SeO3	7.9	7.0		26	14 d	NOEC	inhibition	500	2,3	Wilke, 1988
alkaline phosphatase	moder Ah	N		Na_2SeO_3	3.5	5.4		26	14 d	NOEC	stimulation	50	1,3	Wilke, 1988
alkaline phosphatase	moder Ah	N		Na_2SeO_3	3.5	5.4		26	14 d	NOEC	inhibition	250	1,3	Wilke, 1988
alkaline phosphatase	mor Aeh	N		Na_2SeO_3	2.7	3.4		26	14 d	NOEC	inhibition	50	1,3	Wilke, 1988
alkaline phosphatase	mor Aeh	N		Na_2SeO_3	2.7	3.4		26	14 d	NOEC	inhibition	125	2,3	Wilke, 1988
arylsulfatase				H_2SeO_3	7.6	5.5	30	37	1 h	NOEC	inhibition	99	2	Al-Khafaji and Tabatabai, 1979
arylsulfatase	mull Ah	N		Na_2SeO_3	7.9	7.0		26	14 d	NOEC	inhibition	250	3	Wilke, 1988
arylsulfatase	mor Aeh	N		Na_2SeO_3	2.7	3.4		26	14 d	NOEC	inhibition	25	3	Wilke, 1988
arylsulfatase	mor Aeh	N		Na_2SeO_3	2.7	3.4		26	14 d	NOEC	inhibition	25	3	Wilke, 1988
urease	loam	N	rg	H_2SeO_3	5.8	4.4	23	37	0.5 h	NOEC	inhibition	197	2,5	Tabatabai, 1977
urease	clay loam	N	rg	H_2SeO_3	7.8	6.4	30	37	0.5 h	NOEC	inhibition	197	2,5	Tabatabai, 1977
urease	clay loam	N	rg	H_2SeO_3	7.8	6.4	30	37	0.5 h	NOEC	inhibition	39	1,5	Tabatabai, 1977
urease	silty clay	N	rg	H_2SeO_3	6.8	7.4	42	37	0.5 h	NOEC	inhibition	197	2,5	Tabatabai, 1977

Process/Activity	Soil type	A	Purity [%]	Test compound	pH	o.m. [%]	Clay [%]	Temp [°C]	Exp. time	Criterion	Test endpoint	Result test soil [mg/kg_{dw}]	Notes	Reference
urease	silty clay loam	N	rg	H_2SeO_3	7.4	9.3	34	37	0.5 h	NOEC	inhibition	39	1,5	Tabatabai, 1977

Notes
1. NOEC is set equal to LOEC (=10% effect)
2. NOEC calculated as LOEC/2
3. perfusion experiment.
4. WHC 70%; 4 test concentrations: 0.05-50 mmol/kg; EC10 calculated from logistic dose response model fitted through data presented by author.
5. WHC approx. 60%.

Table A3. 15. Toxicity of molybdenum to soil microbial processes and enzyme activity.

Process/Activity	Soil type	A	Purity [%]	Test compound	pH	o.m. [%]	Clay [%]	Temp [°C]	Exp. time	Criterion	Test endpoint	Result test soil [mg/kg_{dw}]	Notes	Reference
Microbial processes														
N-mineralisation	loam	N	rg	H_2MoO_4	5.8	4.4	23	30	20 d	NOEC	inhibition	480	1	Liang and Tabatabai, 1977
Enzymatic activity														
alkaline phosphatase	silty clay loam	N	rg	H_2MoO_4	7.4	9.3	34	37	0.5 h	NOEC	inhibition	120	2	Juma and Tabatabai, 1977
arylsulfatase				H_2MoO_4	7.0	9.0	34	37	1 h	NOEC	inhibition	1199	2	Al-Khafaji and Tabatabai, 1979
urease	silt loam	N	rg	H_2MoO_4	5.1	2.6	17	37	0.5 h	NOEC	inhibition	480	1	Tabatabai, 1977
urease	clay loam	N	rg	H_2MoO_4	6.1	5.6	30	37	0.5 h	NOEC	inhibition	240	2	Tabatabai, 1977
urease	loam	N	rg	H_2MoO_4	5.8	4.4	23	37	0.5 h	NOEC	inhibition	240	2	Tabatabai, 1977
urease	clay loam	N	rg	H_2MoO_4	7.8	6.4	30	37	0.5 h	NOEC	inhibition	240	2	Tabatabai, 1977
urease	clay loam	N	rg	H_2MoO_4	7.8	6.4	30	37	0.5 h	NOEC	inhibition	24	2	Tabatabai, 1977
urease	silty clay	N	rg	H_2MoO_4	6.8	7.4	42	37	0.5 h	NOEC	inhibition	480	1	Tabatabai, 1977
urease	silty clay loam	N	rg	H_2MoO_4	7.4	9.3	34	37	0.5 h	NOEC	inhibition	240	2	Tabatabai, 1977
urease	silty clay loam	N	rg	H_2MoO_4	7.4	9.3	34	37	0.5 h	NOEC	inhibition	48	1	Tabatabai, 1977

Notes
1. NOEC is set equal to LOEC (=10% effect)
2. NOEC calculated as LOEC/2

Table A3. 16. Toxicity of tin to soil microbial processes and enzyme activity.

Process/Activity	Soil type	A	Purity [%]	Test compound	pH	o.m. [%]	Clay [%]	Temp [°C]	Exp. time	Criterion	Test endpoint	Result [mg/kg$_{dw}$]	Notes	Reference
Microbial processes														
soil respiration	sandy loam	N		$SnCl_2$	8.2	4.7	11	20	9 d	EC10	inhibition	6.8	1	Lighthart et al., 1983
soil respiration	silt loam	N		$SnCl_2$	7.2	1.7	21	20	9 d	EC10	inhibition	25	1	Lighthart et al., 1983
soil respiration	clay	N		$SnCl_2$	7.0	5.5	51	20	9 d	EC10	inhibition	760	1	Lighthart et al., 1983
soil respiration		N		$SnCl_2$	6.2	64		20	9 d	EC10	inhibition	667	1	Lighthart et al., 1983
N-mineralisation	loam	N	rg	$SnCl_2$	5.8	4.4	23	30	20 d	NOEC	inhibition	593	2,3	Liang and Tabatabai, 1977
N-mineralisation	clay	N	rg	$SnCl_2$	6.6	5.0	45	30	20 d	NOEC	inhibition	593	2,3	Liang and Tabatabai, 1977
N-mineralisation	clay loam	N	rg	$SnCl_2$	7.8	6.4	30	30	20 d	NOEC	inhibition	297	3,4	Liang and Tabatabai, 1977
N-mineralisation	silty clay	N	rg	$SnCl_2$	7.4	9.3	34	30	20 d	NOEC	inhibition	297	3,4	Liang and Tabatabai, 1977
N-mineralisation	sandy cambisol	Y	rg	$SnSO_4$	6.0	2.0	9	field	8-9 y	NOEC	inhibition	234	2,5	Wilke, 1989
nitrification	silty clay loam	N	rg	$SnCl_2$	7.4	9.3	34	30	10 d	NOEC	inhibition	593	2,5	Liang and Tabatabai, 1978
nitrification	sandy cambisol	Y		Sn_2SO_4	6.0	2.0	9	field	8-9 y	NOEC	stimulation	59	4,5	Wilke, 1989
nitrification	sandy cambisol	Y		$SnSO_4$	6.0	2.0	9	field	8-9 y	NOEC	stimulation	234	4,5	Wilke, 1989
Enzymatic activity														
acid phosphatase	clay loam	N	rg	$SnCl_2$	7.8	6.4	30	37	0.5 h	NOEC	inhibition	1484	4	Juma and Tabatabai, 1977
acid phosphatase	loam	N	rg	$SnCl_2$	5.8	4.4	23	37	0.5 h	NOEC	inhibition	148	4	Juma and Tabatabai, 1977
alkaline phosphatase	silty clay loam	N	rg	$SnCl_2$	7.4	9.3	34	37	0.5 h	NOEC	inhibition	297	2	Juma and Tabatabai, 1977
arylsulfatase				$SnCl_2$	7.6	5.5	30	37	1 h	NOEC	inhibition	1484	4	Al-Khafaji and Tabatabai, 1979
arylsulfatase				$SnCl_2$	7.6	5.5	30	37	1 h	NOEC	inhibition	297	2	Al-Khafaji and Tabatabai, 1979
arylsulfatase				$SnCl_2$	6.5	5.0	26	37	1 h	NOEC	inhibition	297	2	Al-Khafaji and Tabatabai, 1979
urease	clay loam	N	rg	$SnCl_2$	6.1	5.6	30	37	0.5 h	NOEC	inhibition	297	3,4	Tabatabai, 1977
urease	clay loam	N	rg	$SnCl_2$	7.8	6.4	30	37	0.5 h	NOEC	inhibition	297	3,4	Tabatabai, 1977
urease	clay loam	N	rg	$SnCl_2$	7.8	6.4	30	37	0.5 h	NOEC	inhibition	59	2,3	Tabatabai, 1977
urease	silty clay	N	rg	$SnCl_2$	6.8	7.4	42	37	0.5 h	NOEC	inhibition	297	3,4	Tabatabai, 1977
urease	silty clay loam	N	rg	$SnCl_2$	7.4	9.3	34	37	0.5 h	NOEC	inhibition	297	3,4	Tabatabai, 1977
urease	silty clay loam	N	rg	$SnCl_2$	7.4	9.3	34	37	0.5 h	NOEC	inhibition	59	2,3	Tabatabai, 1977

Table A3. 17. Toxicity of barium to soil microbial processes and enzyme activity.

Process/Activity	Soil type	A	Purity [%]	Test compound	pH	o.m. [%]	Clay [%]	Temp [°C]	Exp. time	Criterion	Test endpoint	Result [mg/kg_{dw}]	Notes	Reference
Enzymatic activity														
acid phosphatase	clay loam	N	rg	$BaCl_2$	7.8	6.4	30	37	0.5 h	NOEC	inhibition	3434	1	Juma and Tabatabai, 1977
acid phosphatase	silty clay loam	N	rg	$BaCl_2$	7.4	9.3	34	37	0.5 h	NOEC	inhibition	3434	1	Juma and Tabatabai, 1977
acid phosphatase	loam	N	rg	$BaCl_2$	5.8	4.4	23	37	0.5 h	NOEC	inhibition	3434	1	Juma and Tabatabai, 1977
acid phosphatase	loam	N	rg	$BaCl_2$	5.8	4.4	23	37	0.5 h	NOEC	inhibition	343	1	Juma and Tabatabai, 1977
alkaline phosphatase	clay loam	N	rg	$BaCl_2$	7.8	6.4	30	37	0.5 h	NOEC	inhibition	1717	2	Juma and Tabatabai, 1977
alkaline phosphatase	silty clay loam	N	rg	$BaCl_2$	7.4	9.3	34	37	0.5 h	NOEC	inhibition	3434	1	Juma and Tabatabai, 1977
alkaline phosphatase	silty clay loam	N	rg	$BaCl_2$	7.4	9.3	34	37	0.5 h	NOEC	inhibition	343	1	Juma and Tabatabai, 1977
arylsulfatase	clay loam	N	rg	$BaCl_2$	7.6	5.5	30	37	1 h	NOEC	inhibition	1717	2	Al-Khafaji and Tabatabai, 1979
arylsulfatase	clay loam	N	rg	$BaCl_2$	7.6	5.5	30	37	1 h	NOEC	inhibition	172	2	Al-Khafaji and Tabatabai, 1979
arylsulfatase	loam	N	rg	$BaCl_2$	6.5	5.0	26	37	1 h	NOEC	inhibition	1717	2	Al-Khafaji and Tabatabai, 1979
arylsulfatase	loam	N	rg	$BaCl_2$	6.5	5.0	26	37	1 h	NOEC	inhibition	343	1	Al-Khafaji and Tabatabai, 1979
arylsulfatase	clay loam	N	rg	$BaCl_2$	7.0	9.0	34	37	1 h	NOEC	inhibition	1717	2	Al-Khafaji and Tabatabai, 1979
urease	silt loam	N	rg	$BaCl_2$	5.1	2.6	17	37	0.5 h	NOEC	inhibition	687	1	Tabatabai, 1977
urease	clay loam	N	rg	$BaCl_2$	6.1	5.6	30	37	0.5 h	NOEC	inhibition	687	1	Tabatabai, 1977
urease	loam	N	rg	$BaCl_2$	5.8	4.4	23	37	0.5 h	NOEC	inhibition	343	2	Tabatabai, 1977
urease	clay loam	N	rg	$BaCl_2$	7.8	6.4	30	37	0.5 h	NOEC	inhibition	687	1	Tabatabai, 1977
urease	silty clay	N	rg	$BaCl_2$	6.8	7.4	42	37	0.5 h	NOEC	inhibition	687	1	Tabatabai, 1977
urease	silty clay loam	N	rg	$BaCl_2$	7.4	9.3	34	37	0.5 h	NOEC	inhibition	687	1	Tabatabai, 1977

Notes
1. NOEC is set equal to LOEC (≤ 10% effect)
2. NOEC calculated as LOEC/2

Table A3. 18. Toxicity of beryllium to soil organisms, microbial processes and enzyme activity: data not used.

Process/Activity	Soil type	A	Purity [%]	Test compound	pH	o.m. [%]	Clay [%]	Temp [°C]	Exp. time	Criterion	Test endpoint	Result test soil [mg/kg_{dw}]	Notes	Reference
Microbial processes														
soil respiration	silt loam	N		$BeSO_4$	7.2	1.7	21	20	9 d	EC10	inhibition	0.00054	1	Lighthart et al., 1983
N-mineralisation	sandy cambisoil	Y		Be_2SO_4	6.0	2.0	9		8-9 y	EC43	inhibition	30		Wilke, 1989
N-mineralisation	sandy cambisoil	Y		$BeSO_4$	6.0	2.0	9		8-9 y	EC48	inhibition	80		Wilke, 1989

Notes
1. Result not used since EC10 was more than a factor of 2 below the LOEC.

Table A3. 19. Toxicity of vanadium to soil organisms, microbial processes and enzyme activity: data not used.

Species	Species properties (age, sex)	Soil type	A	Purity [%]	Test compound	pH	o.m. [%]	Clay [%]	T [°C]	Exp. time	Criterion	Test endpoint	Result test soil [mg/kg$_{dw}$]	Notes	Reference
Macrophyta															
Brassica oleracea	seeds	sandy loam	Y		$VOSO_4$	6.5	1.9	4	22-33	98 d	EC10	growth	≥100		Kaplan et al., 1990
Glycine max	Seed		Y		NH_4VO_3	5.8	1.2	32		45 d	EC10	growth	>75	1	Wang and Liu, 1999
Microbial processes															
soil respiration		N	N		$VOSO_4$	6.2	64		20	9 d	EC10	inhibition	>2547	2	Lighthart et al., 1983
nitrification		loam	N	rg		5.8	4.4	23	30	10 d	EC62	inhibition	255		Liang and Tabatabai, 1978
nitrification		silty clay loam	N	rg		7.4	9.3	34	30	10 d	EC38	inhibition	255		Liang and Tabatabai, 1978
Enzymatic activity															
acid phosphatase		clay loam	N	rg		7.8	6.4	30	37	0.5 h	EC45	inhibition	1274		Juma and Tabatabai, 1977
acid phosphatase		silty clay loam	N	rg		7.4	9.3	34	37	0.5 h	EC55	inhibition	1274		Juma and Tabatabai, 1977
acid phosphatase		loam	N	rg		5.8	4.4	23	37	0.5 h	EC49	inhibition	1274		Juma and Tabatabai, 1977
acid phosphatase		loam	N	rg		5.8	4.4	23	37	0.5 h	EC30	inhibition	127		Juma and Tabatabai, 1977
alkaline phosphatase		clay loam	N	rg	$VOSO_4$	7.8	6.4	30	37	0.5 h	EC61	inhibition	1274		Juma and Tabatabai, 1977
alkaline phosphatase		silty clay loam	N	rg	$VOSO_4$	7.4	9.3	34	37	0.5 h	EC60	inhibition	1274		Juma and Tabatabai, 1977
alkaline phosphatase		silty clay loam	N	rg	$VOSO_4$	7.4	9.3	34	37	0.5 h	EC21	inhibition	127		Juma and Tabatabai, 1977
arylsulfatase						6.2	4.6	29	37	1 h	EC87	inhibition	1274		Al-Khafaji and Tabatabai, 1979
arylsulfatase						7.6	5.5	30	37	1 h	EC88	inhibition	1274		Al-Khafaji and Tabatabai, 1979
arylsulfatase						7.6	5.5	30	37	1 h	EC32	inhibition	127		Al-Khafaji and Tabatabai, 1979
arylsulfatase						6.5	5.0	26	37	1 h	EC90	inhibition	1274		Al-Khafaji and Tabatabai, 1979
arylsulfatase						6.5	5.0	26	37	1 h	EC76	inhibition	127		Al-Khafaji and Tabatabai, 1979
arylsulfatase						7.0	9.0	34	37	1 h	EC85	inhibition	1274		Al-Khafaji and Tabatabai, 1979
urease		silt loam	N	rg	$VOSO_4$	5.1	2.6	17	37	0.5 h	EC39	inhibition	255		Tabatabai, 1977
urease		silty clay loam	N		$VOSO_4$	7.4	9.3	34	37	0.5 h	EC28	inhibition	255		Tabatabai, 1977

Notes
1. Soil is called "Red earth soil". Cb = 35 mg V/kg, of which 0.67 mg V/kg was extractable. Data presented in a graph were plotted as a dose-response relationship. The EC10 was determined after fitting a logistic through the data using nonlinear regression.
2. EC10 higher than highest test concentration.

Table A3. 20. Toxicity of cobalt to soil organisms, microbial processes and enzyme activity: data not used.

Process/Activity	Soil type	A	Purity [%]	Test compound	pH	o.m. [%]	Clay [%]	Temp [°C]	Exp. time	Criterion	Test endpoint	Result test soil [mg/kg$_{dw}$]	Notes	Reference
Microbial processes														
soil respiration	silt loam	N		$CoSO_4$	6.7	3.1	27	20	9 d	EC10	inhibition	0.12	1	Lighthart et al., 1983
nitrification	loam	N	rg	$CoSO_4$	5.8	4.4	23	30	10 d	EC79	inhibition	295	2	Liang and Tabatabai, 1978
nitrification	clay loam	N	rg	$CoSO_4$	7.8	6.4	30	30	10 d	EC22	inhibition	295	2	Liang and Tabatabai, 1978
nitrification	silty clay loam	N	rg	$CoSO_4$	7.4	9.3	34	30	10 d	EC34	inhibition	295	2	Liang and Tabatabai, 1978
Enzymatic activity														
acid phosphatase	loam	N	rg	$CoSO_4$	5.8	4.4	23	37	0.5 h	EC0	inhibition	147		Juma and Tabatabai, 1977
urease	silt loam	N	rg	$CoCl_2$	5.1	2.6	17	37	0.5 h	EC22	inhibition	295		Tabatabai, 1977
urease	loam	N	rg	$CoCl_2$	5.8	4.4	23	37	0.5 h	EC23	inhibition	295		Tabatabai, 1977
urease	clay loam	N	rg	$CoCl_2$	7.8	6.4	30	37	0.5 h	EC35	inhibition	295		Tabatabai, 1977
urease	silty clay	N	rg	$CoCl_2$	6.8	7.4	42	37	0.5 h	EC24	inhibition	295		Tabatabai, 1977
urease	silty clay loam	N	rg	$CoCl_2$	7.4	9.3	34	37	0.5 h	EC29	inhibition	295		Tabatabai, 1977
urease	silty clay loam	N	rg	$CoCl_2$	7.4	9.3	34	37	0.5 h	EC22	inhibition	29		Tabatabai, 1977

Notes
1. Result not used since EC10 was more than a factor of 2 below the LOEC. WHC=70%; 4 test concentrations: 0.05-50.0 mmol/kg; EC10/EC50 calculated by fitting a logistic dose response model through data reported by author.
2. WHC approx. 60%.

Table A3. 21. Toxicity of selenium to soil organisms, microbial processes and enzyme activity: data not used.

