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R. van Herwijnen | C.E. Smit

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R. van Herwijnen
C.E. Smit

Contact:
R. van Herwijnen
Expertise Centre for Substances
rene.van.herwijnen@rivm.nl

This investigation has been performed by order and for the account of Directorate-General for Environmental Protection, Directorate Environmental Safety and Risk Management, within the framework of the project ‘International and National Environmental Quality Standards for Substances in the Netherlands (INS)’.

RIVM, P.O. Box 1, 3720 BA Bilthoven, the Netherlands Tel +31 30 274 91 11 www.rivm.nl

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Rapport in het kort

Milieurisicogrenzen voor borium

Dit rapport geeft milieurisicogrenzen voor borium in (grond)water en bodem. Milieurisicogrenzen zijn de technisch-wetenschappelijke advieswaarden voor de uiteindelijke milieukwaliteitsnormen in Nederland. De milieurisicogrenzen voor borium zijn gebaseerd op de uitkomsten van de EU risicobeoordeling voor borium (Biociden Richtlijn 98/8). De afleiding van de milieurisicogrenzen sluit tevens aan bij de richtlijnen uit de Kaderrichtlijn Water. De nieuwe milieurisicogrenzen voor oppervlaktewater worden waarschijnlijk niet overschreden in Nederland.

Trefwoorden: milieukwaliteitsnormen; milieurisicogrenzen; borium; maximaal toelaatbaar risiconiveau; verwaarloosbaar risiconiveau

Contents

Summary

Environmental risk limits are derived using ecotoxicological, physico-chemical, and human toxicological data. They represent environmental concentrations of a substance offering different levels of protection to man and ecosystems. It should be noted that the ERLs are scientifically derived values. They serve as advisory values for the Dutch Steering Committee for Substances, which is appointed to set the Environmental Quality Standards (EQSs) from these ERLs. ERLs should thus be considered as preliminary values that do not have any official status.

This report contains ERLs for boron in water, groundwater and soil. The following ERLs are derived for surface water and groundwater: Negligible Concentration (NC), Maximum Permissible Concentration (MPC), Maximum Acceptable Concentration for ecosystems (MAC$_{eco}$), and Serious Risk Concentration for ecosystems (SRC$_{eco}$). A natural background concentration could not be obtained for soil. For this compartment, ERLs could therefore only be expressed in terms of added concentrations. No risk limits were derived for the sediment compartment, because of the relatively low sediment-water partition coefficient. For boron, also no risk limits for the air compartment were derived because release of boron to air will be minimal.
Boric acid and related boron compounds are included in Annex I of Directive 98/8/EC, and are authorised for use as an active ingredient in wood preservatives. The risk limits were solely based on data presented in the Competent Authority Report (CAR) that was prepared within the context of the authorisation procedure under 98/8/EC.

For the derivation of the MPC and MAC$_{eco}$ for water, the methodology used is in accordance with the Water Framework Directive. This methodology is based on the Technical Guidance Document on risk assessment for new and existing substances and biocides (European Commission (Joint Research Centre), 2003). For the NC and the SRC$_{eco}$, the guidance developed for the project ‘International and National Environmental Quality Standards for Substances in the Netherlands’ was used (Van Vlaardingen and Verbruggen, 2007). An overview of the derived environmental risk limits is given below in Table 1 expressed as additions, and in Table 2 as concentrations including background levels.

Monitoring data indicate that the newly derived ERLs for fresh surface water are most likely not exceeded.

Table 1. Derived MPA, NA, MAA$_{eco}$, and SRA$_{eco}$ values for added boron in water and soil.

Compartment	Unit	Environmental Risk Limit			
		MPA	NA	MAA$_{eco}$	SRA$_{eco}$
water	mg B.L^{-1}	0.18	1.8 x 10^{-3}	0.45	6.8
drinking water	mg B.L^{-1}	n.a.	n.a.	n.a.	n.a.
groundwater	mg B.L^{-1}	0.18	1.4 x 10^{-2}	n.a.	6.8
soil	mg B.kg$_{dwt}^{-1}$	0.40	4.0 x 10^{-3}	n.a.	10.9

Table 2. Derived MPC, NC, MAC$_{eco}$, and SRC$_{eco}$ values for boron in water, including background levels.

Compartment	Unit	Environmental Risk Limit			
		MPC	NC	MAC$_{eco}$	SRC$_{eco}$
water	mg B.L^{-1}	0.24	6.4 x 10^{-2}	0.51	6.9
drinking water	mg B.L^{-1}	1.0	n.a.	n.a.	n.a.
groundwater	mg B.L^{-1}	0.19	1.4 x 10^{-2}	n.a.	6.8

1 Introduction

1.1 Project framework

In this report environmental risk limits (ERLs) for surface water (freshwater and marine), soil and groundwater are derived for boron. The risk limits are based on the European risk assessment for the use of several borates as wood preservative under the Biocides Directive 98/8/EC (European Commission, 2008; see 1.4.1). The following ERLs are considered (VROM, 2004):

- Negligible Concentration (NC) – concentration at which effects to ecosystems are expected to be negligible and functional properties of ecosystems must be safeguarded fully. It defines a safety margin which should exclude combination toxicity. The NC is derived by dividing the MPC (see next bullet) by a factor of 100.
- Maximum Permissible Concentration (MPC) – concentration in an environmental compartment at which:
  1 no effect to be rated as negative is to be expected for ecosystems;
  2a no effect to be rated as negative is to be expected for humans (for non-carcinogenic substances);
  2b for humans no more than a probability of 10^{-6} over the whole life (one additional cancer incident in 10^{6} persons taking up the substance concerned for 70 years) can be calculated (for carcinogenic substances) (Lepper, 2005).
- Maximum Acceptable Concentration (MAC_{eco}) – concentration protecting aquatic ecosystems for effects due to short-term exposure or concentration peaks.
- Serious Risk Concentration (SRC_{eco}) – concentration at which serious negative effects in an ecosystem may occur.

It should be noted that ERLs are scientifically derived values, based on (eco)toxicological, fate and physico-chemical data. They serve as advisory values for the Dutch Steering Committee for Substances, which is appointed to set the Environmental Quality Standards (EQSs) from these ERLs. ERLs should thus be considered as preliminary values that do not have any official status.

1.2 Production and use of boron

Borates are intended to be used as a preventive and curative wood preservative for wood and construction timbers. Other uses are for human and veterinary hygiene, in disinfectants, in preservatives and in insecticides. No information is available on production volume and potential quantity of use.

1.3 Current standards for boron

The current freshwater standard for boron is 0.65 mg/L, originating from Van de Plassche et al. (1999). This value refers to a concentration that may be added to the natural background concentration (see 2.2.1). There are no officially established values for background concentrations of boron in the Netherlands.

1.4 European risk assessments for boron

1.4.1 Biocides risk