Species	Species properties (age, sex)	Soil type	A	Purity [%]	Test compound	pH	o.m. [%]	Clay [%]	T [°C]	Exp. time	Criterion	Test endpoint	Result test soil [mg/kg$_{dw}$]	Notes	Reference
Macrophyta															
Hordeum vulgare	seed	sand	Y		Na_2SeO_4	6.3	0.1	3.2	21.4	19 d	EC10	weight	0.013	1	TN&Associates Inc., 2000
Medicago sativa	seed	sand	Y		Na_2SeO_4	6.3	0.1	3.2	21.4	22 d	EC50	weight	<0.25	2	TN&Associates Inc., 2000
Solanum tuberosum	plants	sand	N		H_2SeO_4	6.4			15-25	15 w	NOEC	roots yield	< 0.075	3	Turakainen et al., 2004
Solanum tuberosum	plants	sand	N		H_2SeO_4	6.4			15-25	15 w	NOEC	leaf yield	≥ 0.3	4	Turakainen et al., 2004
Sorghum vulgare	seed	sand	Y		Na_2SeO_3	5.5	18.5	4.7		42 d	NOEC	biomass	≥ 4	5	Carlson et al., 1991
Annelida															
Lumbricus terrestris		sandy top soil			SeO_3		1.7	9.5		60 d	LC50	mortality	>5		Gissel-Nielsen and Gissel-Nielsen, 1975
Microbial processes															
ammonification		moder Ah	N		Na_2SeO_3	3.5	5.4		26	14 d	EC23	stimulation	50		Wilke, 1988
ammonification		moder Ah	N		Na_2SeO_3	3.5	5.4		26	14 d	EC61	stimulation	250		Wilke, 1988
ammonification		mor Aeh	N		Na_2SeO_3	2.7	3.4		26	14 d	EC26	stimulation	50		Wilke, 1988
soil respiration		moder Ah	N		Na_2SeO_3	3.5	5.4		26	14 d	EC22	inhibition	50		Wilke, 1988
soil respiration		moder Ah	N		Na_2SeO_3	3.5	5.4		26	14 d	EC34	inhibition	250		Wilke, 1988
soil respiration		sandy loam	N		SeO_2	8.2	4.7	11	20	9 d	EC10	inhibition	0.0083	6	Lighthart et al., 1983
N-mineralisation		sandy cambisol	Y		Se^{2+}	6.0	2.0	9	field	8-9 y	EC0		40		Wilke, 1989
nitrification		loam	N	rg	H_2SeO_3	5.8	4.4	23	30	10 d	EC94	inhibition	395		Liang and Tabatabai, 1978
nitrification		clay loam	N	rg	H_2SeO_3	7.8	6.4	30	30	10 d	EC90	inhibition	395		Liang and Tabatabai, 1978
nitrification		silty clay loam	N	rg	H_2SeO_3	7.4	9.3	34	30	10 d	EC88	inhibition	395		Liang and Tabatabai, 1978
nitrification		mull Ah	N		Na_2SeO_3	7.9	7.0		26	14 d	NOEC	stimulation	1000		Wilke, 1988
nitrification		moder Ah	N		Na_2SeO_3	3.5	5.4		26	14 d	NOEC	stimulation	50		Wilke, 1988
nitrification		moder Ah	N		Na_2SeO_3	3.5	5.4		26	14 d	EC129	stimulation	250		Wilke, 1988
nitrification		mor Aeh	N		Na_2SeO_3	2.7	3.4		26	14 d	EC0	stimulation	250		Wilke, 1988
Enzymatic activity															
acid phosphatase		clay loam	N	rg	H_2SeO_3	7.8	6.4	30	37	0.5 h	EC39	inhibition	1974		Juma and Tabatabai, 1977
acid phosphatase		silty clay loam	N	rg	H_2SeO_3	7.4	9.3	34	37	0.5 h	EC34	inhibition	1974		Juma and Tabatabai, 1977
acid phosphatase		loam	N	rg	H_2SeO_3	5.8	4.4	23	37	0.5 h	EC24	inhibition	1974		Juma and Tabatabai, 1977
alkaline phosphatase		clay loam	N	rg	H_2SeO_3	7.8	6.4	30	37	0.5 h	EC30	inhibition	1974		Juma and Tabatabai, 1977
alkaline phosphatase		silty clay loam	N	rg	H_2SeO_3	7.4	9.3	34	37	0.5 h	EC35	inhibition	1974		Juma and Tabatabai, 1977
alkaline phosphatase		mull Ah	N		Na_2SeO_3	7.9	7.0		26	14 d	EC0	inhibition	250		Wilke, 1988
arylsulfatase					H_2SeO_3	6.2	4.6	29	37	1 h	EC32	inhibition	1974		Al-Khafaji and Tabatabai, 1979

Species	Species properties (age, sex)	Soil type	A	Purity [%]	Test compound	pH	o.m. [%]	Clay [%]	T [°C]	Exp. time	Criterion	Test endpoint	Result test soil [mg/kg$_{dw}$]	Notes	Reference
arylsulfatase					H_2SeO_3	7.6	5.5	30	37	1 h	EC26	inhibition	1974		Al-Khafaji and Tabatabai, 1979
arylsulfatase					H_2SeO_3	6.5	5.0	26	37	1 h	EC42	inhibition	1974		Al-Khafaji and Tabatabai, 1979
arylsulfatase					H_2SeO_3	6.5	5.0	26	37	1 h	EC21	inhibition	197		Al-Khafaji and Tabatabai, 1979
arylsulfatase					H_2SeO_3	7.0	9.0	34	37	1 h	EC26	inhibition	1974		Al-Khafaji and Tabatabai, 1979
arylsulfatase		mull Ah	N		Na_2SeO_3	7.9	7.0		26	14 d	EC22	inhibition	1000		Wilke, 1988
arylsulfatase		moder Ah	N		Na_2SeO_3	3.5	5.4		26	14 d	EC22	inhibition	50		Wilke, 1988
arylsulfatase		moder Ah	N		Na_2SeO_3	3.5	5.4		26	14 d	EC45	inhibition	250		Wilke, 1988
arylsulfatase		mor Aeh	N		Na_2SeO_3	2.7	3.4		26	14 d	EC64	inhibition	250		Wilke, 1988
dehydrogenase		mull Ah	N		Na_2SeO_3	7.9	7.0		26	14 d	EC31	inhibition	250		Wilke, 1988
dehydrogenase		mull Ah	N		Na_2SeO_3	7.9	7.0		26	14 d	EC66	inhibition	1000		Wilke, 1988
dehydrogenase		moder Ah	N		Na_2SeO_3	3.5	5.4		26	14 d	EC62	inhibition	50		Wilke, 1988
dehydrogenase		moder Ah	N		Na_2SeO_3	3.5	5.4		26	14 d	EC83	inhibition	250		Wilke, 1988
urease		silt loam	N	rg	H_2SeO_3	5.1	2.6	17	37	0.5 h	EC33	inhibition	395		Tabatabai, 1977
urease		clay loam	N	rg	H_2SeO_3	6.1	5.6	30	37	0.5 h	EC24	inhibition	395		Tabatabai, 1977
urease		silty clay loam	N	rg	H_2SeO_3	7.4	9.3	34	37	0.5 h	EC24	inhibition	395		Tabatabai, 1977

Notes
1. EC10/EC50 calculated by fitting a logistic dose response model through raw data reported by author, based on nominal concentrations.
2. Dose-response could not be fitted adequately, EC10 extrapolated a factor of 19 below lowest test concentration.
3. Transient effect after 8 weeks (not dose-related). Selenium applied three times corresponding to a total addition of 0.075, and 0.30 mg Se/kg at one-week intervals .
4. Endpoints: both plant leaf dry weight a 8 weeks exposure and stolon dry weight at 15 weeks.
5. Unlimed soil; EC10 was determined by fitting a logistic dose-response relationship through reported data.
6. WHC 70%; 4 test concentrations: 0.05-50 mmol/kg; EC10 calculated from logistic dose response model fitted through data presented by author. Result not used since EC10 was more than a factor of 2 below the LOEC.

Table A3. 22. Toxicity of molybdenum to soil organisms, microbial processes and enzyme activity: data not used.

Process/Activity	Soil type	A	Purity [%]	Test compound	pH	o.m. [%]	Clay [%]	Temp [°C]	Exp. time	Criterion	Test endpoint	Result test soil [mg/kg$_{dw}$]	Notes	Reference
Microbial processes														
N-mineralisation	clay	N	rg	H_2MoO_4	6.6	5.0	45	30	20 d	EC22	inhibition	480		Liang and Tabatabai, 1977
N-mineralisation	clay loam	N	rg	H_2MoO_4	7.8	6.4	30	30	20 d	EC22	inhibition	480		Liang and Tabatabai, 1977
N-mineralisation	silty clay loam	N	rg	H_2MoO_4	7.4	9.3	34	30	20 d	EC54	inhibition	480		Liang and Tabatabai, 1977
nitrification	loam	N	rg	H_2MoO_4	5.8	4.4	23	30	10 d	EC74	inhibition	480		Liang and Tabatabai, 1978
nitrification	clay loam	N	rg	H_2MoO_4	7.8	6.4	30	30	10 d	EC39	inhibition	480		Liang and Tabatabai, 1978
nitrification	silty clay loam	N	rg	H_2MoO_4	7.4	9.3	34	30	10 d	EC48	inhibition	480		Liang and Tabatabai, 1978
Enzymatic activity														
acid phosphatase	clay loam	N	rg	H_2MoO_4	7.8	6.4	30	37	0.5 h	EC41	inhibition	2399		Juma and Tabatabai, 1977
acid phosphatase	silty clay loam	N	rg	H_2MoO_4	7.4	9.3	34	37	0.5 h	EC68	inhibition	2399		Juma and Tabatabai, 1977
acid phosphatase	loam	N	rg	H_2MoO_4	5.8	4.4	23	37	0.5 h	EC93	inhibition	2399		Juma and Tabatabai, 1977
acid phosphatase	loam	N	rg	H_2MoO_4	5.8	4.4	23	37	0.5 h	EC69	inhibition	240		Juma and Tabatabai, 1977
alkaline phosphatase	clay loam	N	rg	H_2MoO_4	7.8	6.4	30	37	0.5 h	EC25	inhibition	2399		Juma and Tabatabai, 1977
alkaline phosphatase	silty clay loam	N	rg	H_2MoO_4	7.4	9.3	34	37	0.5 h	EC22	inhibition	2399		Juma and Tabatabai, 1977
arylsulfatase				H_2MoO_4	6.2	4.6	29	37	1 h	EC63	inhibition	2399		Al-Khafaji and Tabatabai, 1979
arylsulfatase				H_2MoO_4	7.6	5.5	30	37	1 h	EC60	inhibition	2399		Al-Khafaji and Tabatabai, 1979
arylsulfatase				H_2MoO_4	7.6	5.5	30	37	1 h	EC26	inhibition	240		Al-Khafaji and Tabatabai, 1979
arylsulfatase				H_2MoO_4	6.5	5.0	26	37	1 h	EC79	inhibition	2399		Al-Khafaji and Tabatabai, 1979
arylsulfatase				H_2MoO_4	6.5	5.0	26	37	1 h	EC40	inhibition	240		Al-Khafaji and Tabatabai, 1979
phosphatase	spar-mor			Na_2MoO_4	4.3	93.0	<1	22	3 h	EC79	inhibition	960		Denneman and Van Gestel, 1990a, b
phosphatase	mull			Na_2MoO_4	6.3	13.0	29	22	3 h	EC68	inhibition	960		Denneman and Van Gestel, 1990a, b

Table A3. 23. Toxicity of tin to soil organisms, microbial processes and enzyme activity: data not used.

Process/Activity	Soil type	A	Purity [%]	Test compound	pH	o.m. [%]	Clay [%]	Temp [°C]	Exp. time	Criterion	Test endpoint	Result test soil [mg/kg$_{dw}$]	Notes	Reference
Microbial processes														
soil respiration	silt loam	N		$SnCl_2$	6.7	3.1	27	20	9 d	EC10	inhibition	0.32	1	Lighthart et al., 1983
N-mineralisation	sandy cambisol	Y		Sn_2SO_4	6.0	2.0	9	field	8-9 y	EC0	inhibition	117		Wilke, 1989
nitrification	loam	N	rg	$SnCl_2$	5.8	4.4	23	30	10 d	EC94	inhibition	593		Liang and Tabatabai, 1978
nitrification	clay loam	N	rg	$SnCl_2$	7.8	6.4	30	30	10 d	EC25	inhibition	593		Liang and Tabatabai, 1978
Enzymatic activity														
acid phosphatase	silty clay loam	N	rg	$SnCl_2$	7.4	9.3	34	37	0.5 h	EC21	inhibition	2967		Juma and Tabatabai, 1977
acid phosphatase	loam	N	rg	$SnCl_2$	5.8	4.4	23	37	0.5 h	EC41	inhibition	2967		Juma and Tabatabai, 1977
alkaline phosphatase	clay loam	N	rg	$SnCl_2$	7.8	6.4	30	37	0.5 h	EC25	inhibition	2967		Juma and Tabatabai, 1977
alkaline phosphatase	silty clay loam	N	rg	$SnCl_2$	7.4	9.3	34	37	0.5 h	EC38	inhibition	2967		Juma and Tabatabai, 1977
arylsulfatase				$SnCl_2$	6.2	4.6	29	37	1 h	EC60	inhibition	2967		Al-Khafaji and Tabatabai, 1979
arylsulfatase				$SnCl_2$	6.5	5.0	26	37	1 h	EC45	inhibition	2967		Al-Khafaji and Tabatabai, 1979
arylsulfatase				$SnCl_2$	7.0	9.0	34	37	1 h	EC32	inhibition	2967		Al-Khafaji and Tabatabai, 1979
urease	silt loam	N	rg	$SnCl_2$	5.1	2.6	17	37	0.5 h	EC56	inhibition	593		Tabatabai, 1977
urease	loam	N	rg	$SnCl_2$	5.8	4.4	23	37	0.5 h	EC24	inhibition	593		Tabatabai, 1977

Notes
1. WHC 70%; 4 test concentrations: 0.05-50 mmol/kg; EC10 calculated from logistic dose response model fitted through data presented by author. Result not used since EC10 was more than a factor of 2 below the LOEC.

Table A3. 24. Toxicity of antimony to soil organisms, microbial processes and enzyme activity: data not used.

Species	Species properties (age, sex)	Soil type	A	Purity [%]	Test compound	pH	o.m. [%]	Clay [%]	T [°C]	Exp. time	Criterion	Test endpoint	Result test soil [mg/kg$_{dw}$]	Notes	Reference
Algae															
Chlorococcum infusionum		Cambisol	N		$K_2(C_4H_2O_6Sb)_2$	5.6	2.38			14 d	EC50	chlorophyll	1000	1	Hammel et al.,1998
Chlorococcum infusionum		Cambisol	N		Sb_2S_3	5.6	2.38			14 d	EC50	chlorophyll	1000		Hammel et al.,1998
Chlorococcum infusionum		Cambisol	N		Sb_2S_5	5.6	2.38			14 d	EC50	chlorophyll	1000	1	Hammel et al.,1998
Chlorococcum infusionum		Chernozem	N		$K_2(C_4H_2O_6Sb)_2$	7.3	3.23			14 d	EC50	chlorophyll	1000	2	Hammel et al.,1998
Chlorococcum infusionum		Chernozem	N		Sb_2S_3	7.3	3.23			14 d	EC50	chlorophyll	125	2	Hammel et al.,1998
Chlorococcum infusionum		Chernozem	N		Sb_2S_5	7.3	3.23			14 d	EC50	chlorophyll	314	2	Hammel et al.,1998
Chlorococcum infusionum		Luvisol	N		$K_2(C_4H_2O_6Sb)_2$	7.6	1.87			14 d	EC50	chlorophyll	1000	3	Hammel et al.,1998
Chlorococcum infusionum		Luvisol	N		Sb_2S_3	7.6	1.87			14 d	EC50	chlorophyll	257	3	Hammel et al.,1998
Chlorococcum infusionum		Luvisol	N		Sb_2S_5	7.6	1.87			14 d	EC50	chlorophyll	172	3	Hammel et al.,1998
Macrophyta															
Pinus sylvestris	seedling	loamy sand			$K_2(C_4H_2O_6Sb)_2$	3.3	5			8-10 mo	NOEC	biomass	≥0.3	4	Hartley et al., 1999

Notes
1. pH = pH CaCl2; Total background concentration = "n.n.", meaning unknown
2. pH = pH CaCl2; Total background concentration = 4.0 mg/kg d.w.
3. pH = pH CaCl2; Total background concentration 1.0 mg/kg d.w.
4. Duration was 8, 9 and 10 months, in which no significant effects on seedling growth were observed compared to the control. One treatment.

Table A3. 25. Toxicity of barium to soil organisms, microbial processes and enzyme activity: data not used.

Species	Species properties (age, sex)	Soil type	A	Purity [%]	Test compound	pH	o.m. [%]	Clay [%]	T [°C]	Exp. time	Criterion	Test endpoint	Result test soil [mg/kg_{dw}]	Notes	Reference
Enzymatic activity															
urease		clay loam	N	rg	$BaCl_2$	7.8	6.4	30	37	0.5 h	EC0	inhibition	69		Tabatabai, 1977
urease		silty clay loam	N	rg	$BaCl_2$	7.4	9.3	34	37	0.5 h	EC0	inhibition	69		Tabatabai, 1977
arylsulfatase		clay loam	N	rg	$BaCl_2$	6.2	4.6	29	37	1 h	EC24	inhibition	3434		Al-Khafaji and Tabatabai, 1979

Table A3. 26. Toxicity of thallium to soil organisms, microbial processes and enzyme activity: data not used.

Species	Species properties (age, sex)	Soil type	A	Purity [%]	Test compound	pH	o.m. [%]	Clay [%]	T [°C]	Exp. time	Criterion	Test endpoint	Result test soil [mg/kg$_{dw}$]	Notes	Reference
Macrophyta															
Brassica napus		forest soil			$TlNO_3$	4.8					EC10	growth	262	1	Hoffmann et al., 1982
Brassica napus		forest soil			$TlNO_3$	4.8					EC50	growth	500	1	Hoffmann et al., 1982
Brassica napus		forest soil			$TlNO_3$	4.8					EC10	growth	116	2	Hoffmann et al., 1982
Brassica napus		forest soil			$TlNO_3$	4.8					EC50	growth	237	2	Hoffmann et al., 1982
Lactuca sativa		forest soil			$TlNO_3$	4.8					EC10	growth	1.4	1	Hoffmann et al., 1982
Lactuca sativa		forest soil			$TlNO_3$	4.8					EC50	growth	81	1	Hoffmann et al., 1982

Notes
1. EC10 or EC50 calculated by fitting a logistic dose response model through data reported by author; Valence of Tl not specified; background concentration was 3 mg Tl/kg.
2. EC10 or EC50 calculated by fitting a logistic dose response model through data reported by author; valence of Tl not specified; background concentration was 3 mg Tl/kg; German name: Gruenraps, no Latin name given.

Appendix 4. Aquatic toxicity data used for extrapolation

Contents

Legend to taxonomic groups:

cyan	=	Cyanobacteria
prot	=	Protozoa
alg	=	Algae
bry	=	Bryophyta
macr	=	Macrophyta
fun	=	Fungi
por	=	Porifera
coel	=	Coelenterata
cten	=	Ctenophora
plat	=	Platyhelminthes
nem	=	Nematoda
gast	=	Gastrotricha
rot	=	Rotifera
ect	=	Ectoprocta
moll	=	Mollusca
ann	=	Annelida
chel	=	Chelicerata
crus	=	Crustacea
ins	=	Insecta
ech	=	Echinodermata
cha	=	Chaetognatha
hem	=	Hemichordata
tun	=	Tunicata
ceph	=	Cephalochordata
agn	=	Agnatha
pisc	=	Pisces
amph	=	Amphibia
rep	=	Reptilia
av	=	Aves
mam	=	Mammalia

Table A4. 1. Beryllium; selected data for ERL derivation (combined freshwater and marine for acute data).

taxonomic group	NOEC/EC10 [mg.l^{-1}]	taxonomic group	L(E)C50 [mg.l^{-1}]
bact	0.020	bact	0.0014
cyan	0.430	alg	1.5
prot	0.51	nem	0.14
prot	0.0040	crus, *Daphnia*	7.1[a]
prot	0.017	ann	10
alg	0.030	pisc	6.1
pisc	0.080	pisc	0.16[b]
		pisc	1.9[c]
		pisc	0.12[d]
		pisc	0.081
		pisc	0.19[e]
		amph	3.2[f]
		amph	6.0[g]

[a]geometric mean of 18 and 2.8 mg/l, parameter immobility for *Daphnia magna*.
[b]lowest value (parameter mortality) from four studies with different hardness for *Lebistes reticulatus*.
[c]geometric mean of 6.7 and 0.54 mg/l, parameter mortality for *Leuciscus idus melanotus*.
[d]geometric mean of 0.14 and 0.10 mg/l, parameter mortality for *Rutilus rutilus*.
[e]lowest value (parameter mortality) from two studies with different hardness for *Poecilia reticulata*.
[f]lowest value (parameter mortality) from two studies with different hardness for *Ambystoma opacum*.
[g]lowest value (parameter mortality) from two studies with different hardness for *Ambystoma maculatum*.

Table A4. 2. Vanadium; selected data for ERL derivation, combined freshwater and marine.

taxonomic group	NOEC/EC10 [mg.l^{-1}]	taxonomic group	L(E)C50 [mg.l^{-1}]
alg	0.34	prot	14[b]
alg	0.050	coel	4.5[c]
alg	0.054	moll	0.91
daph	0.24[a]	moll	64
pisc	0.041	ann	31
		ann	11
		crus	12
		crus	1.8[d]
		crus	0.37
		crus	35
		ech	1.1
		pisc	4.0
		pisc	2.5[e]
		pisc	5.0
		pisc	12
		pisc	11
		pisc	2.6
		pisc	3.4[f]

taxonomic group	NOEC/EC10 [mg.l^{-1}]	taxonomic group	L(E)C50 [mg.l^{-1}]
		pisc	17[g]
		pisc	0.37[h]
		pisc	7.9
		pisc	7.0[i]
		pisc	28
		pisc	0.5

[a]geometric mean of 1.9 and 0.03, parameter reproduction for *Daphnia magna*.
[b]geometric mean of 18, 18 and 9 mg/l, parameter growth for *Tetrahymena pyriformis*.
[c]lowest parameter (growth rate) for *Cordylophora caspia*.
[d]lowest value (parameter immobilisation) from two different V compounds for *Daphnia magna*.
[e]lowest value (parameter mortality) from four different V compounds for *Carassius auratus*.
[f]geometric mean of 4.7, 4.8, 2.0, 2.5, 3.8, 3.0, 3.4, 4.6, 3.6, 3.0, 2.5, 2.4, 2.4, 3.7, 5.4, 5.6, 2.9, 4.2 mg/l, parameter mortality for *Oncorhynchus mykiss*.
[g]test result was identical (parameter mortality) for two different tests with the same species.
[h]lowest value (parameter mortality) from different V compounds for *Poecilia reticulata*.
[i]lowest value (parameter mortality) from two different for different life stage of *Salvelinus fontinalis*.

Table A4. 3. Cobalt; selected data for ERL derivation, combined freshwater and marine.

taxonomic group	NOEC/EC10 [mg.l^{-1}]	taxonomic group	L(E)C50 [mg.l^{-1}]
cyan	0.50	bact	1.7[d]
alg	1.0	bact	0.02[e]
alg	0.58	prot	28
alg	0.73	prot	11
alg	1.7	prot	43[f]
alg	2.5	alg	0.52
macr	0.39[a]	alg	95
plat	0.024	alg	24
crus	0.0050	alg	0.30
crus	110	macr	0.24
crus	0.45	macr	0.14
pisc	0.060	plat	2.0[g]
pisc	1.1	nem	1273
pisc	1.6[b]	rot	28
pisc	45	moll	1.7
amph	0.94[c]	ann	133
		ann	211[h]
		ann	179
		crus	8.8
		crus	3.5[i]
		crus	39
		crus	16
		crus	1.3
		crus	2.0[j]

taxonomic group	NOEC/EC10 [mg.l^{-1}]	taxonomic group	L(E)C50 [mg.l^{-1}]
		crus	3.4
		crus	4.0
		crus	10
		crus	10[k]
		crus	4.5
		crus	3.3[l]
		ins	57
		ins	32
		ins	32
		ins	16
		pisc	102
		pisc	333
		pisc	344
		pisc	0.3
		pisc	4.8
		pisc	53
		amph	18
		amph	1.5[m]

[a]geometric mean of 0.47 and 0.33 mg/l, parameter mortality for *Lemna minor*.
[b]geometric mean of 1.2, 1.8 and 1.9 mg/l, parameter mortality for *Pimephales promelas*.
[c]lowest parameter (malformations) for *Xenopus laevis*.
[d]lowest value (luminescence) for *Vibrio fisheri*.
[e]lowest value (luminescence) for *Vibrio harveyi*.
[f]geometric mean of 50, 56, 50 and 24 mg/l, parameter growth for *Tetrahymena pyriformis*.
[g]geometric mean of 1.12 and 3.5 mg/l, parameter mortality (in a 10 d test) for *Dugesia tigrina*.
[h]geometric mean of 239, 180, 240 and 326 mg/l, parameter mortality for *Tubifex tubifex*.
[i]geometric mean of 2.3, 4.6 and 4.2 mg/l, parameter immobilisation for *Ceriodaphnia dubia*.
[j]geometric mean of 1.1, 5.0 and 1.5 mg/l, parameter immobilisation for *Daphnia magna*.
[k]lowest parameter (hatching rate) for *Aremia salina*.
[l]geometric mean of 3.5, 2.5, 2.5, 6.1, 3.6, 3.1, 5.1, 3.1 and 2.4 mg/l, parameter mortality for *Tisbe holothuriae*.
[m]lowest parameter (malformations) for *Xenopus laevis*.

Table A4. 4. Selenium; selected data for ERL derivation, combined freshwater and marine.

taxonomic group	NOEC/EC10 [mg.l^{-1}]	taxonomic group	L(E)C50 [mg.l^{-1}]
bact	11	bact	0.11[n]
cyan	1.0[a]	bact	52
cyan	5.0	bact	12[o]
cyan	9.4	cyan	4.8[p]
cyan	0.079	cyan	6.4[q]
cyan	6.2[b]	cyan	1.1[r]
prot	0.062	prot	52
prot	0.0018	alg	0.80[s]
prot	0.118	alg	0.90[t]
alg	1.0[c]	alg	0.30[u]
alg	6.5[d]	alg	0.56[v]

taxonomic group	NOEC/EC10 [mg.l^{-1}]	taxonomic group	L(E)C50 [mg.l^{-1}]
alg	10	alg	0.08[w]
alg	0.10	alg	1.20[x]
alg	0.19[e]	macr	2.4
alg	1.8[f]	rot	16
alg	7.9	rot	17
alg	0.28[g]	moll	0.26
alg	0.010	moll	2.9
alg	0.0050	moll	1.9
alg	0.0091	crus	0.46[y]
alg	2.5	crus	1.9[z]
alg	0.050	crus	0.25[aa]
alg	0.52	crus	0.07[ab]
alg	0.20	crus	3.1
macr	0.080[h]	crus	1.7[ac]
crus	0.050[i]	crus	0.34[ad]
crus	0.46	crus	4.8
crus	0.025[j]	crus	4.6
crus	0.20	crus	1.0
crus	0.030[k]	crus	6.1
crus	0.044	crus	1.5
crus	0.14	crus	1.2
ins	0.30	crus	36[ae]
pisc	0.010[l]	ins	24[af]
pisc	0.015[m]	ins	52[ag]
pisc	0.47	ins	0.70[ah]
		ins	3.1
		ann	7.7
		pisc	12
		pisc	30[ai]
		pisc	12[aj]
		pisc	2.3
		pisc	15[ak]
		pisc	11
		pisc	7.6[al]
		pisc	13[am]
		pisc	6.5
		pisc	110
		pisc	11
		pisc	7.8[an]
		pisc	1.8[ao]
		pisc	13[ap]
		pisc	16
		pisc	1.0[aq]
		pisc	13[ar]
		pisc	10
		pisc	12
		pisc	34[as]

taxonomic group	NOEC/EC10 [mg.l^{-1}]	taxonomic group	L(E)C50 [mg.l^{-1}]
		pisc	6.4
		pisc	8.9[at]
		pisc	7.4
		pisc	4.4
		pisc	3.1[au]
		pisc	14[av]
		pisc	23[aw]
		pisc	12[ax]
		amph	0.69[ay]

[a]geometric mean of 1.0 and 1.0 mg/l, parameter growth for *Anabaena flos-aquae*.
[b]lowest value (parameter growth) from different Se species for *Agmenellum quadruplicatum*.
[c]lowest value (parameter growth) from different Se species for *Amphidinium carterae*.
[d]lowest value (parameter growth) from different Se species for *Chaetoceros vixvisibilis*.
[e]lowest value (parameter growth) from different Se species for *Dunaliella tertiolecta*.
[f]lowest value (parameter growth) from different Se species for *Isochrysis galbana*.
[g]lowest value (parameter growth) from different Se species for *Pavlova lutheri*.
[h]lowest value (parameter growth as surface coverage) from three different Se species for *Lemna minor*.
[i]lowest value (parameter reproduction) for three different generations for *Ceriodaphnia affinis*.
[j]lowest value (parameter reproduction) from different Se species for *Daphnia magna*.
[k]lowest value (parameter mortality) from different Se species for *Hyalella azteca*.
[l]lowest value (parameter reproduction) from different Se species for *Lepomis macrochirus*
[m]lowest value (parameter mortality) from different Se species for *Oncorhynchus mykiss*.
[n]lowest value (parameter luminescence) from different Se species for *Vibrio fisheri*.
[o]lowest value (parameter growth) from different Se species for *Pseudomonas putida*.
[p]lowest value (parameter biomass) from different Se species for *Anabaena flos-aquae*.
[q]lowest value (parameter biomass) from different Se species for *Mycrocystis aeruginosa*
[r]lowest value (parameter biomass) from different Se species for *Oscillatoria agardhii*.
[s]lowest value (parameter biomass) from different Se species for *Chlorella* sp.
[t]lowest value (parameter biomass) from different Se species for *Monoraphidium contortum*.
[u]lowest value (parameter biomass) from different Se species for *Monoraphidium convolutum*.
[v]lowest value (parameter biomass) from different Se species for *Monoraphidium griffithii*.
[w]lowest value (parameter biomass) from different Se species for *Scenedesmus obliquus*.
[x]lowest value (parameter biomass) from different Se species for *Selenastrum capricornutum*.
[y]geometric mean of 0.60 and 0.35 mg/l for *Ceriodaphnia affinis*.
[z]geometric mean of 1.9 and 2.0 mg/l for *Ceriodaphnia dubia*.
[aa]lowest value from different Se species and life stages for *Daphnia magna*.
[ab]lowest value from different Se species and life stages for *Daphnia pulex*.
[ac]geometric mean of 2.5 and 1.2 mg/l, parameter mortality for *Gammarus pseudolimnaeus*.
[ad]lowest value (parameter mortality) from different Se species for *Hyalella azteca*.
[ae]geometric mean of 39 and 33 mg/l, parameter mortality for *Scylla serrata*.
[af]lowest value (parameter mortality) from different Se species for *Chironomus decorus*.
[ag]geometric mean of 6.7 and 4.1, parameter mortality for *Chironomus riparius*.
[ah]lowest value (parameter immobilisation/mortality) from different Se species for *Chironomus thummi*.
[ai]geometric mean of 31 and 29 mg/l, parameter mortality for *Catostomus commersoni*.
[aj]lowest value (parameter mortality) for *Catostomus latipinnis*.
[ak]lowest value (parameter mortality) from different Se species for *Danio rerio*.

[al]geometric mean of 7.6 and 4.6 mg/l, parameter mortality for *Etroplus maculatus*.
[am]lowest value (parameter mortality) from different Se species for *Gila elegans*.
[an]lowest value (parameter mortality) from different Se species for *Oncorhynchus kisutch*.
[ao]lowest value (parameter mortality) from different Se species for *Oncorhynchus mykiss*.
[ap]lowest value (parameter mortality) from different Se species for *Oncorhynchus tshawytscha*.
[aq]lowest value (parameter mortality) from different Se species for *Pimephales promelas*.
[ar]lowest value (parameter mortality) from different Se species for *Ptychocheilus lucius*.
[as]lowest value (parameter mortality) from different Se species for *Thymallus arcticus*.
[at]lowest value (parameter mortality) from different Se species for *Xyrauchen texanus*.
[au]lowest value (parameter mortality) from geometric mean of 3.4, 3.3, 3.8, 3.9 and 1.6 mg/l, and geometric mean of 26, 24, 26, 29 for two different Se species for *Morone saxatilis*.
[av]lowest value (parameter mortality) from different Se species for *Oncorhynchus kisutch*.
[aw]lowest value (parameter mortality) from different Se species for *Oncorhynchus tshawytscha*.
[ax]owest value (parameter mortality) from different Se species for *Pagrus major*.
[ay]lowest value (parameter mortality) from different Se species for *Xenopus laevis*.

Table A4. 5. Molybdenum; selected data for ERL derivation, combined freshwater and marine.

taxonomic group	NOEC/EC10 [mg.l^{-1}]	taxonomic group	L(E)C50 [mg.l^{-1}]
alg	54	moll	150
		moll	1900
		ann	29
		crus	2700
		crus	1900
		crus	1100
		crus	247
		pisc	1940
		pisc	211
		pisc	1028[a]
		pisc	550
		pisc	2600

[a]geometric mean of 1320 and 800 mg/l, parameter mortality for *Oncorhynchus mykiss*.

Table A4. 6. Tin; selected data for ERL derivation, combined freshwater and marine.

taxonomic group	NOEC/EC10 [mg.l^{-1}]	taxonomic group	L(E)C50 [mg.l^{-1}]
cyan	25	bact	1.6
cyan	0.030	cyan	52
alg	0.053[a]	prot	54[b]
crus	0.18	alg	50
pisc	7.8	alg	12[c]
pisc	0.076	alg	0.21
		alg	0.20
		ann	27[d]
		crus	50
		crus	34[e]
		crus	95
		ins	3.6

taxonomic group	NOEC/EC10 [mg.l^{-1}]	taxonomic group	L(E)C50 [mg.l^{-1}]
		pisc	295

[a]lowest value (parameter growth) from two different Sn species for *Ankistrodesmus falcatus*.
[b]lowest value (parameter growth) from two different Sn species for *Tetrahymena pyriformis*.
[c]lowest value (parameter primary production) from two different Sn species for *Ankistrodesmus falcatus*.
[d]geometric mean of 30, 30, 21 and 27.5 mg/l, parameter mortality/immobilisation for *Tubifex tubifex*.
[e]geometric mean of 22 and 55 mg/l, parameter immobilisation for *Daphnia magna*.

Table A4. 7. Antimony; selected data for SRA_{ECO} derivation[a], only chronic freshwater data shown.

taxonomic group	NOEC/EC10 [mg.l^{-1}]	taxonomic group	L(E)C50 [mg.l^{-1}]
cyan	33		
prot	121		
alg	>2000		
crus	0.80[b]		
pisc	4.8		

[a]The ERLs NC and MPC are not derived for antimony, since an EU-RAR is currently being drafted (see section 1.2.1). Therefore only data used for SRA_{ECO} derivation are shown.
[b]lowest value (parameter reproduction) for *Daphnia magna*.

Table A4. 8. Barium; selected data for ERL derivation, combined freshwater and marine.

taxonomic group	NOEC/EC10 [mg.l^{-1}]	taxonomic group	L(E)C50 [mg.l^{-1}]
cyan	47	bact	13
alg	34	prot	343[d]
bry	44[a]	macr	95
macr	5.8[b]	plat	15
macr	17	nem	385
crus	2.9	rot	372
crus	8.9[c]	moll	0.19
		crus	46
		crus	66[e]
		crus	125[f]
		crus	232[g]
		crus	78
		crus	372
		crus	4738
		pisc	570
		pisc	150

[a]lowest value (parameter growth of branches) for *Scapania undulata*.
[b]geometric mean of 6.2 and 5.5 mg/l, parameter growth for *Lemna minor*.
[c]lowest value (parameter mortality) for *Cancer anthonyi*.
[d]geometric mean of 350, 330 and 350 mg/l, parameter growth for *Tetrahymena pyriformis*.

[e]geometric mean of 170, 15, 110 and 70 mg/l, parameter growth for *Daphnia magna*.
[f]geometric mean of 122 and 129 mg/l, parameter growth for *Echinogammarus berilloni*.
[g]geometric mean of 238 and 227 mg/l, parameter growth for *Gammarus pulex*.

Table A4. 9. Thallium; selected data for ERL derivation, combined freshwater and marine.

taxonomic group	NOEC/EC10 [mg.l^{-1}]	taxonomic group	L(E)C50 [mg.l^{-1}]
alg	0.0048	bact	6.3[c]
macr	0.0076	alg	3.0
crus	0.0016[a]	alg	0.43
pisc	0.030[b]	alg	0.34
		fung	155
		macr	1.4
		nem	123
		rot	7.7
		crus	1.7[d]
		crus	3.8
		crus	0.076[e]
		crus	0.33
		crus	32
		pisc	120
		pisc	140
		pisc	0.86
		pisc	21

[a]lowest parameter (reproduction) for *Hyalella azteca*.
[b]lowest parameter (growth) for *Pimephales promelas*.
[c]lowest value (parameter luminescence) for *Vibrio fisheri*.
[d]geometric mean of 1.6, 0.11, 3.4, 6.5 and 3.3 mg/l, parameter mortality/immobilisation for *Daphnia magna*.
[e]geometric mean of 0.052, 0.086 and 0.10 mg/l, parameter mortality for *Hyalella azteca*.

Appendix 5. Terrestrial toxicity data used for extrapolation

Contents

Legend to taxonomic groups, processes and enzymatic reactions

Taxonomic groups:

macr	=	Macrophyta
moll	=	Mollusca
ann	=	Annelida
ins	=	Insecta
proc	=	microbial processes
enz	=	enzyme reactions

Table A5. 1. Beryllium; selected terrestrial data for ERL derivation.

taxonomic group	NOEC/EC10 [mg.kg^{-1}]	taxonomic group	L(E)C50 [mg.kg^{-1}]
macr	113		
macr	318		
macr	166		
macr	58[a]		
ann	45[b]		
ann	42[c]		
ins	18[d]		
proc	4.3[e]		
proc	30[f]		

[a]lowest value (parameter growth) for *T. repens*.
[b]lowest value (parameter reproduction) for *E. fetida*.
[c]lowest value (parameter reproduction) for *E. crypticus*.
[d]lowest value (parameter mortality) for *F. candida*.
[e]lowest value for inhibition of soil respiration in silt loam soil.
[f]lowest value for inhibition of nitrification in silt loam soil.

Table A5. 2. Vanadium; selected terrestrial data for ERL derivation.

taxonomic group	NOEC/EC10 [mg.kg^{-1}]	taxonomic group	L(E)C50 [mg.kg^{-1}]
macr	62	macr	250
macr	25	macr	570
proc	1.6[a]	ann	370
proc	127[b]		
proc	100[c]		
enz	13[d]		

[a]lowest value for inhibition of soil respiration in silt loam soil.
[b]lowest value for inhibition of N-mineralisation in several soils.
[c]lowest value for stimulation of soil nitrification in sandy (field) soil.
[d]lowest value for inhibition of urease activity in silty clay loam soil.

Table A5. 3. Cobalt; selected terrestrial data for ERL derivation.

taxonomic group	NOEC/EC10 [mg.kg^{-1}]	taxonomic group	L(E)C50 [mg.kg^{-1}]
macr	22[a]		
macr	2.6[b]		
macr	10[c]		
ann	92[d]		
proc	2.3[e]		
proc	147[f]		
enz	466[g]		
enz	466[h]		
enz	233[i]		
enz	57		
enz	16[j]		

[a]lowest value (parameter growth (as weight)) for *H. vulgare* in two soils.

[b]lowest value (parameter growth (as weight)) for *M. sativa* in two soils.
[c]lowest value (parameter growth (as weight)) for *R. sativus* in two soils.
[d]identical lowest value for both growth and reproduction of *E. fetida*.
[e]lowest value for inhibition of soil respiration in sandy loam soil.
[f]lowest value for inhibition of N-mineralisation.
[g]geometric mean of 1473 and 147 for inhibition of acid phosphatase activity by $CoSO_4$ in loam soil.
[h]geometric mean of 1473 and 147 for inhibition of alkaline phosphatase activity by $CoSO_4$ in silty clay loam soil.
[i]geometric mean of 737 and 74 for inhibition of arylsulfatase activity by $CoSO_4$ in clay loam soil.
[j]lowest value for inhibition of urease activity in clay loam soil.

Table A5. 4. Selenium; selected terrestrial data for ERL derivation.

taxonomic group	NOEC/EC10 [mg.kg^{-1}]	taxonomic group	L(E)C50 [mg.kg^{-1}]
macr	1.0[a]		
macr	5.0		
macr	2.0		
macr	0.31[b]		
macr	0.29[c]		
macr	3.1		
proc	250		
proc	20[d]		
proc	395		
proc	20[e]		
enz	99		
enz	79[f]		
enz	25[g]		
enz	39[h]		

[a]lowest value (parameter growth (as weight)) for *B. napa* in two soils.
[b]lowest value (parameter growth) for *M. sativa* in sandy loam soil.
[c]lowest value (parameter biomass) for *S. vulgare* in sand soil.
[d]lowest value for inhibition of soil respiration in silt loam soil.
[e]lowest value for stimulation of nitrification in sandy cambisoil.
[f]geometric mean of 50 and 125 for inhibition of alkaline phosphatase activity by Na_2SeO_3 in mor Aeh soil.
[g]geometric mean of 25 and 25 for inhibition of arylsulfatase activity by Na_2SeO_3 in mor soil.
[h]lowest value for inhibition of urease activity in silty clay loam soil.

Table A5. 5. Molybdenum; selected terrestrial data for ERL derivation.

taxonomic group	NOEC/EC10 [mg.kg^{-1}]	taxonomic group	L(E)C50 [mg.kg^{-1}]
proc	480		
enz	120		
enz	1200		
enz	76[a]		

[a]geometric mean of 240 and 24 for inhibition of urease activity in clay loam.

Table A5. 6. Tin; selected terrestrial data for ERL derivation.

taxonomic group	NOEC/EC10 [mg.kg^{-1}]	taxonomic group	L(E)C50 [mg.kg^{-1}]
proc	6.8[a]		
proc	234[b]		
proc	117[c]		
enz	148[d]		
enz	297		
enz	297[e]		
enz	133[f]		

[a]lowest value for inhibition of soil respiration in sandy loam soil.
[b]lowest value for inhibition of N-mineralisation.
[c]geometric mean of 59 and 234 for inhibition of nitrification in a sandy field soil.
[d]lowest value for inhibition of acid phosphatase activity in loam soil.
[e]lowest value for inhibition of arylsulfatase activity in mor soil.
[f]geometric mean for of 297 and 59 for inhibition of urease activity in clay loam and in silty clay loam soil.

Table A5. 7. Antimony; selected terrestrial data for ERL derivation.

taxonomic group	NOEC/EC10 [mg.kg^{-1}]	taxonomic group	L(E)C50 [mg.kg^{-1}]
macr	56[a]		
ann	17[b]		
ann	141[c]		
ins	49[d]		

[a]lowest value (parameter biomass) for *O. sativa*.
[b]lowest value (parameter reproduction) for *E. fetida*.
[c]lowest value (parameter reproduction) for *E. crypticus*.
[d]lowest value (parameter reproduction) for *F. candida*.

Table A5. 8. Barium; selected terrestrial data for ERL derivation.

taxonomic group	NOEC/EC10 [mg.kg^{-1}]	taxonomic group	L(E)C50 [mg.kg^{-1}]
ann	250[a]	macr	799
ann	425[b]	macr	2955
ins	82[c]	macr	1803
enz	1086[d]	ann	4182
enz	1086[e]		
enz	543[f]		
enz	343		

[b]lowest value (parameter reproduction) for *E. fetida*.
[c]lowest value (parameter reproduction) for *E. crypticus*.
[d]lowest value (parameter reproduction) for *F. candida*.
[d]geometric mean for of 3434 and 343 for inhibition of acid phosphatase activity in loam.
[e]geometric mean for of 3434 and 343 for inhibition of alkaline phosphatase activity in silty clay loam soil.
[f]geometric mean for of 1717 and 172 for inhibition of arylsulfatase activity in clay loam soil.

Table A5. 9. Thallium; selected terrestrial data for ERL derivation.

taxonomic group	NOEC/EC10 [mg.kg^{-1}]	taxonomic group	L(E)C50 [mg.kg^{-1}]
macr	1.0[a]	macr	16
moll	1.0[b]	macr	266
ann	3.2[a]	ann	47

[a]lowest value (parameter shoot growth) for *L sativum*.
[b]lowest value (parameter hatchability) for *A. arbustorum*.
[c]geometric mean of 1 and 10 for reproduction of *E. fetida*.

Appendix 6. Water concentrations of several elements

In this appendix yearly averages for aqueous concentrations of beryllium, vanadium, cobalt, selenium, antimony and barium are given. The raw data were extracted from the WaterBase database, accessible via internet (RIZA/RIKZ, 2003). Calculations were performed on these data in order to calculate yearly average concentrations. Data that were designated with a '<' sign (concentration below the limit of detection) and concentrations reported as '0' (zero) were excluded from the calculations.

Contents

Table A6. 1. Beryllium concentrations (µg/l) in major rivers and lakes in the Netherlands: 1975-1981.

	1975			1976			1977			1978			1979			1980			1981		
Location	**av.**	**s.d.**	***n***	**av.**	**s.d.**	***n***	**av.**	**s.d.**	***n***	**av.**	**s.d.**	***n***	**av.**	**s.d.**	***n***	**av.**	**s.d.**	***n***	**av.**	**s.d.**	***n***
De Punt (Drentse Aa)							0.047	0.046	3				0.067	0.092	12	0.063	0.045	12	0.138	0.118	4
Den Oever							0.023	0.009	12												
Dordrecht drinkwaterinlaat							0.067	0.029	3	0.076	0.051	10	0.068	0.056	12	0.091	0.056	12	0.164	0.116	11
Gat van de Kerksloot							0.035	0.021	2	0.088	0.049	9	0.064	0.062	13	0.037	0.025	12	0.063	0.023	8
Hagestein																			0.138	0.064	12
Haringvlietbrug				0.080	#DIV/0!	1	0.030	0.025	11				0.083	0.094	10	0.045	0.035	12	0.060	0.022	5
Haringvlietsluis	0.050	#DIV/0!	1	0.117	0.115	3	0.033	0.025	11	0.030	0.015	9	0.095	0.173	11	0.029	0.024	12	0.063	0.025	4
Houtribbaai							0.036	0.038	12												
Jutphaas				0.170	0.125	24	0.174	0.105	26	0.163	0.176	9									
Kampen	0.079	0.039	17	0.074	0.042	13	0.098	0.066	26	0.052	0.037	18	0.076	0.064	12	0.082	0.061	13	0.158	0.084	13
Keizersveer	0.069	0.023	7	0.076	0.025	5	0.056	0.067	26	0.039	0.026	19									
Kornwerd							0.023	0.009	12												
Lith boven	0.100	0.050	3	0.060	0.022	5	0.068	0.059	13	0.067	0.038	10									
Lobith ponton	0.082	0.034	16	0.089	0.043	18	0.117	0.076	25	0.133	0.173	18	0.230	0.585	25	0.137	0.154	26	0.179	0.116	26
Loenderveense Plas							0.020	0.000	3	0.020	0.000	8	0.020	0.000	12	0.020	0.000	13			
Maaseik				0.050	#DIV/0!	1	0.084	0.061	25												
Maassluis	0.097	0.100	6				0.068	0.036	12	0.073	0.047	9	0.095	0.100	11	0.135	0.133	11	0.085	0.055	13
Moerdijk bruggen	0.077	0.021	3	0.058	0.020	6	0.083	0.131	10												
Nieuwegein																					
Oosterdijk							0.047	0.046	3	0.028	0.014	8									
Oosterleek							0.178	0.226	11												
Pampus west				0.050	0.000	3	0.037	0.036	13	0.070	0.077	8									
Sas van Gent										0.020	0.000	15	0.025	0.012	12	0.025	0.012	11	0.120	0.130	5
Schaar van Ouden Doel	0.358	0.449	16							0.633	0.321	3	0.425	0.507	25	0.324	0.279	27	0.338	0.623	24
Urk				0.075	0.035	2	0.057	0.095	12												
Valkenburg							0.020	0.000	3				0.033	0.024	13	0.078	0.069	12	0.083	0.058	3
Veen (Afgedamde Maas)				0.083	0.024	4	0.080	0.182	14	0.034	0.026	10									
Vrouwezand	0.037	0.023	3	0.050	#DIV/0!	1	0.029	0.024	12	0.036	0.030	7	0.045	0.032	10	0.083	0.088	10	0.117	0.140	6
Vuren	0.073	0.025	18	0.090	0.054	7	0.101	0.083	25	0.086	0.061	18	0.091	0.056	12	0.092	0.089	13	0.150	0.079	13
Zutphen				0.069	0.026	8	0.129	0.089	14	0.073	0.047	9									

Table A6. 2. Beryllium concentrations (µg/l) in major rivers and lakes in the Netherlands: 1982-2000.

	Nieuwegein			Lobith		
Year	av.	s.d.	*n*	av.	s.d.	*n*
1988	0.048	0.021	11			
1989	0.043	0.017	9			
1990	0.034	0.026	10			
1991	0.025	0.013	4			
1992	0.055	0.034	11			
1993	0.075	0.033	4			
1994	0.114	0.044	5			
1995	0.095	0.070	4			
1996	0.148	0.056	4	4.0	-	1
1997	0.083	0.049	6	0.1	-	1
1998	0.080	0.016	4			
1999	0.108	0.022	4			
2000	0.165	0.034	4			

Table A6. 3. Vanadium concentrations (µg/l) in major rivers and lakes in the Netherlands: 1975-1981.

	1975	1975	1975	1976	1976	1976	1977	1977	1977	1978	1978	1978	1979	1979	1979	1980	1980	1980	1981	1981	1981
Location	**av.**	**s.d.**	***n***	**av.**	**s.d.**	***n***	**av.**	**s.d.**	***n***	**av.**	**s.d.**	***n***	**av.**	**s.d.**	***n***	**av.**	**s.d.**	***n***	**av.**	**s.d.**	***n***
De Punt (Drentse Aa)							2.00	0.00	3	2.30	0.95	10	2.75	1.36	12	2.75	1.36	12			
Den Oever							4.92	1.98	12												
Dordrecht drinkwaterinlaat							10.00	0.00	3	6.70	2.98	10	5.83	1.95	12	5.42	1.44	12	5.83	1.95	12
Eijsden ponton	10.06	3.52	18	5.72	1.71	18	5.46	2.27	26	8.75	6.46	20	10.00	12.16	24	7.48	5.16	27	9.52	11.50	21
Gat van de Kerksloot							3.50	2.12	2	4.56	2.51	9	5.31	2.36	13	5.00	0.00	12	5.00	0.00	9
Hagestein																			5.77	1.88	13
Haringvlietbrug	8.67	2.80	6	8.75	2.31	8	6.36	2.34	11				7.00	3.50	10	4.75	0.87	12	5.00	0.00	11
Haringvlietsluis	7.56	2.88	9	7.78	2.64	9	5.00	0.00	11	4.57	1.13	7	6.82	4.62	11	4.25	1.36	12	5.00	0.00	10
Houtribbaai							4.92	1.98	12												
Jutphaas				11.71	4.98	21	10.19	2.64	26	10.56	5.83	9									
Kampen	11.35	3.37	23	11.56	4.45	25	9.04	2.01	26	6.39	2.30	18	6.55	2.88	11	5.00	0.00	13	6.92	2.53	13
Keizersveer	11.80	4.81	15	5.73	1.68	11	4.85	1.43	26	4.95	1.54	19									
Kornwerd							4.00	1.48	12												
Lith boven	10.09	3.24	11	5.00	0.00	8	5.15	1.68	13	5.20	1.93	10									
Lobith ponton	12.38	4.32	24	13.42	5.77	24	11.20	5.64	25	8.61	3.76	18	9.00	5.20	25	6.15	2.57	26	6.35	2.67	26
Loenderveense Plas							2.00	0.00	3	2.00	0.00	9	2.00	0.00	12	2.00	0.00	13			
Maaseik				18.33	9.61	12	9.00	4.79	25												
Maassluis	13.33	5.77	9	16.15	3.63	13	11.25	3.77	12	8.33	3.54	9	7.27	3.44	11	8.64	4.52	11	5.38	1.39	13
Moerdijk bruggen	12.82	12.55	11	7.33	2.50	12	6.70	3.80	10												
Oosterdijk							4.00	1.73	3	4.57	1.13	7									
Oosterleek							8.00	8.44	11												
Pampus west				7.63	3.54	8	3.38	1.56	13	6.25	2.31	8									
Sas van Gent				17.39	6.24	23	17.00	6.57	20	15.56	4.16	18	18.75	4.33	12	19.55	6.88	11	14.58	6.56	12
Schaar van Ouden Doel	50.44	39.05	27	30.16	8.98	25	18.57	14.15	21	19.44	13.16	18	20.88	11.28	25	19.81	14.64	27	18.20	19.94	25
Urk				9.29	3.45	7	6.42	3.50	12												
Valkenburg							5.00	0.00	3	5.00	0.00	10	4.54	1.13	13	7.50	2.61	12	5.00	0.00	6
Veen (Afgedamde Maas)				7.43	4.79	7	5.21	5.41	14	3.80	1.55	10									
Vrouwezand	13.33	9.56	6	5.00	0.00	2	5.42	1.44	12	4.14	1.46	7	5.90	3.07	10	5.70	2.45	10	5.50	1.58	10
Vuren	11.00	3.81	25	11.10	3.56	21	9.88	3.15	25	8.33	2.43	18	6.67	2.46	12	5.38	1.39	13	5.77	1.88	13
Zutphen				14.10	2.88	10	9.64	3.08	14	6.67	2.50	9									

Table A6. 4. Cobalt concentrations (µg/l) in major rivers and lakes in the Netherlands: 1972-1978.

	1972	1972	1972	1973	1973	1973	1974	1974	1974	1975	1975	1975	1976	1976	1976	1977	1977	1977	1978	1978	1978
Location	**av.**	**s.d.**	***n***	**av.**	**s.d.**	***n***	**av.**	**s.d.**	***n***	**av.**	**s.d.**	***n***	**av.**	**s.d.**	***n***	**av.**	**s.d.**	***n***	**av.**	**s.d.**	***n***
Bocht van Watum midden oost							1.00	0.00	2												
Brienenoord (kilometer 996.5)							2.17	0.41	6												
De Punt (Drentse Aa)																					
Dordrecht drinkwaterinlaat																					
Eijsden ponton	1.43	0.53	7	2.70	3.02	10	2.25	1.82	24	1.30	0.48	10	1.27	0.46	15	1.56	0.98	18	2.53	1.70	17
Enschede	1.00	-	1	1.60	0.89	5	17.67	14.45	6												
Fort Crevecoeur (monding van de Dieze)	3.17	0.72	12	3.40	1.67	5	4.00	-	1												
Gat van de Kerksloot																					
Geertruidenberg Amercentrale				1.83	0.75	6	2.00	1.07	8												
Gennep	2.56	1.01	9	2.00	1.00	5															
Grave boven							1.67	0.58	3												
Hagestein							3.00	-	1							1.50	0.71	2	2.00	1.20	8
Haringvlietbrug				2.00	0.63	6	1.71	0.49	7	1.40	0.55	5									
Haringvlietsluis				1.60	0.55	5	1.50	0.55	6												
Jutphaas																					
Kampen																2.50	0.71	2	2.38	0.74	8
Keizersveer	1.50	0.53	10	1.58	0.51	12	1.67	0.78	12												
Ketelmond	3.10	1.29	10	2.42	0.79	12	2.22	0.67	9												
Klundert				2.17	0.41	6	1.50	0.53	8												
Kornwerd	1.33	0.58	3	1.00	0.00	7				3.00	-	1									
Lith boven										2.88	4.12	8	1.44	0.53	9	1.82	0.75	11	1.44	0.53	9
Lobith ponton				3.37	1.43	41	3.52	2.04	50	2.40	0.97	50	3.25	1.11	51	2.58	1.43	52	2.47	1.37	49
Loenderveense Plas																					
Maassluis							1.67	0.49	12	1.60	0.52	10									
Middelharnis				1.60	0.55	5	1.33	0.52	6												
Mond der Donge brug				2.00	0.71	5	4.00	-	1												
Oosterdijk	1.40	0.55	5	1.25	0.50	4															
Puttershoek							1.88	0.99	8												
Roermond (monding van de Roer)	2.50	1.17	12	2.50	1.73	4															
Rotterdamse Hoek	2.00	1.10	6	1.71	1.11	7	1.40	0.55	5												
Sas van Gent										1.00	-	1									
Valkenburg																					

Location	1972 av.	1972 s.d.	1972 *n*	1973 av.	1973 s.d.	1973 *n*	1974 av.	1974 s.d.	1974 *n*	1975 av.	1975 s.d.	1975 *n*	1976 av.	1976 s.d.	1976 *n*	1977 av.	1977 s.d.	1977 *n*	1978 av.	1978 s.d.	1978 *n*
Veen (Afgedamde Maas)																					
Vianen													1.00	-	1						
Vrouwezand										1.67	1.15	3									
Vuren							4.00	-	1							1.50	0.71	2	2.14	0.90	7
Wagenpad																					
Zuidhaven (kilometer 976.6)				3.20	0.45	5	2.00	1.25	10												

Table A6. 5. Cobalt concentrations (µg/l) in major rivers and lakes in the Netherlands: 1979-1984.

	1979	1979	1979	1980	1980	1980	1981	1981	1981	1982	1982	1982	1983	1983	1983	1984	1984	1984
Location	**av.**	**s.d.**	***n***	**av.**	**s.d.**	***n***	**av.**	**s.d.**	***n***	**av.**	**s.d.**	***n***	**av.**	**s.d.**	***n***	**av.**	**s.d.**	***n***
De Punt (Drentse Aa)	2.08	0.79	12	1.30	0.67	10	1.40	0.52	10									
Dordrecht drinkwaterinlaat	2.08	0.90	12	1.43	0.76	14	1.18	0.40	11									
Eijsden ponton	4.06	9.07	16	1.64	0.99	25	1.44	0.81	16	1.04	0.21	23	1.18	1.67	25	1.16	1.59	25
Gat van de Kerksloot	1.75	0.62	12	1.46	0.88	13	1.00	0.00	12									
Hagestein	2.13	0.99	8	1.63	1.41	8	1.44	0.53	9	1.00	-	1						
Haringvlietsluis	1.92	1.00	12	1.31	0.63	13	1.00	0.00	10									
Jutphaas	2.17	1.11	12	1.64	0.93	14	1.31	0.48	13	1.00	-	1						
Kampen	2.50	0.93	8	1.75	1.16	8	1.33	0.50	9	1.00	-	1						
Lith boven	1.78	0.97	9	4.60	5.78	10	1.71	1.11	7									
Lobith ponton	2.43	1.14	51	2.15	1.22	47	1.71	0.96	52	1.21	0.41	24	1.12	0.39	26	1.09	0.23	26
Loenderveense Plas	1.38	0.65	13	1.33	0.78	12	1.00	0.00	11									
Maassluis										1.00	0.00	2						
Oosterdijk	1.78	0.67	9	1.50	0.71	10	1.18	0.40	11									
Valkenburg	1.92	0.76	13	1.42	0.67	12	1.09	0.30	11									
Veen (Afgedamde Maas)	1.45	0.82	11	1.46	0.88	13	1.13	0.35	8									
Vianen	1.00	-	1															
Vuren	2.25	1.04	8	1.50	1.07	8	1.67	1.32	9	1.00	-	1						

Table A6. 6. Selenium concentrations (µg/l) in major rivers and lakes in the Netherlands: 1975-1981.

	1975	1975	1975	1976	1976	1976	1977	1977	1977	1978	1978	1978	1979	1979	1979	1980	1980	1980	1981	1981	1981
Location	**av.**	**s.d.**	***n***	**av.**	**s.d.**	***n***	**av.**	**s.d.**	***n***	**av.**	**s.d.**	***n***	**av.**	**s.d.**	***n***	**av.**	**s.d.**	***n***	**av.**	**s.d.**	***n***
De Punt (Drentse Aa)							1.00	0.00	3	1.00	0.00	10	1.00	0.00	11	1.00	0.00	12			
Den Oever							1.17	0.39	12												
Dordrecht drinkwaterinlaat							1.00	0.00	3	1.00	0.00	10	1.00	0.00	12	1.00	0.00	12			
Eijsden (ponton)	2.00	0.00	3	2.00	0.00	2	1.00	0.00	26	1.00	0.00	20	1.00	0.00	24	1.00	0.00	27	10.00	-	1
Gat van de Kerksloot							1.00	0.00	2	1.00	0.00	9	1.00	0.00	13	1.00	0.00	12			
Hagestein																					
Haringvlietbrug	3.50	1.00	4				1.45	0.93	11				1.00	0.00	9	1.00	0.00	12			
Haringvlietsluis	3.40	0.89	5				1.45	0.93	11	1.00	0.00	8	1.00	0.00	11	1.00	0.00	12			
Houtribbaai							1.33	0.89	12												
Jutphaas				2.00	0.00	3	1.19	0.69	26	1.00	0.00	9									
Kampen	3.33	2.31	3	2.29	0.76	7	1.04	0.20	26	1.00	0.00	18	1.00	0.00	11	1.00	0.00	13			
Keizersveer	3.17	1.47	6				1.00	0.00	26	1.00	0.00	19									
Kornwerd							1.09	0.30	11												
Lith boven	2.00	0.00	3				1.00	0.00	13	1.00	0.00	10									
Lobith ponton	3.20	1.32	10	2.00	0.00	2	1.12	0.33	25	1.00	0.00	18	1.00	0.00	25	1.00	0.00	26			
Loenderveense Plas							1.00	0.00	3	1.00	0.00	9	1.00	0.00	11	1.00	0.00	13			
Maaseik				2.00	-	1	1.04	0.20	25												
Maassluis	2.50	0.71	2	2.00	-	1	1.22	0.44	9	1.00	0.00	9	1.00	0.00	11	1.00	0.00	11			
Moerdijk bruggen	3.50	1.22	6				1.20	0.42	10												
Nieuwegein																					
Oosterdijk							1.00	0.00	3	1.00	0.00	8									
Oosterleek							1.27	0.90	11												
Pampus west							1.08	0.28	13	1.00	0.00	8									
Sas van Gent													0.38	0.15	12	0.50	0.00	11	0.50	0.00	8
Schaar van Ouden Doel													1.27	0.62	25	1.52	0.92	27	0.58	0.19	24
Urk							1.00	0.00	11												
Valkenburg							1.00	0.00	3	1.00	0.00	8	1.00	0.00	13	1.00	0.00	12			
Veen (Afgedamde Maas)							1.00	0.00	14	1.00	0.00	10									
Vrouwezand	3.33	2.08	3				1.17	0.39	12	1.00	0.00	7	1.00	0.00	10	1.00	0.00	10			
Vuren	3.00	1.41	8	3.00	1.41	2	1.04	0.20	25	1.00	0.00	18	1.00	0.00	12	1.00	0.00	13			
Zutphen				2.00	-	1	1.29	0.83	14	1.00	0.00	9									

Table A6. 7. Selenium concentrations (µg/l) in major rivers and lakes in the Netherlands: 1994-2000.

	1994	1994	1994	1995	1995	1995	1996	1996	1996	1997	1997	1997	1998	1998	1998	1999	1999	1999	2000	2000	2000
Location	**av.**	**s.d.**	***n***	**av.**	**s.d.**	***n***	**av.**	**s.d.**	***n***	**av.**	**s.d.**	***n***	**av.**	**s.d.**	***n***	**av.**	**s.d.**	***n***	**av.**	**s.d.**	***n***
De Punt (Drentse Aa)							0.70	0.50	8	0.42	0.29	11	0.31	0.12	9	0.35	0.13	11	0.16	0.13	10
Eijsden (ponton)	2	-	0																		
Gat van de Kerksloot													0.32	0.27	8	0.21	0.15	10	0.15	0.10	9
Houtribbaai													0.28	0.19	10	0.27	0.16	2	1.15	0.21	2
Keizersveer							0.56	0.37	6	0.34	0.03	2	0.92	1.56	6	0.28	0.15	5	0.18	0.12	5
Lobith ponton	2	-	0																		
Maaseik							0.17	0.62	2	1.00	-	1									

Table A6. 8. Antimony concentrations (µg/l) in major rivers and lakes in the Netherlands: 1975-1981.

	1975	1975	1975	1976	1976	1976	1977	1977	1977	1978	1978	1978	1979	1979	1979	1980	1980	1980	1981	1981	1981
Location	**av.**	**s.d.**	***n***	**av.**	**s.d.**	***n***	**av.**	**s.d.**	***n***	**av.**	**s.d.**	***n***	**av.**	**s.d.**	***n***	**av.**	**s.d.**	***n***	**av.**	**s.d.**	***n***
De Punt (Drentse Aa)							1.00	0.00	3												
Den Oever							1.17	0.39	12												
Dordrecht drinkwaterinlaat							1.33	0.58	3	1.00	0.00	10									
Eijsden (ponton)	2.67	0.52	6	2.33	0.50	9	1.04	0.20	26	1.00	0.00	20	1.04	0.20	24	1.00	0.00	27	2.00	-	1
Gat van de Kerksloot							1.00	0.00	2												
Haringvlietbrug	2.00	-	1	2.00	0.00	4	1.09	0.30	11												
Haringvlietsluis				2.00	0.00	4	1.00	0.00	11	1.00	0.00	8									
Houtribbaai							1.00	0.00	12												
Jutphaas				2.00	0.00	3	1.00	0.00	26												
Kampen	2.56	0.73	9	2.00	0.00	5	1.00	0.00	26	1.00	0.00	18									
Keizersveer	2.00	-	1	2.00	0.00	4	1.00	0.00	26	1.00	0.00	19									
Kornwerd				2.00	-	1	1.08	0.29	12												
Lith boven	2.00	-	1				1.00	0.00	13												
Lobith ponton	2.36	0.50	11	2.13	0.35	8	1.08	0.28	25	1.00	0.00	18	1.00	0.00	25	1.00	0.00	26			
Loenderveense Plas							1.00	0.00	3												
Maaseik							1.00	0.00	25												
Maassluis	2.00	0.00	2				1.00	-	1	1.00	0.00	9	1.00	0.00	11	1.00	0.00	11			
Moerdijk bruggen	3.00	-	1	2.00	0.00	4	1.10	0.32	10												
Oosterdijk							1.00	0.00	3	1.00	0.00	8									
Oosterleek							1.00	0.00	11												
Pampus west							1.00	0.00	13	1.00	0.00	8									
Sas van Gent													2.27	0.79	11	2.82	1.08	11	5.33	2.74	9
Schaar van Ouden Doel													6.36	1.38	25	3.89	1.40	27	2.71	0.86	24
Urk				2.00	0.00	2	1.08	0.29	12												
Valkenburg							1.00	0.00	3												
Veen (Afgedamde Maas)							1.00	0.00	14												
Vrouwezand	1.00	-	1	2.00	0.00	2	1.08	0.29	12				1.00	0.00	10	1.00	0.00	10			
Vuren	2.33	0.52	6	2.00	0.00	4	1.00	0.00	25												
Zutphen				2.00	0.00	6	1.00	0.00	14												

Table A6. 9. Antimony concentrations (µg/l) in major rivers and lakes in the Netherlands: 1995-2000.

	1995	1995	1995	1996	1996	1996	1997	1997	1997	1998	1998	1998	1999	1999	1999	2000	2000	2000	1981	1981	1981
Location	**av.**	**s.d.**	***n***	**av.**	**s.d.**	***n***	**av.**	**s.d.**	***n***	**av.**	**s.d.**	***n***	**av.**	**s.d.**	***n***	**av.**	**s.d.**	***n***	**av.**	**s.d.**	***n***
Eijsden (ponton)	0.30	-	1	0.69	0.60	9	0.25	0.18	6	0.42	0.28	10	0.26	0.12	10	0.40	0.44	7			
Lobith ponton	0.20	-	1	0.44	0.28	9	0.31	0.11	5	0.49	0.20	10	0.31	0.13	9	0.22	0.13	5			

Table A6. 10. Barium concentrations (µg/l) in major rivers and lakes in the Netherlands: 1978-1984.

	1978	1978	1978	1979	1979	1979	1980	1980	1980	1981	1981	1981	1982	1982	1982	1983	1983	1983	1984	1984	1984
Location	**av.**	**s.d.**	***n***	**av.**	**s.d.**	***n***	**av.**	**s.d.**	***n***	**av.**	**s.d.**	***n***	**av.**	**s.d.**	***n***	**av.**	**s.d.**	***n***	**av.**	**s.d.**	***n***
De Punt (Drentse Aa)	40	7	9	53	16	12	43	10	12	37	14	6	40	8	4	40	0	4			
Dordrecht drinkwaterinlaat	117	21	10	125	22	11	119	21	12	105	22	12	110	20	4						
Eijsden ponton	50	32	20	65	70	24	49	19	27	65	74	24									
Gat van de Kerksloot	61	35	9	56	13	13	53	5	12	48	12	12	58	13	4	58	22	4	50	10	3
Hagestein										121	26	13									
Haringvlietbrug				91	15	10	85	9	12	78	19	13									
Haringvlietsluis	74	12	9	88	29	11	78	11	12	68	13	13	83	10	4	88	17	4	86	24	7
Jutphaas	138	33	9										120	14	4	110	18	4	110	20	3
Kampen	118	21	16	130	31	12	137	29	13	130	39	13									
Keizersveer																					
Lobith ponton	143	42	18	144	37	25	139	26	26	136	34	26									
Loenderveense Plas	81	6	9	86	28	12	94	10	13	88	17	12	95	6	4						
Maassluis				103	10	11	96	17	11	92	22	13									
Nieuwegein																					
Oosterdijk	76	11	8										88	10	4	88	10	4	103	31	3
Sas van Gent				35	14	12	37	8	11	31	9	12									
Schaar van Ouden Doel				78	48	24	75	41	27	67	68	25									
Valkenburg	58	16	10	55	15	13	57	12	12	47	15	7	50	18	4	60	0	3			
Veen (Afgedamde Maas)	47	12	10										55	13	4	73	17	4	67	6	3
Vrouwezand	81	27	7	101	33	10	95	29	10	85	37	11									
Vuren	126	30	18	127	26	12	118	15	13	122	29	13									

Table A6. 11. Barium concentrations in major rivers and lakes in the Netherlands: 1978-2000.

	Eijsden ponton			Haringvlietsluis			Keizersveer			Lobith ponton			Nieuwegein		
Year	**av.**	**s.d.**	***n***	**av.**	**s.d.**	***n***	**av.**	**s.d.**	***n***	**av.**	**s.d.**	***n***	**av.**	**s.d.**	***n***
1978	50	32								143	42				
1979	65	70								144	37				
1980	49	19								139	26				
1981	65	74								136	34				
1982															
1983															
1984															
1985															
1986															
1987															
1988													124.6	20	12
1989													149.6	25	12
1990													153.3	46	12
1991													137.5	18	4
1992													146.8	24	11
1993	21	2	10							86	35	13	163.8	23	4
1994	20	2	13							88	16	13	169.4	42	5
1995	21	3	12							83	13	13	175.3	58	3
1996	20	3	12							97	19	12	110.0	25	2
1997	22	3	13							94	5	2	133.2	26	6
1998	24	4	13	58	7	11	31	7	14	96	10	13	120.8	43	4
1999	26	3	13	58	7	13	32	5	13	88	13	13	96.5	29	4
2000	21	2	13	51	5	12	29	3	13	74	8	13	119.8	23	4

Appendix 7. Water solubilities of salts

In this appendix, water solubilities of the metal salts that have been used in toxicity experiments are shown. For most salts, one or more values for aqueous solubility were found. In general, water solubilities were so high, that no solubility limitations were anticipated in toxicity experiments. For some salts, no values could be retrieved (denoted with '-'). References are given below the table. Solubilities were given either in weight percentages (wt%) or in g/l. All values were recalculated to mg/l for reasons of comparison.

Test results from studies conducted with $BaSO_4$ and $CoCO_3$ were rejected because the resulting toxicity values were higher than the water solubilities of the salts used. Solubility of some antimony salts (Sb_2O_3, Sb_2S_3, Sb_2S_5) is also problematic. Several studies conducted with Sb_2O_3 were rejected because effect concentrations far above the water solubility were reported.

Table A7. 1. Water solubilities of metal salts used in toxicity experiments retrieved in this report.

Salt	S_w	unit	T [°C]	S_w [mg/l]	Reference
Beryllium					
$BeCl_2$	71.5	wt%	20	715000	[1]
$Be(NO_3)_2$	107	wt%	20	1070000	[1]
$Be(NO_3)_2$	51.2	wt%	15	512000	[3]
$BeSO_4$	41.3	wt%	25	413000	[1]
$BeSO_4$	28.7	wt%	25	287000	[3]
$BeSO_4$	27.5	wt%	15	275000	[3]
$Be(SO_4)_2$	-				
Vanadium					
$NaVO_3$	17.42	wt%	25	174200	[3]
$NaVO_3$	21	wt%	25	210000	[1]
Na_3VO_4	s H_2O				[1]
NH_4VO_3	4.35	wt%	18	43500	[3]
$VOSO_4$	s H_2O				[1]
V_2O_5	0.07	wt%	25	700	[3]
Cobalt					
$CoCl_2$	34.6	wt%	20	346000	[3]
$CoCl_2$	56.2	wt%	25	562000	[1]
$CoCl_3$	-				
$CoCO_3$	0.00014	wt%	20	1.4	[1]
$Co(NO_3)_2$	49.75	wt%	20	497500	[3]
$Co(NO_3)_2$	103	wt%	25	1030000	[1]
$CoSO_4$	26.5	wt%	20	265000	[3]
$CoSO_4$	25.6	wt%	20	256000	[3]
$CoSO_4$	38.3	wt%	25	383000	[1]
Selenium					
H_2SeO_3	62.5	wt%	20	625000	[3]
K_2SeO_3	67	wt%	19.5	670000	[3]
K_2SeO_4	52.6	wt%	20	526000	[3]
K_2SeO_4	53.7	wt%	20	537000	[3]
K_2SeO_4	114	wt%	25	1140000	[1]

Salt	S_w	unit	T [°C]	S_w [mg/l]	Reference
$NaHSeO_3$	-				
Na_2SeO_3	46.12	wt%	19.5	461200	[3]
Na_2SeO_3	89.3	wt%	25	893000	[1]
Na_2SeO_4	29	wt%	18	290000	[3]
Na_2SeO_4	58.5	wt%	25	585000	[1]
SeO_2	72.52	wt%	22	725200	[3]
SeO_2	264	wt%	22	2640000	[1]
Molybdenum					
H_2MoO_4	-				
$(NH_4)_6Mo_7O_{24}.4H_2O$	43	wt%	-	430000	[1]
$NaMoO_4$	39.27	wt%	15.5	392700	[3]
$NaMoO_4$	39.4	wt%	18	394000	[3]
$NaMoO_4$	65	wt%	25	650000	[1]
Tin					
$SnCl_2$	72.9	wt%	15	729000	[3]
$SnCl_2$	178	wt%	10	1780000	[1]
$SnCl_4$	reac. H_2O				[1]
$SnCl_4.5H_2O$	vs H_2O				[1]
$SnSO_4$	15.9	wt%	19	159000	[3]
$SnSO_4$	18.8	wt%	19	188000	[1]
Sn_2SO_4	-				
Antimony					
$KSbC_4H_4O_6$	-				
$K[Sb(OH)_6)]$	-				
$SbCl_3$	96.9	wt%	25	969000	[3]
$SbCl_3$	987	wt%	25	9870000	[1]
$SbCl_5$	reac. H_2O				[1]
Sb_2O_3	sl. H_2O			1.9	[1], [4]
Sb_2S_3	0.00175	g/l	18	1.75	[3]
Sb_2S_5	i. H_2O				[1]
$Sb_2(SO_4)_3$	sl. H_2O				[1]
Barium					
$Ba(CH_3CHOO)_2$	40.9	wt%	17.5	409000	[3]
$Ba(CH_3CHOO)_2$	42.1	wt%	21.6	421000	[3]
$Ba(CH_3CHOO)_2$	79.2	wt%	25	792000	[1]
$BaCl_2$	26.6	wt%	20	266000	[3]
$BaCl_2$	26.28	wt%	20	262800	[3]
$BaCl_2$	37	wt%	25	370000	[1]
$Ba(NO_3)_2$	8.27	wt%	20	82700	[3]
$Ba(NO_3)_2$	10.3	wt%	25	103000	[1]
$BaSO_4$	0.00223	g/l	25	2.23	[3]
$BaSO_4$	0.00031	wt%	20	3.1	[1]
Thallium					
TlCl	343.3	g/l	18.5	343300	[3]
TlCl	3.4	g/l	20	3400	[3], [2]
TlCl	3.05	wt%	17.7	30500	[3]
TlCl	3.3	g/l	20	33000	[3]
TlCl	0.325	wt%	20	3250	[3]

Salt	S_w	unit	T [°C]	S_w [mg/l]	Reference
TlCl	0.33	wt%	20	3300	[1]
Tl_2CO_3	4.69	wt%	20	46900	[3]
Tl_2CO_3	52.3	g/l	20	523000	[2]
$TlNO_3$	8.72	wt%	20	87200	[3]
$TlNO_3$	9.55	wt%	20	95500	[3]
$TlNO_3$	86.7	g/l	20	867000	[2]
$Tl(NO_3)_3$	reac. H_2O				[1]
Tl_2SO_4	48.59	g/l	20	48590	[3]
Tl_2SO_4	4.64	wt%	20	46400	[1], [2]

[1] Lide DR, ed. 2001. CRC Handbook of Chemistry and Physics, 82nd ed. Boca Raton: CRC Press.
[2] Schoer J. 1984. Thallium. In: Hutzinger O, ed. The Handbook of Environmental Chemistry. Vol 3 Part C. Anthropogenic compounds. Berlin: Springer-Verlag. p. 143-214.
[3] Stephen H, Stephen T, eds. 1963. Solubilities of inorganic compounds. Volume 1, Part 1. Oxford: Pergamon press.
[4] Unpublished draft version of EU-RAR for diantimony trioxide.

Appendix 8. References to toxicity data

Abbasi SA, Nipaney PC, Soni R. 1993. An examination of the water quality criteria of vanadium with reference to impact studies on freshwater teleost *Nuria denricus* (Hamilton). Pollut Res 12: 85-90.

Abbott OJ. 1977. The toxicity of ammonium molybdate to marine invertebrates. Mar Pollut Bull 8: 204-205.

Abdel-Hamid MI, Skulberg OM. 1995. Effect of selenium on the growth of some selected green and blue-green algae. Lakes Reserv Res Manag 1: 205-211.

Ahsanullah M, Palmer DH. 1980. Acute toxicity of selenium to three species of marine invertebrates, with notes on a continuous-flow test system. Aust J Mar Freshwater Res 31: 795-802.

Ahsanullah M. 1982. Acute toxicity of chromium, mercury, molybdenum and nickel to the amphipod *Allorchestes compressa*. Aust J Mar Freshwater Res 33: 465-474.

Ahsanullah M, Brand GW. 1985. Effect of selenite and seleniferous fly-ash leachate on growth and viability of the marine amphipod *Allorchestes compressa*. Mar Biol 89: 245-248.

Al-Khafaji AA, Tabatabai MA. 1979. Effects of trace elements on arylsulfatase activity in soils. Soil Sci 127: 129-133.

Amiard JC. 1976. Etude expérimentale de la toxicité, aigue de sels de cobalt, d'antimoine, de strontium et d'argent chez quelques crustacés et leurs larves et chez quelques téléostéens. Rev Intern Océanog Méd Tome 43: 79-95.

Anderson BG. 1948. The apparent thresholds of toxicity to *Daphnia magna* for chlorides of various metals when added to lake Erie water. Trans Am Fish Soc 78: 96-113.

Baudouin MF, Scoppa P. 1974. Acute toxicity of various metals to freshwater zooplankton. Bull Environ Contam Toxicol 12: 745-751.

Bengtsson B-E. 1978. Use of a harpacticoid copepod in toxicity tests. Mar Pollut Bull 9: 238-241.

Beusen JM, Neven B. 1987. Toxicity of vanadium to different freshwater organisms. Bull Environ Contam Toxicol 39: 194-201.

Biesinger KE, Christensen GM. 1972. Effects of various metals on survival, growth, reproduction, and metabolism of *Daphnia magna*. J Fish Res Board Can 29: 1691-1700.

Birge WJ, Black JA, Ramey BA. 1981. The reproductive toxicology of aquatic contaminants. In: Saxena J, Fisher F, eds. Hazard assessment of chemicals. Current Developments. New York: Acedamic Press. p. 59-115.

Borgmann U, Cheam V, Norwood WP, Lechner J. 1998. Toxicity and bioaccumulation of thallium in Hyalella azteca, with comparison to other metals and prediction of environmental impact. Environ Pollut 99: 105-114.

Boutet C, Chaisemartin C. 1973. Propriétés toxiques spécifiques des sels métalliques chez *Austropotamobius pallipes pallipes* et *Orconectes limosus*. C R Soc Biol Paris 167: 1933-1938.

Brandão JC, Bohets HHL, Van de Vyver IE, Dierickx PJ. 1992. Correlation between the in vitro cytotoxicity to cultured fathead minnow fish cells and fish lethality data for 50 chemicals. Chemosphere 25: 553-562.

Brasher AM, Ogle RS. 1993. Comparative Toxicity of Selenite and Selenate to the Amphipod Hyalella azteca. Arch Environ Contam Toxicol 24: 182-186.

Bringmann G, Kühn R. 1959. Vergleichende wasser-toxikologische Untersuchungen an Bakterien, Algen und Kleinkrebsen. Gesundheits-Ingenieur 80: 115-120.

Bringmann G, Kühn R. 1976. Vergleichende Befunde der Schadwirkung wassergefährdender

Stoffe gegen Bakterien (*Pseudomonas putida*) und Blaualgen (*Microcystis aeruginosa*). GWF Wasser/Abwasser 117: 410-413.
Bringmann G, Kühn R. 1977a. Befunde der Schadwirkung wassergefährdender Stoffe gegen *Daphnia magna*. Z Wasser-Abwasser-Forsch 10: 161-166.
Bringmann G, Kühn R. 1977b. Grenzwerte der Schadwirkung wassergefährdender Stoffe gegen Bakterien (*Pseudomonas putida*) und Grünalgen (*Scenedesmus quadricauda*) im Zellvermehrungshemmtest. Z Wasser-Abwasser-Forsch 10: 87-98.
Bringmann G. 1978. Bestimmung der biologischen Schadwirkung wassergefährdender Stoffe gegen Protozoen I. Bakterienfressende Flagellaten (Modellorganismus: *Entosiphon sulcatum* Stein). Z Wasser-Abwasser-Forsch 11: 210-215.
Bringmann G, Kühn R. 1978. Grenzwerte der Schadwirkung wassergefährdender Stoffe gegen Blaualgen (*Microcystis aeruginosa*) und Grünalgen (*Scenedesmus quadricauda*) im Zellvermehrungshemmtest. Vom Wasser 50: 45-60.
Bringmann G, Kühn R. 1980. Bestimmung der biologischen Schadwirkung wassergefährdender Stoffe gegen Protozoen II. Bakterienfressende Ciliaten. Z Wasser-Abwasser-Forsch 13: 26-31.
Bringmann G, Kühn R, Winter A. 1980. Bestimmung der biologischen Schadwirkung wassergefährdender Stoffe gegen Protozoen III. Saprozoische Flagellaten. Z Wasser-Abwasser-Forsch 13: 170-173.
Bringmann G, Kühn R. 1982. Ergebnisse der Schadwirkung wassergefährdender Stoffe gegen *Daphnia magna* in einem weiterentwickelten standardisierten Testverfahren. Z Wasser-Abwasser-Forsch 15: 1-6.
Brix KV, Henderson DG, Adams WJ, Reash RJ, Carlton RG, McIntyre DO. 2001. Acute toxicity of sodium selenate to two daphnids and three amphipods. Environ Toxicol 16: 142-150.
Brown BT, Rattigan BM. 1979. Toxicity of soluble copper and other metal ions to *Elodea canadensis*. Environ Pollut 20: 303-314.
Browne CL, Dumont JN. 1979. Toxicity of selenium to developing *Xenopus laevis* embryos. J Toxicol Environ Health 5: 699-709.
Buccafusco RJ, Ells SJ, LeBlanc GA. 1981. Acute toxicity of priority pollutants to bluegill (*Lepomis macrochirus*). Bull Environ Contam Toxicol 26: 446-452.
Buhl KJ, Hamilton SJ. 1991. Relative sensitivity of early life stages of arctic grayling, coho salmon, and rainbow trout to nine inorganics. Ecotoxicol Environ Saf 22: 184-197.
Buhl KJ, Hamilton SJ. 1996. Toxicity of inorganic contaminants, individually and in environmental mixtures, to three endangered fishes (Colorado squawfish, bonytail, and razorback sucker). Arch Environ Contam Toxicol 30: 84-92.
Buikema AL, Cairns J, Sullivan GW. 1974. Evaluation of *Philodina acuticornis* (Rotifera) as a bioassay organism for heavy metals. Water Resour Bull 10: 648-661.
Calleja MC, Persoone G, Geladi P. 1994. Comparative acute toxicity of the first 50 multicentre evaluation of in vitro cytotoxicity chemicals to aquatic non-vertebrates. Arch Environ Contam Toxicol 26: 69-78.
Canterford GS, Canterford DR. 1980. Toxicity of heavy metals to the marine diatom *Ditylum brightwellii* (West) Grunow: correlation between toxicity and metal speciation. J mar biol Ass UK 60: 227-242.
Cardwell RD, Foreman DG, Payne TR, Wilbur DJ. 1976. Acute toxicity of selenium dioxide to freshwater fishes. Arch Environ Contam Toxicol 4: 129-144.
Chapman DC. 1992. Failure of gas bladder inflation in striped bass: effect on selenium toxicity. Arch Environ Contam Toxicol 22: 296-299.
Chaudry FM, Wallace A, Mueller RT. 1977. Barium toxicity in plants. Commun Soil Sci Plant Anal 8: 795-797.

Chidambaram N, Sastry CA. 1991. Toxicity and bioaccumulation of selenate in the teleost fish, *Oreochromis mossambicus* (Peters). Indian J Environ Prot 11: 496-501.
Cleveland L, Little EE, Buckler DR, Wiedmeyer H. 1993. Toxicity and bioaccumulation of waterborne and dietary selenium in juvenile bluegill. Aquat Toxicol 27: 265-280.
Coleman RD, Coleman RL, Rice EL. 1971. Zinc and cobalt bioconcentration and toxicity in selected algal species. Bot Gaz 132: 102-109.
Das BK, Kaviraj A. 1994. Individual and interactive lethal toxicity of cadmium, potassium permanganate and cobalt chloride to fish, worm and plankton. Geobios 21: 223-227.
Dave G, Xiu R. 1991. Toxicity of mercury, copper, nickel, lead and cobalt to embryos and larvae of zebrafish, *Brachydanio rerio*. Arch Environ Contam Toxicol 21: 126-134.
Denneman CAJ, Van Gestel CAM. 1990. Bodemverontreiniging en bodemecosystemen: voorstel voor C-(toetsings)waarden op basis van ecotoxicologische risico's. Bilthoven, the Netherlands: National Institute for Public Health and Environmental Protection (RIVM). Report no. 725201001.
DeYoung DJ, Bantle JA, Fort DJ. 1991. Assessment of the developmental toxicity of ascorbic acid, sodium selenate, coumarin, serotonin and 13-*cis* retinoic acid using FETAX. Drug Chem Toxicol 14: 127-141.
Diamond JM, Winchester EL, Mackler DG, Rasnake WJ, Fanelli JK, Gruber D. 1992. Toxicity of cobalt to freshwater indicator species as a function of water hardness. Aquat Toxicol 22: 163-179.
Dirilgen N, Inel Y. 1994. Cobalt-copper and cobalt-zinc effects on duckweed growth and metal accumulation. J Environ Sci Health A29: 63-81.
Dobbs MG, Cherry DS, Cairns Jr. J. 1996. Toxicity and bioaccumulation of selenium to a three-trophic level food chain. Environ Toxicol Chem 15: 340-347.
Dorfman D. 1977. Tolerance of *Fundulus heteroclitus* to different metals in salt waters. Bull New Jersey Acad Sci 22: 21-23.
Duncan DA, Klaverkamp JF. 1983. Tolerance and resistance to cadmium in white suckers (*Catostomus commersoni*) previously exposed to cadmium, mercury, zinc or selenium. Can J Fish Aquat Sci 40: 128-138.
El-Nady FE, Atta MM. 1996. Toxicity and biaoccumulation of heavy metals to some marine biota from the Egyptian coastal waters. J Environ Sci Health A31: 1529-1545.
Ernst WR, Garside ET. 1987. Lethal effects of vanadium to two life stages of brook trout *Salvelinus fontinalis* (Mitchill). Can J Zool 65: 628-634.
Fargašová A. 1994. A comparative study on the toxicity and inhibitory effects of inorganic tin compounds on various biological subjects. Biologia 49: 307-311.
Fargašová A. 1997. Sensitivity of *Chironomus plumosus* larvae to V^{5+}, Mo^{6+}, Mn^{2+}, Ni^{2+}, Cu^{2+} and Cu^{+} metal ions and their combinations. Bull Environ Contam Toxicol 59: 956-962.
Fargašová A, Bumbálová A, Havránek E. 1999. Ecotoxicological effects and uptake of metals (Cu+, Cu2+, Mn2+, Mo6+, Ni2+, V5+) in freshwater alga Scenedesmus quadricauda. Chemosphere 35: 1165-1173.
Fargašová A. 2001. Interactive effect of manganese, molybdenum, nickel, copper I and II and vanadium on the freshwater alga *Scendesmus quadricauda*. Bull Environ Contam Toxicol 67: 688-695.
Fichet D, Miramand P. 1998. Vanadium toxicity to three marine invertebrates larvae: *Crassostrea gigas*, *Paracentrotus lividus* and *Artemia salina*. Chemosphere 37: 1363-1368.
Gaikwad SA. 1989. Acute toxicity of mercury, copper and selenium to the fish *Etroplus maculatus*. Environ Ecol 7: 694-696.
Gaur JP, Noraho N, Chauhan YS. 1994. Relationship between heavy metal accumulation and

toxicity in *Spirodela polyrhiza* (L.) Schleid. and *Azolla pinnata* R. Br. Aquat Bot 49: 182-192.
Gissel-Nielsen M, Gissel-Nielsen G. 1975. Selenium in soil-animal relationships. Pedobiologia 15: 65-67.
Glickstein N. 1978. Acute toxicity of mercury and selenium to *Crassostrea gigas* embryos and *Cancer magister* larvae. Mar Biol 49: 113-117.
Goettl JP, Davies PH, Sinley JR. 1976. Laboratory studies. Water pollution studies. In: Cope DB, ed. Colorado Fish Res Rev 1972-1975. Boulder, CO, USA: Colorado Div.of Wildl. p. 68-75.
Halter MT, Adams WJ, Johnson HE. 1980. Selenium toxicity to *Daphnia magna*, *Hyalella azteca* and the fathead minnow in hard water. Bull Environ Contam Toxicol 24: 102-107.
Hamilton SJ, Buhl KJ. 1990a. Acute toxicity of boron, molybdenum, and selenium to fry of chinook salmon and coho salmon. Bull Environ Contam Toxicol 19: 366-373.
Hamilton SJ, Buhl KJ. 1990b. Safety assessment of selected inorganic elements to fry of chinook salmon (*Oncorhynchus tshawytscha*). Ecotoxicol Environ Saf 20: 307-324.
Hamilton SJ. 1995. Hazard assessment of inorganics to three endangered fish in the Green River, Utah. Ecotoxicol Environ Saf 30: 134-142.
Hamilton SJ, Buhl KJ. 1997a. Hazard assessment of inorganics, individually and in mixtures, to two endangered fish species in the San Juan river, New Mexico. Environ Toxicol Water Qual 12: 195-209.
Hamilton SJ, Buhl KJ. 1997b. Hazard evaluation of inorganics, singly and in mixtures, to flannelmouth sucker *Catostomus latipinnis* in the San Juan river, New Mexico. Ecotoxicol Environ Saf 38: 296-308.
Hammel W, Steubing L, Debus R. 1998. Assessment of the ecotoxic potential of soil contaminants by using a soil-algae test. Ecotoxicol Environ Saf 40: 173-176.
Hartley J, Cairney JWG, Freestone P, Woods C, Meharg AA. 1999. The effects of multiple metal contamination on ectomycorrhizal Scots pine (*Pinus sylvestris*) seedlings. Environ Pollut 106: 413-424.
Hartwell SI, Jin JH, Cherry DS, Cairns Jr. J. 1989. Toxicity versus avoidance response of golden shiner, Notemigonus crysoleucas, to five metals. J Fish Biol 35: 447-456.
He M, Yang J. 1999. Effects of different forms of antimony on rice during the period of germination and growth and antimony concentration in rice tissue. Sci Total Environ 243/244: 149-155.
Heim M, Wappelhorst O, Markert B. 2002. Thallium in terrestrial environments - occurence and effects. Ecotoxicology 11: 369-377.
Heitmuller PT, Hollister TA, Parrish PR. 1981. Acute toxicity of 54 industrial chemicals to sheepshead minnows (*Cyprinodon variegatus*). Bull Environ Contam Toxicol 27: 596-604.
Hermanutz RO, Allen KN, Roush TH, Hedtke SF. 1992. Effects of elevated selenium concentrations on bluegills (*Lepomis macrochirus*) in outdoor experimental streams. Environ Toxicol Chem 11: 217-224.
Hildebrand SG, Cushman RM. 1978. Toxicity of gallium and beryllium to developing carp eggs (*Cyprinus carpio*) utilizing copper as a reference. Toxicol Lett 2: 91-95.
Hiraoka Y, Ishizawa S, Kamada T, Okuda H. 1985. Acute toxicity of 14 different kinds of metals affecting medaka fry. Hiroshima Journal of Medical Sciences 34: 327-330.
Hodson PV, Spry DJ, Blunt BR. 1980. Effects on rainbow trout (*Salmo gairdneri*) of a chronic exposure to waterborne selenium. Can J Fish Aquat Sci 3: 233-240.
Hoffmann Gg, Schweiger P, Scholl W. 1982. Aufnahme von Thallium durch landwirtschaftliche und gärtnerische Nutzpflanzen. Landwirtsch Forschung 35: 45-54.
Holdway DA, Sprague JB. 1979. Chronic toxicity of vanadium to flagfish. Water Res 13:

905-910.
Hunn JB, Hamilton SJ, Bucker DR. 1987. Toxicity of sodium selenite to rainbow trout fry. Water Res 21: 233-238.
HydroQual Laboratories Ltd. 1994a. Toxicity test results. Vanadium. *Eisenia foetida*. Calgary, Alberta, Canada: HydroQual Laboratories Ltd. Report no. none. Project 93067-1, tests 940317E1-940317E3.
HydroQual Laboratories Ltd. 1994b. Toxicity test results. Vanadium. *Lactuca sativa*. Calgary, Alberta, Canada: HydroQual Laboratories Ltd. Report no. none. Project 93067-1, tests 940361L1-940361L3.
HydroQual Laboratories Ltd. 1994c. Toxicity test results. Vanadium. *Raphanus sativa*. Calgary, Alberta, Canada: HydroQual Laboratories Ltd. Report no. none. Project 93067-1, tests 940359R1-940359R3.
HydroQual Laboratories Ltd. 1996. Seedling emergence and earthworm toxicity tests on barium and thallium. Calgary, Alberta, Canada: HydroQual Laboratories Ltd. Report no. Report96.doc. 63 pp.
Ibrahim AM, Spacie S. 1990. Toxicity of inorganic selenium to the green alga *Selenastrum capricornutum* Printz. Environ Exp Bot 30: 265-269.
Ingersoll CG, Dwyer FJ, May TW. 1990. Toxicity of inorganic and organic selenium to *Daphnia magna* (Cladocera) and *Chironomus riparius* (Diptera). Environ Toxicol Chem 9: 1171-1181.
Jacobsen T. 1995. Acute toxicity of 16 water-soluble chemicals to the fungus Geotrichum candidum measured by reduction in glucose uptake. Toxic in Vitro 9: `169-173.
Jagoe CH, Matey VE, Haines TA, Komov VT. 1993. Effect of beryllium on fish in acid water in analogous to aluminium toxicity. Aquat Toxicol 24: 241-256.
Jenner HA, Janssen-Mommen JPM. 1993. Duckweed *Lemna minor* as a tool for testing toxicity of coal residues and polluted sediments. Arch Environ Contam Toxicol 25: 3-11.
Johnston PA. 1987. Acute toxicity of inorganic selenium to *Daphnia magna* (Strauss) and the effect of sub-acute exposure upon growth and reproduction. Aquat Toxicol 10: 335-352.
Juhnke I, Lüdemann D. 1978. Ergebnisse der Untersuchung von 200 chemischen Verbindungen auf akute Fischtoxizität mit dem Goldorfentest. Z Wasser-Abwasser-Forsch 11: 161-164.
Juma NG, Tabatabai MA. 1977. Effects of trace elements on phosphatase activity in soils. Soil Sci Soc Am J 41: 343-346.
Kafka Z, Puncocharova J, Svadlenka J, Kuras M. 1997. Determination of acute toxicity of heavy metals. Toxicol Environ Chem 63: 119-124.
Kapur K, Yadav NA. 1982. The effects of certain heavy metal salts on the development of eggs in common carp, *Cyprinus carpio* , var. communis. Acta Hydroch Hydrobiol 10: 517-522.
Khangarot BS, Seghal A, Bhasin MK. 1985. 'Man and biosphere'-Studies on the Sikkim Himalayas. part 5: acute toxicity of selected heavy metals on the tadpoles of the frog *Rana hexadactyla*. Acta Hydroch Hydrobiol 13: 259-263.
Khangarot BS, Ray PK. 1989a. Investigation of correlation between physicochemical properties of metals and their toxicity to the water flea *Daphnia magna* Straus. Ecotoxicol Environ Saf 18: 109-120.
Khangarot BS, Ray PK. 1989b. Sensitivity of midge larvae of *Chironomus tentans* Fabricius (diptera Chironomidae) to heavy metals. Bull Environ Contam Toxicol 42: 325-330.
Khangarot BS. 1991. Toxicity of metals to a freshwater tubificid worm, *Tubifex tubifex* (Muller). Bull Environ Contam Toxicol 46: 906-912.
Kiffney P, Knight AW. 1990. The toxicity and bioaccumulation of selenate, selenite and seleno-DL-methionine in the cyanobacterium *Anabaena flos-aquae*. Arch Environ

Contam Toxicol 19: 488-494.
Kissa E, Moraitou-Apostolopoulou M, Kiortsis V. 1984. Effects of four heavy metals on survival and hatching rate of *Artemia salina* (L.). Arch Hyrdobiol 102: 255-264.
Klaverkamp JF, Hodgins DA, Lutz A. 1983. Selenite toxicity and mercury-selenium interactions in juvenile fish. Arch Environ Contam Toxicol 12: 405-413.
Knie J, Hälke A, Juhnke I, Schiller W. 1983. Ergebnisse der Untersuchungen von chemischen Stoffen mit vier Biotests. DGM 27: 77-79.
Knothe DW, Van Riper GG. 1988. Acute toxicity of sodium molybdate dihydrate (molyhibit 100) to selected saltwater organisms. Bull Environ Contam Toxicol 40: 785-790.
Knudtson BK. 1979. Acute toxicity of vanadium to two species of freshwater fish. Bull Environ Contam Toxicol 23: 9-99.
Krebs F. 1991. Bestimmung der biolgischen Schadwirkung wassergefährdender Stoffe im Assimilations-Zehrungs-Test (A-Z-Test). DGM 35: 161-170.
Krishnaja AP, Rege MS, Joshi AG. 1987. Toxic effects of certain heavy metals (Hg, Cd, Pb, As and Se) on the intertidal crab *Scylla serrata*. Mar Environ Res 21: 109-119.
Krishnamukari L, Varshney PK, Gajbhiye SN, Govindan K, Vijayalakshmi RN. 1983. Toxicity of some metals on the fish Therapon jarbua (Forsskal, 1775). In J Mar Sci 12: 64-66.
Kuperman RG, Checkai RT, Phillips CT, Simini M, Speicher JA, Barclift DJ. 2002. Toxicity assessments of antimony, barium, beryllium, and manganese for development of ecological soil screening levels (Eco-SSL) using Enchytraeid reproduction benchmark values. Aberdeen Proving Ground, MD, USA: Edgewood. Chemical Biological Center. U.S. Army soldier and biological chemical command. Report no. ECBC-TR-324. 84 pp.
Kwan KHM, Smith S. 1988. The effect of thallium on the growth of *Lemna minor* and plant tissue concentrations in relation to both exposure and toxicity. Environ Pollut 52: 203-219.
LeBlanc GA, Dean JW. 1984. Antimony and thallium toxicity to embryos and larvae of fathead minnows (*Pimephales promelas*). Bull Environ Contam Toxicol 32: 565-569.
Lee LH, Lustigman B. 1996. Effect of Barium and Nickel on the growth of *Anacystis nidulans*. Bull Environ Contam Toxicol 56: 985-992.
Liang CN, Tabatabai MA. 1977. Effects of trace elements on nitrogen mineralization in soils. Environ Pollut 12: 141-147.
Liang CN, Tabatabai MA. 1978. Effects of trace elements on nitrification in soils. J Environ Qual 7: 291-293.
Lighthart B, Baham J, Volk VV. 1983. Microbial respiration and chemical speciation in metal-amended soils. J Environ Qual 12: 543-548.
Lilius H, Isomaa B, Holmström T. 1994. A comparison of the toxicity of 50 reference chemicals to freshly isolated rainbow trout hepatocytes and *Daphnia magna*. Aquat Toxicol 30: 47-60.
Lilius H, Hästbacka T, Isomaa B. 1995. A comparison of the toxicity of 30 reference chemicals to *Daphnia magna* and *Daphnia pulex*. Environ Toxicol Chem 14: 2085-2088.
Lin HC, Hwang PP. 1998. Acute and chronic effects of antimony chloride ($SbCl_3$) on tilapia (*Oreochromis mossambicus*). Bull Environ Contam Toxicol 61: 129-134.
Maier KJ, Knight AW. 1993. Comparative acute toxicity and bioconcentration of selenium by the midge *Chironomus decorus* exposed to selenate, selenite and seleno-DL-methionine. Arch Environ Contam Toxicol 25: 365-370.
Maier KJ, Foe CG, Knight AW. 1993. Comparative toxicity of selenate, selenite, seleno-DL-methionine and seleno-DL-cystine to *Daphnia magna*. Environ Toxicol Chem 12: 755-763.
Marr JCA, Hansen JA, Meyer JS, Cacela D, Podrabsky T, Lipton J, Bergmann HL. 1998.

Toxicity of cobalt and copper to rainbow trout: application of a mechanistic model for predicting survival. Aquat Toxicol 43: 225-238.
Martin TR, Holdich DM. 1986. The acute lethal toxicity of heavy metals to peracarid crustaceans (with particular reference to fresh-water asellids and gammarids). Water Res 20: 1137-1147.
Mauk RJ, Brown ML. 1999. Acute toxicity of sodium selenite to juvenile walleye. Bull Environ Contam Toxicol 63: 188-194.
McCloskey JT, Newman MC, Clark SB. 1996. Predicting the relative toxicity of metal ions using ion characteristics: Microtox® bioluminescence assay. Environ Toxicol Chem 15: 1730-1737.
McConnell RP. 1977. Toxicity of molybdenum to rainbow trout under laboratory conditions. In: Chappell WP, Kellogg-Petersen K, eds. Molybdenum in the environment. Volume 2: The geochemistry, cycling and industrial uses of molybdenum). Proceedings of an international symposium on Molybdenum in the environment held in Denver, Colorado. New York: Marcel Dekker. p. 725-730.
Miramand P, Unsal M. 1978. Toxicite aigue du vanadium vis-a-vis de quelques especes benthiques et phytoplanctoniques marines. Chemosphere 10: 827-832.
Morgan JD, Mitchell DG, Chapman PM. 1986. Individual and combined toxicity of manganese and molybdenum to mussel, *Mytilus edulis*, larvae. Bull Environ Contam Toxicol 37: 303-307.
Naddy RB, La Point TW, Klaine SJ. 1995. Toxicity of arsenic, molybdenum and selenium combinations to *Ceriodaphnia dubia*. Environ Toxicol Chem 14: 329-336.
Naleçz-Jawecki G, Sawicki J. 1997. Toxicity of inorganic compounds in the Spirotox Test: a miniaturized version of the *Spirostomum ambiguum* test. Arch Environ Contam Toxicol 34: 1-5.
Nassos PA, Coats JR, Metcalf RL, Brown DD, Hansen LG. 1980. Model ecosystem, toxicity and uptake evaluation of Se-selenite. Bull Environ Contam Toxicol 24: 752-758.
Nelson DA, Miller JE, Calabrese A. 1988. Effect of heavy metals on bay scallops, surf clams, and blue mussels in acute and long-term exposures. Arch Environ Contam Toxicol 17: 595-600.
Neuhauser EF, Meyer JA, Malecki MR, Thomas JM. 1984. Dietary cobalt supplements and the growth and reproduction of the earthworm *Eisenia foetida*. Soil Biol Biochem 16: 521-525.
Niimi AJ, LaHam QN. 1976. Relative toxicity of organic and inorganic compounds of selenium to newly hatched zebrafish (*Bracydanio rerio*). Can J Zool 54: 501-509.
Overnell J. 1975. The effect of some heavy metals ions on photosynthesis in a freshwater alga. Pestic Biochem Physiol 5: 19-26.
Owsley JA, McCauley DE. 1986. Effect of extended sublethal exposure to sodium selenite to *Ceriodaphnia affinis*. Bull Environ Contam Toxicol 36: 876-880.
Palawski D, Hunn JB, Dwyer FJ. 1985. Sensitivity of young striped bass to organic and inorganic contaminants in fresh and saline waters. Trans Am Fish Soc 114: 748-753.
Pawlik-Skowronska B, Kaczorowska R, Skowronski T. 1997. The impact of inorganic tin on the planktonic cyanobacterium *Synechobacterium aquatilis*: the effect of pH and humic acid. Environ Pollut 97: 65-69.
Phillips CT, Checkai RT, Kuperman RG, Simini M, Speicher JA, Barclift DJ. 2002. Toxicity assessments of antimony, barium, beryllium, and manganese for development of ecological soil screening levels (Eco-SSL) using Folsomia reproduction benchmark values. Aberdeen Proving Ground, MD, USA: Edgewood. Chemical Biological Center. U.S. Army soldier and biological chemical command. Report no. ECBC-TR-326. 81 pp.
Plowman MC, Peracha H, Hopfer SM, Sunderman FW. 1991. Teratogenicity of cobalt

chloride in *Xenopus laevis*, assayed by the FETAX procedure. Teratogenesis Carcinog Mutagen 11: 83-92.
Rachlin JW, Grosso A. 1992. The growth response of the green alga *Chlorella vulgaris* to combined divalent cation exposure. Arch Environ Contam Toxicol 24: 16-20.
Ralph L, Twiss MR. 2002. Comparative toxicity of Thallium (I), Thallium (III) and Cadmium (II) to the unicellular alga Chlorella isolated from Lake Erie. Bull Environ Contam Toxicol 68: 261-268.
Reading JT, Buikema Jr AL. 1983. Chronic effects of selenite-selenium on *Daphnia pulex*. Arch Environ Contam Toxicol 12: 399-404.
Ringelband U, Karbe L. 1996. Effects of vanadium on population growth and Na-K-ATPase activity of the brackish water hydroid *Cordylophora caspia*. Bull Environ Contam Toxicol 57: 118-124.
Ringelband U. 2001. Salinity dependence of vanadium toxicity against the brackish water hydroid *Cordylophora caspia*. Ecotoxicol Environ Saf 48: 18-26.
Romney EM, Childress JD. 1965. Effects of beryllium in plants and soil. Soil Sci 100: 210-217.
Rosko JJ, Rachlin JW. 1975. The effect of copper, zinc, cobalt and manganese on the growth of the marine diatom *Nitzschia closterium*. Bull Torrey Bot Club 102: 100-106.
Sauvant MP, Pepin D, Groliere CA, Bohatier J. 1995a. Effects of organic and inorganic substances on the cell proliferation of L-929 fibroblasts and Tetrahymena pyriformis GL protozoa used for toxicological bioassays. Bull Environ Contam Toxicol 55: 171-178.
Sauvant MP, Pepin D, Bohatier J, Groliere CA. 1995b. Microplate technique for screening and assessing cytotoxicity of xenobiotics with *Tetrahymena pyriformis*. Ecotoxicol Environ Saf 32: 159-165.
Sauvant MP, Pepin D, Bohatier J, Groliere CA, Guillot J. 1997. Toxicity assessment of 16 inorganic environmental pollutants by six bioassays. Ecotoxicol Environ Saf 37: 131-140.
Savant KB, Nilkanth GV. 1991. On comparative studies of acute toxicity of hexavalent chromium and selenium to *Scylla serrata* (Forskal). Pollut Res 10: 239-243.
Schultz TW, Freeman SR, Dumont JN. 1980. Uptake, depuration and distribution of selenium in *Daphnia* and its effects on survival and ultrastructure. Arch Environ Contam Toxicol 9: 23-40.
Sharma RM, Panigrahi S, Azeez PA. 1987. Effect of cobalt on the primary productivity of *Spirulina platensis*. Bull Environ Contam Toxicol 39: 716-720.
Sielicki M, Burnham JC. 1973. The effect of selenite on the physiological and morphological properties of the blue-green alga *Phormidium luridum* var. Olivacea. J Phycol 9: 509-514.
Simini M, Checkai RT, Kuperman RG, Phillips CT, Speicher JA, Barclift DJ. 2002. Toxicity assessments of antimony, barium, beryllium, and manganese for development of ecological soil screening levels (Eco-SSL) using earthworm (*Eisenia fetida*) benchmark values. Aberdeen Proving Ground, MD, USA: Edgewood. Chemical Biological Center. U.S. Army soldier and biological chemical command. Report no. ECBC-TR-325. 74 pp.
Singh M, Singh N. 1978. Selenium toxicity in plants and its detoxification by phosphorus. Soil Sci 126: 255-262.
Slonim AR. 1973. Acute toxicity of beryllium sulfate to the common guppy. J Water Poll Control Fed 45: 2110-2122.
Slonim AR, Ray EE. 1975. Acute toxicity of beryllium sulfate to Salamander larvae (*Ambystoma* spp). Bull Environ Contam Toxicol 13: 307-312.
Slonim CB, Slonim AR. 1973. Effect of water hardness on the tolerance of the guppy to beryllium sulfate. Bull Environ Contam Toxicol 10: 295-301.
Smith DP, Kennedy JH, Dickson KL. 1991. An evaluation of a naidid oligochaete as a toxicity test organism. Environ Toxicol Chem 10: 1459-1465.

Snell TW, Moffat BD, Janssen C, Persoone. G. 1991a. Acute toxicity tests using rotifers. III. Effects of temperature, strain and exposure time on the sensitivity of *Branchionus plicatilis*. Environ Toxicol Water Qual 6: 63-75.

Snell TW, Moffat BD, Janssen C, Persoone. G. 1991b. Acute toxicity tests using rotifers. IV. Effects of cyst age, temperature and salinity on the sensitivity of *Branchionus plicatilis*. Environ Toxicol Water Qual 21: 308-317.

Solski A, Piontek M. 1987. The use of the planarian *Dugesia tigrina* Girard for the assessment of chronic intoxications. Pol Arch Hydrobiol 34: 543-550.

Soltanpour PN, Workman SM. 1980. Use of NH_4HCO_3-DTPA soil test to assess availability and toxicity of selenium to alfalfa plants. Commun Soil Sci Plant Anal 11: 1147-1156.

Spangenberg JV, Cherr GN. 1996. Developmental effects of barium exposure in a marine bivalve (*Mytilus californianus*). Environ Toxicol Chem 15: 1769-1774.

Srivastava AK, Agrawal SJ. 1979. Haematological anomalies in a fresh water teleost, *Colisa fasciatus* on acute exposure to cobalt. Acta Pharmacol Toxicol 44: 197-199.

Srivastava DK, Tyagi RK. 1984. Toxicity of selenium and vanadium to the striped gourami, *Colisa fasciatus* (Bloch and Schneider). Acta Hydrobiol 25/26: 481-486.

Stanley RA. 1974. Toxicity of heavy metals and salts to Eurasian watermilfoil (*Myriophyllum spicatum* L.). Arch Environ Contam Toxicol 2: 331-341.

Stendahl DH, Sprague JB. 1982. Effects of water hardness and pH on vanadium lethality to rainbow trout. Water Res 16: 1479-1488.

Tabatabai MA. 1977. Effects of trace elements on urease activity in soils. Soil Biol Biochem 9: 9-13.

Takayanagi K. 2001. Acute toxicity of waterborne Se (IV), Se (VI), Sb (III) and Sb (V) on red seabream (*Pagrus major*). Bull Environ Contam Toxicol 66: 808-813.

Tatara CP, Newman MC, McCloskey JT, Williams PL. 1998. Use of ion characteristics to predict relative toxicity of mono-, di- and trivalent metal ions: *Caenorhabditis elegans* LC50. Aquat Toxicol 42: 255-269.

Taylor D, Maddock BG, Mance G. 1985. The acute toxicity of nine 'grey list' metals (arsenic, boron, chromium, copper, lead , nickel, tin, vanadium and zinc) to two marine fish species: dab (*Limanda limanda*) and grey mullet (*Chelon labrosus*). Aquat Toxicol 7: 135-144.

TN&A Associates I. 2000. Plant toxicity testing to support development of ecological soil screening levels. Oak Ridge, TN USA: National Center for Environmental Assessment (Washington DC, USA). Report no. SC-IDIQ-1999142-29.

Van der Hoeven N. 1990. Effect of 3,4-dichloroaniline and metavanadate on Daphnia populations. Ecotoxicol Environ Saf 20: 53-70.

Vincent M, Debord J, Penicaut B. 1986. Action comparée de la toxicité de chlorures métalliques et d'un milluscicide organique de synthese, la N-trityl-morpholine, sur deux amphipodes dulcaquicoles *Gammarus pulex* et *Echinogammarus berilloni*. Ann Rech Vet 17: 441-446.

Vocke RW, Sears KL, O'Toole JJ, Wildman RB. 1980. Growth responses of selected freshwater algae to trace elements and scrubber ash slurry generated by coal-fired power plants. Water Res 14: 141-150.

Vranken G, Vanderhaeghen R, Heip C. 1991. Effects of pollutants on life-history parameters of the marine nematode *Monhystera disjuncta*. ICES J mar Sci 48: 325-334.

Walsh GE, McLaughlin LL, Lores EM, Louie MK, Deans CH. 1985. Effects of organotins on growth and survival of two marine diatoms, *Skeletonema costatum* and *Thalassiosira pseudonana* . Chemosphere 14: 383-392.

Wan HF, Mikkelsen RL, Page AL. 1988. Selenium uptake by some agricultural crops form central California soils. J Environ Qual 17: 269-272.

Wang JF, Liu Z. 1999. Effect of vanadium on the growth of soybean seedlings. Plant Soil 216: 47-51.
Wang W. 1986. Toxicity tests of aquatic pollutants using common duckweed. Environ Pollut (Ser B) 11: 1-14.
Ward GS, Hollister TA, Heitmuller PT, Parrish PR. 1981. Acute and chronic toxicity of selenium to estuarine organisms. Northeast Gulf Sci 4: 73-78.
Warnick SL, Bell HL. 1969. The acute toxicity of some heavy metals to different species of aquatic insects. J Water Poll Control Fed 41: 280-284.
Watling HR, Watling RJ. 1982. Comparative effects of metals on the filtering rate of the brown mussel (*Perna perna*). Bull Environ Contam Toxicol 29: 651-657.
Weir PA, Hine CH. 1970. Effects of various metals on behavior of conditioned goldfish. Arch Environ Health 20: 45-51.
Wheeler AE, Zingaro RA, Irgolic K. 1982. The effect of selenate, selenite, and sulfate on the growth of six unicellular marine algae. J Exp Mar Biol Ecol 57: 181-194.
Wilke BM. 1989. Long-term effects of different inorganic pollutants on nitrogen transformations in a sandy cambisol. Biol Fertil Soils 7: 254-258.
Williams PL, Dusenbery DB. 1990. Aquatic toxicity testing using the nematode, *Caenorhabditis elegans*. Environ Toxicol Chem 9: 1285-1290.
Wong D, Oliviera L. 1991. Effects of selenite and selenate on the growth and motility of seven species of marine microalgae. Can J Fish Aquat Sci 48: 1193-1200.
Wong PTS, Chau YK, Kramar O, Bengert GA. 1982. Structure-toxicity relationship of tin compounds on algae. Can J Fish Aquat Sci 39: 483-488.
Woodiwiss FS, Fretwell G. 1974. The toxicities of sewage effluents, industrial discharges and some chemical substances to brown trout (*Salmo trutta*) in the Trent river authority area. Water Pollut Control 73: 396-405.

Appendix 9. References of studies not used for risk assessment

Abbott OJ. 1977. The toxicity of ammonium molybdate to marine invertebrates. Mar Pollut Bull 8: 204-205.

Al-Attar AF, Martin MH, Nickless G. 1988. A comparison between selenium and tellurium uptake and toxicity to *Lolium perenne* seedlings. Chemosphere 17: 845-850.

Allus MA, Brereton RG, Nickless G. 1988. Chemometric studies of the effect of toxic metals on plants: The use of response surface methodology to investigate the influence of thallium, cadmium, and silver on the growth of cabbage seedlings. Environ Pollut 52: 169-182.

Allus MA, Martin MH, Nickless G. 1987. Comperative toxicity of thallium to two plant species. Chemosphere 16: 929-932.

Anderson BG. 1948. The apparent thresholds of toxicity to *Daphnia magna* for chlorides of various metals when added to lake Erie water. Trans Am Fish Soc 78: 96-113.

Angle JS, Chaney RL. 1991. Heavy metal effects on soil populations and heavy metal tolerance of *Rhizobium meliloti*, nodulation, and growth of alfalfa. Water, Air, Soil Pollut 57-58: 597-604.

Anke M, Groppel B. 1987. Toxic actions of essential trace elements (Mo, Cu, Zn, Fe, Mn).Trace Element - Analytical Chemistry in Medicine and Biology, Vol. 4. Berlin: Walter de Gruyter & Co. p. 201-236.

Aslam M, Harbit KB, Huffaker RC. 1990. Comparative effects of selenite and selenate on nitrate assimilation in barley seedlings. Plant, Cell Environ 13: 773-782.

Badsha KS, Goldspink CR. 1988. Heavy metals levels in three species of fish in Tjeukemeer, a Dutch polder lake. Chemosphere 17: 459-463.

Banerjee S, Mukherji S. 1995. Toxic effects of selenium and its interaction with sulfur on germination and growth of rice (Oryza sativa L.). Indian Biologist 27: 6-9.

Basu A. 1998. Effect of some fungicides, herbicides and selective nontoxic chemicals on the growth, nodulation and yield of groundnut. Environ Ecol 16: 638-641.

Beyers DW, Sodergren C. 2002. Assessment of exposure of larval razorback sucker to selenium in natural waters. Arch Environ Contam Toxicol 42: 53-59.

Biacs PA, Daood HG, Kádár I. 1995. Effect of Mo, Se, Zn and Cr treatments on the yield, element concentration, and carotenoid content of carrot. J Agric Food Chem 43: 589-591.

Bierkens J, Maes J, Vander Plaetse F. 1998. Dose-dependent induction of heat shock protein 70 synthesis in *Raphidocelis subcapitata* following exposure to different classes of environmental pollutants. Environ Pollut 101: 91-97.

Blaise C, Legault R, Bermingham N, Van Coillie R, Vasseur P. 1986. A simple microplate algal assay technique for aquatic toxicity assessment. Toxicity Assessment: An International Quarterly 1: 261-281.

Blatt CR. 1990. Effect of arsenic and molybdenum on plant response of cauliflower (*Brassica oleracea*) grown in sand culture. Plant nutrition - Physiology and Applications 303-306.

Boisson F, Gnassia-Barelli M, Romeo M. 1995. Toxicity and accumulation of selenite and selenate in the unicellular marine alga *Cricosphaera elongata*. Arch Environ Contam Toxicol 28: 487-493.

Botsford JL. 1998. A simple assay for toxic chemicals using a bacterial indicator. World Journal of Microbiology & Biotechnology 14: 369-376.

Bryan GW, Langstone WJ. 1992. Bioavailability, accumulation and effects of heavy metals in sediments with special reference to United Kingdom estuaries: a review. Environ Pollut 76: 89-131.

Cabejszek I, Stasiak M. 1960. Studies on the influence of some metals on water biocenosis employing *Daphnia magna* index. Roczniki pzh XI: 303-311.

Cabejszek I, Stasiak M. 1960. Studies on the toxic effect of some metals on water biocenosis - *Daphnia magna* employed as index (Part II). Roczniki pzh XI: 533-540.

Carlson CL, Adriano DC, Sajwan KS, Abels SL, Thoma DP, Driver JT. 1991. Effects of selected trace metals on germinating seeds of six plant species. Water, Air, Soil Pollut 59: 231-240.

Cebrian E, Martí R, Uriz JM, Turon X. 2003. Sublethal effects of contamination on the Mediterranean sponge *Crambe crambe*: metal accumulation and biological responses. Mar Pollut Bull 46: 1273-1284.

Chaudry FM, Wallace A, Mueller RT. 1977. Barium toxicity in plants. Commun Soil Sci Plant Anal 8: 795-797.

Cippolini ML, Pickering JL. 1986. Determination of the phytotoxicity of barium in leach-field disposal of gas well brines. Plant Soil 92: 159-169.

Coyle JJ, Buckler DR, Ingersoll CG, Fairchild JF, May TW. 1993. Effect of dietary selenium on the reproductive success of bluegills (*Lepomis macrochirus*). Environ Toxicol Chem 12: 551-565.

Davis RD, Beckett PHT, Wollan E. 1978. Critical levels of twenty potentially toxic elements in young spring barley. Plant Soil 49: 395-408.

Debnath R, Mukherji S. 1982. Barium effects in *Phaseolus aureus*, *Cephalandra indica*, *Canna indica*, *Beta vulgaris*, *Triticum aestivum* and *Lactuca sativa*. Biol Plant 24: 423-429.

Den Dooren de Jong LE. 1965. Tolerance of *Azotobacter* for metallic and non-metallic ions. Antonie van Leeuwenhoek 37: 119-124.

Den Dooren de Jong LE. 1965. Tolerance of *Chlorella vulgaris* for metallic and non-metallic ions. Antonie van Leeuwenhoek 31: 301-313.

Dhillon SK, Dhillon KS. 2000. Selenium adsorption in soils as influenced by different anions. J Plant Nutr Soil Sci 163: 577-582.

Dierickx PJ, Bredael-Rozen E. 1996. Correlation between the *in vitro* cytotoxicity of inorganic metal compoounds to cultured fathead minnow fish cells and the toxicity to *Daphnia magna*. Bull Environ Contam Toxicol 57: 107-110.

Dorfman D. 1977. Tolerance of *Fundulus heteroclitus* to different metals in salt waters. Bull New Jersey Acad Sci 22: 21-23.

Drobne D, Hopkin SP. 1994. Ecotoxicological laboratory test for assessing the effects of chemicals on terrestrial isopods. Bull Environ Contam Toxicol 53: 390-397.

Dubey SK, Rai LC. 1990. Heavy metal toxicity in a N_2-fixing cyanobacterium, *Anabaena doliolum*: regulation of toxicity by certain environmental factors. Biomedical and Environmental Sciences 3: 240-249.

Efroymson RA, Sample BE, Suter II GW. 2001. Uptake of inorganic chemicals from soil by plant leaves: regressions of field data. Environ Toxicol Chem 20: 2561-2571.

Fargašová A. 1994. Toxicity of metals on *Daphnia magna* and *Tubifex tubifex*. Ecotoxicol Environ Saf 27: 210-213.

Fargašová A. 1998. Root growth inhibition, photosynthetic pigments production, and metal accumulation in *Sinapsis alba* as the parameters for trace metals effect determination. Bull Environ Contam Toxicol 61: 762-769.

Farrag EK, Nour El-Deen AFH, Abd El-Azis SA, Rumadan MM, Abdallah NM. 1999. Selenium compounds as molluscides for *Biomphalaria alexandrina* snails. The Egyptian Journal of Biochemistry 17: 235-252.

Fischer E., Molnár L. 1997. Growth and reproduction of *Eisenia fetida* (Oligochaeta, Lumbricidae) in semi-natural soil containing various metal chlorides. Soil Biol Biochem

29: 667-670.
Forsythe II BL, Klaine SJ. 1994. The interaction of sulfate and selenate (Se^{6+}) effects on brine shrimp, *Artemia* spp. Chemosphere 29: 789-800.
Freda J. 1991. The effects of aluminium and other metals on amphibians. Environ Pollut 71: 305-328.
Gissel-Nielsen M, Gissel-Nielsen G. 1975. Selenium in soil-animal relationships. Pedobiologia 15: 65-67.
Gopal R, Dube BK, Sinha P, Chatterjee C. 2003. Cobalt toxicity effects on growth and metabolism of tomato. Commun Soil Sci Plant Anal 34: 619-628.
Grace JK. 1990. Oral toxicity of barium metaborate to the eastern subterranean termite (Isoptera: Rhinotermitidae). J Entomol Sci 25: 112-116.
Hall S, Godwin-Saad E. 1996. Effects of pollutants on freshwater organisms. Wat Environ Res 68: 776-784.
Hamilton SJ, Holley KM, Buhl KJ. 2002. Hazard assessment of selenium to endangered razorback suckers. Sci Total Environ 291: 111-121.
Hamilton SJ, Holley KM, Buhl KJ, Bullard FA, Weston LK, McDonald SF. 1002. Impact of selenium and other trace elements on the endangered adult razorback sucker. Environ Toxicol 17: 297-323.
Hamilton SJ, Palace VP. 2001. Assessment of selenium effects in lotic ecosystems. Ecotoxicol Environ Saf 50: 161-166.
Han G, Cooney JJ. 1995. Effects of butyltins and inorganic tin on chemotaxis of aquatic bacteria. J Indust Microbiol 14: 293-299.
Hardoyo, Kajiwara S, Kato J, Ohtake H. 1993. Bacterial motility as a potential tool for rapid toxicity assays. Biotechnology Techniques 7: 457-462.
Hartley J, Cairney JWG, Freestone P, Woods C, Meharg AA. 1999. The effects of multiple metal contamination on ectomycorrhizal Scots pine (*Pinus sylvestris*) seedlings. Environ Pollut 106: 413-424.
Henderson G. 1989. A comparison of the effects of chromate, molybdate and cadmium oxide on respiration in the yeast Saccharomyces cerevisiae. Biol Metals 2: 83-88.
Hogan GR, Razniak HG. 1991. Selenium-induced mortality and tissue distribution studies in *Tenebrio molitor* (Colopeptera: Tenebrionidae). Environ Entomol 20: 790-794.
Hörnström E. 1990. Toxicity test with algae - a discussion on the batch method. Ecotoxicol Environ Saf 20: 343-353.
HydroQual Laboratories Ltd. 1994. Toxicity test results. Vanadium. *Lactuca sativa*. Calgary, Alberta, Canada: HydroQual Laboratories Ltd. Report no. none. Project 93067-1, tests 940361L1-940361L3.
HydroQual Laboratories Ltd. 1994. Toxicity test results. Vanadium. *Raphanus sativa*. Calgary, Alberta, Canada: HydroQual Laboratories Ltd. Report no. none. Project 93067-1, tests 940344R1, 940344R3, 940344R4.
Hyne RV, Hogan AC, Pablo F, Roach AC. 2002. Toxicity of selenomethionine- and seleno-contaminated sediment to the amphipod *Corophium* sp. Ecotoxicol Environ Saf 52: 30-37.
Ibrahim AM, Spacie S. 1990. Toxicity of inorganic selenium to the green alga *Selenastrum capricornutum* Printz. Environ Exp Bot 30: 265-269.
Jackim E, Hamlin JM, Sonis S. 1970. Effects of metal poisoning on five liver enzymes in the killifish (*Fundulus heteroclitus*). J Fish Res Board Can 27: 383-390.
Janda JM, Fleming RW. 1978. Effect of selenate toxicity on soil mycoflora. J Environ Sci Health A13: 697-706.
Jaworska M, Gorczyca A, Sepiol J, Tomasik P. 1997. Effect of metal ions on the entomopathogenic nematode *Heterorhabditis bacteriophora poinar* (Nematoda: heterohabditidae) under laboratory conditions. Water, Air, Soil Pollut 93: 157-166.

Jaworska M, Sepiol J, Tomasik P. 1996. Effect of metal ions on the entomopathogenic nematode *Steinerma carpocapsae* (Rhabditida: steinernematidae). Water, Air, Soil Pollut 88: 331-341.

Jaworska M, Tomasik P. 1999. Metal-metal interactions in biological systems. Part VI. Effect of some metal ions on mortality, pathogenicity and reproductivity of *Steinernema carpocapsae* and *Heterorhabditis bacteriophora* entomopathogenic nematodes under laboratory conditions. Water, Air, Soil Pollut 110: 181-194.

John SG, Gladden PD, Kenney EP, Johnson MT, Ruggiero CE, Hersman LE, Vanderberg LA, Neu MP. 2000. Metal toxicity in *deinococcus radiodurans*. Division of environmental Chemistry preprints of extended abstracts 40: 426-428.

Juszczak A, Domka F, Seifert K. 1996. The effect of Mo^{2+}, W^{6+}, Cu^{2+} ions on denitrification by *Bacillus Licheniformis*. Polish Journal of Environmental Studies 5: 19-23.

Kampke-Thiel K, Freitag D, Kettrup A, Bahadir M. 1994. Ecotoxicological assessment of inorganic waste disposal in salt mines. Part I: tests with aquatic organisms. Fresenius Envir Bull 3: 113-118.

Kaplan DI, Adriano DC, Carlson CL, Sajwan KS. 1990. Vanadium: toxicity and accumulation by beans. Water, Air, Soil Pollut 49: 81-91.

Kaplan DI, Adriano DC, Sajwan KS. 1990. Thallium toxicity in bean. J Environ Qual 19: 359-365.

Kramer KJM, Jenner HA, De Zwart D. 1989. The valve movement response of mussels: a tool in biological monitoring. Hydrobiologia 188/189: 433-443.

Kudryasheva N, Kratasyuk V, Esimbekova E, Vetrova E, Nemtseva E, Kudinova I. 1998. Development of bioluminescent bioindicators for analysis of envirinmental pollution. Field analytical Chemistry and Technology 2: 277-280.

Kumar MH, Bischoff WL, Jyung WH. The effects of chromium and vanadium on adult survival time of *Drosophila melanogaster*. Chem Res Toxicol XXV: 199-215.

Lachover D, Plaut M, Angel-Malachi. 1958. Some effects of thallium sulfate on plant growth, and its behavior in the soil. Ministry of Agriculture, State of Israel, KTAVIM, Records of the Agricultural Research Station 8: 1-10.

LeBlanc GA. 1980. Acute toxicity of priority pollutants to water flea (*Daphnia magna*). Bull Environ Contam Toxicol 24: 684-691.

Lee LH, Lustigman B, Chu I-Y, Hsu S. 1992. Effect of lead and cobalt on the growth of *Anacystis nidulans*. Bull Environ Contam Toxicol 48: 230-236.

Lee LH, Lustigman B, Murray SR. 2002. Combined effect of mercuric chloride and selenium dioxide on the growth of the cyanobacteria, *Anacystis nidulans*. Bull Environ Contam Toxicol 69: 900-907.

Lee LH, Lustigman B, Murray SR, Koepp S. 1999. Effect of selenium on the growth of the cyanobacterium *Anacystis nidulans*. Bull Environ Contam Toxicol 62: 591-599.

Liao C-M, Lin M-C. 2001. Acute toxicity modeling of rainbow trout and silver sea bream exposed to waterborne metals. Environ Toxicol 16: 349-360.

Llugany M, Poschenrieder C, Barceló. 2000. Assessment of barium toxicity in bush beans. Arch Environ Contam Toxicol 39: 440-444.

Lustigman B, Lee LH, Morata J, Khan F. 2000. Effect of thallium on the growth of *Anacystis nidulans* and *Chlamydomonas reinhardtii*. Bull Environ Contam Toxicol 64: 565-573.

Lustigman B, Lee LH, Weiss-Magasic. 1995. Effect of cobalt and pH on the growth of *Chlamydomonas reinhardtii*. Bull Environ Contam Toxicol 55: 65-72.

Macfie SM, Tarmohamed Y, Welbourn PM. 1994. Effects of cadmium, cobalt, copper and nickel on growth of the green alga *Chlamydomonas reinhardtii*: the influences of the cell wall and pH. Arch Environ Contam Toxicol 27: 454-458.

Malchow DE, Knight AW, Maier KJ. 1995. Bioaccumulation and toxicity of selenium in

Chironomus decorus larvae fed a diet of seliniferous *Selenastrum capricornutum*. Arch Environ Contam Toxicol 29: 104-109.
Manoharan AC, Prabakaran B. 1984. Acute toxicity and genotoxic effect of chromium and selenium on the common loach, Lepidocephalichthys thermalis (Bleeker). Geobios 21: 44-46.
Meisch H-U, Benzschawel H. 1978. The role of vanadium in green plants. III. Influence on cell division of *Chlorella*. Arch Microbiol 116: 91-95.
Minton GA, Wilson RH. 1973. The effect of Ba ions on the growth and mitochondrial metabolism of mung bean seedlings. Plant Soil 39: 611-617.
Moffat BD, Snell TW. 1995. Rapid toxicity assessment using an in vivo enzyme test for *Brachionus plicatilis* (Rotifera). Ecotoxicol Environ Saf 30: 47-53.
Nilsson JR. 1989. Tetrahymena in cytotoxicology: with special reference to effects of heavy metals and selected drugs. Europ J Protistol 25: 2-25.
Nipper MG, Greenstein DJ, Bay SM. 1989. Short- and long-term sediment toxicity test methods with the amphipod *Grandidierella japonica*. Environ Toxicol Chem 8: 1191-1200.
Norberg-King TJ. 1989. An evaluation of the fathead minnow seven-day subchronic test for estimating chronic toxicity. Environ Toxicol Chem 8: 1075-1089.
Obenhuber DC, Huff T. 1999. Microtox toxicity test compared with the daphnid, flathead minnow acute lethality test for use in monitoring wastewater effluent at Nasa, Marshall space flight center. Third aerospace environmental technology conference CP-209258: 700-712.
Pagano G, Cipollaro M, Corsale G, Esposito A, Ragucci E, Giordano GG, Trieff NM. 1986. The sea urchin: bioassay for the assessment of damage from environmental contaminants. Community Toxicity Testing STP 920 : 66-92.
Pandit BR, Prassannakumar PG. 1999. Effect of metals on jowar (*Sorghum bicolour* L.) seedling growth - I. germination, seedling growth and absorption of elements. Pollut Res 18: 459-466.
Passarini F, Rampazzo G, Volpi Ghirardini A, Sperni L, Salizzato M, Pavoni B. 2000. Extraction, identification and quantification of heavy metals in Venice lagoon sediments using toxicity with microorganisms. Annali di Chimica 90: 91-101.
Patel B, Chandy JP, Patel S. 1988. Do selenium and glutathione inhibit the toxic effects of mercury in marine lamellibranchis? Sci Total Environ 76: 147-165.
Pereira AMM, Soares AMVM, Gonçalves F, Ribeiro R. 2000. Water-column, sediment, and *in situ* chronic bioassays with cladocerans. Ecotoxicol Environ Saf 47: 27-38.
Puddu A, Pettine M, La Noce T, Pagnotta R, Bacciu F. 1988. Factors affecting thallium and chromium toxicity to marine algae. Sci Total Environ 71: 572.
Ravera O. 1991. Influence of heavy metals on the reproduction and embryonic development of freshwater pulmonates (Gastropoda; mollusca) and cladocerans (Crustacea; arthropoda). Comp Biochem Physiol 100C: 215-219.
Reish DJ, Oshida PS, Mearns AJ, Ginn TC, Godwin-Saad EM, Buchman M. 1997. Effects of pollution on saltwater organisms. Wat Environ Res 69: 877-892.
Retana J, Parker DR, Amrhein C, Page AL. 1993. Growth and trace element concentrations of five plant species grown in a highly saline soil. J Environ Qual 22: 805-811.
Roméo M. 1991. Toxicologie des métaux traces dans l'environnement marin. Océanis 17: 383-402.
Rueter JG, Petersen RR. 1987. Miconutrient effects on cyanobacterial growth and physiology. New Zealand Journal of Marine and Freshwater Research 21: 435-445.
Sakaguchi T, Nakajima A, Horikoshi T. 1981. Studies on the accumulation of heavy metal elements in biological systems. XVIII. Accumulation of molybdenum by green

microalgae. European J Appl Microbiol Biotechnol 12: 84-89.
Salizzato M, Pavoni B, Volpi Ghirardini A, Ghetti PF. 1998. Sediment toxicity measured using *Vibrio fischeri* as related to the concentrations of organic (PCBs, PAHs) and inorganic (metals, sulphur) pollutants. Chemosphere 36: 2949-2968.
Samantaray S, Rout GR, Das P. 1996. Root growth of *Echinochloa colona*: effects of heavy metals in solution culture. Fresenius Envir Bull 5: 469-473.
Sauvant MP, Pepin D, Piccinni E. 1999. *Tetrahymena pyriformis*: a tool for toxicological studies. A review. Chemosphere 38: 1631-1669.
Seyfried PL, Desjardins RM. 1987. Use of the ATP bioassay to assess toxic effects in marsh treatment systems. Toxicity Assessment: An International Quarterly 2: 29-47.
Shabana EF, El-Attar SA. 1994. Influence of clay minerals on selenium toxicity to algae. Acta Pharmacol Turc 36: 80-91.
Singh BB. 1971. Effect of vanadium on the growth, yield and chemical composition of maize (*Zea mays* L.). Plant Soil 34: 209-212.
Somasundaram R, Muthuchelian K, Murugesan S. 1994. Inhibition of chlorophyll, protein, photosynthesis, nitrate reductase and nitrate content by vanadium in *Oryza sativa* L. J Exp Biol 15: 41-48.
Stemmer BL, Burton Jr. GA, Leibfritz-Frederick S. 1990. Effect of sediment test variables on selenium toxicity to *Daphnia magna*. Environ Toxicol Chem 9: 381-389.
Stokes PM. 1981. Multiple metal tolerance in copper tolerant green algae. J Plant Nutr 3: 667-678.
Sugio T, Katagiri T, Inagaki K, Tano T. 1988. Effect of CO^{2+} on the GSH uptake and release by *Thiobacillus ferrooxidans*. Agricultural and Biological Chemistry 52: 3177-3179.
Tandon SP, Mishra MM. 1968. Effect of some rare elements on nitrification by nitrate forming bacteria in talc medium. Agrochimica XII: 365-368.
Teh SJ, Deng X, Teh F, Hung SO. 2002. Selenium-induced teratogenicity in Sacramento splittail (*Pogonichthys macrolepidotus*). Mar Environ Res 54: 605-608.
Thomulka KW, Lange JH. 1994. Physical, chemical and biological factors affecting a direct bioluminescence-reduction bioassay for *Vibrio harveyi*, a marine bacterium. Journal of Clean Technology and Environmental Sciences 4: 59-77.
Thomulka KW, Lange JH. 1994. Use of *Vibrio harveyi* in an aquatic toxicity test to detect hazardous chemicals in a sand and water interface environment. Journal of Clean Technology and Environmental Sciences 4: 283-294.
Thomulka KW, Lange JH. 1995. Use of the bioluminescent bacterium Vibrio harveyi to detect biohazardous chemicals in soil and water extractions with and without acid. Ecotoxicol Environ Saf 32: 201-204.
Thomulka KW, Schroeder JA, Lange JH. 1997. Use of *Vibrio harveyi* in an aquatic bioluminescent toxicity test to assess the effects of mtal toxicity: treatment of sand and water-buffer, with and without EDTAQ. Environ Toxicol Water Qual 12: 343-348.
Thursby GB, Anderson BS, Wals GE, Steele RL. 1993. A review of the current status of marine algal toxicity testing in the United States. Environmental Toxicology and Risk Assessment 362-377.
Trucco RG, Inda J, Fernandez ML. 1991. Acute toxicity and accumulation of copper, manganese and molybdenum by *Basilichthys australis*. Canadian technical report of fisheries and aquatic sciences 1774: 1132.
Trumble JT, Kund GS, White KK. 1998. Influence of form and quantity of selenium on the development and survival of an insect herbivore. Environ Pollut 101: 175-182.
Wallace A. 1989. Plant responses to some hardly known trace elements and trace element composition and distribution in plants. Soil Sci 147: 461-464.
Wallace A, Alexander GV, Chaudry FM. 1977. Phytotoxicity of cobalt, vanadium, titanium,

silver and chromium. Commun Soil Sci Plant Anal 8: 751-756.
Wallen IE, W.G. Greer, R. Lasater. 1957. Toxicity to *Gambusia affinis* of certain pure chemicals in turbid water. Sewage Ind Wastes 29: 695-711.
Watenpaugh DE, Beitinger TL. 1985. Oxygen consumption in fathead minnows (*Pimephales promelas)* following acute exposure to water-borne selenium. Comp Biochem Physiol, C: Comp Pharmacol Toxicol 80C: 253-256.
Watenpaugh DE, Beitinger TL. 1985. Se exposure and temperature tolerance of fathead minnows, *Pimephales promelas*. J Therm Biol 10: 83-86.
Weber J, Plantikow A, Kreutzmann J. 2000. Ein neuer Biotest mit der Hefe *Saccharomyces cerevisiae* auf aquatische toxizität. Zeitschrift für Umweltchemie und Ökotoxikologie 12: 185-189.
Williams MJ, Ogle RS, Knight AW, Burau RG. 1994. Effects of sulfate on selenate uptake and toxicity in the green alga *Selenastrum capricornutum*. Arch Environ Contam Toxicol 27: 449-453.
Williams PL, Dusenbery DB. 1988. Using the nematode *Caenorhabditis elegans* to predict mammalian acute lethality to metallic salts. Toxicology and Industrial Health 4: 469-478.
Williams RJB, Le Riche HH. 1968. The effect of traces of beryllium on the growth of kale, grass and mustard. Plant Soil XXIX: 317-326.
Woock SE, Garrett WR, Partin WE, Bryson WT. 1987. Decreased survival and teratogenesis during laboratory selenium exposures to bluegill, *Lepomis macrochirus*. Bull Environ Contam Toxicol 39: 998-1005.
Yarzhombek AA, Mikulin AYe, Zhdanova AN. 1991. Toxicity of substances in relation to form of exposure. J Ichthol 31: 99-106.
Young TC, Waltman MR, Theis TL, DePinto JV. 1992. Studies of heavy metal sorption by Trenton Channel (Detroit River) sediments. Hydrobiologia 235/236: 649-660.
Yu R, Coffman JP, Van Fleet-Stalder V, Chasteen TG. 1997. Toxicity of oxyanions of selenium and of a proposed bioremediation intermediate, dimethyl selenone. Environ Toxicol Chem 16: 140-145.
Yuanxun Z, Moro R, Gialanella G. 1996. Toxic effects of selenium on marine fish. Journal of Environmental Sciences 8: 151-156.
Zimakowska-Gnoinska D, Bech J, Tobias FJ. 2000. Assessment of the heavy metal pollution effects on the soil respiration in the baix Llobregat (Catalonia, NE Spain). Environ Monit Assess 61: 301-313.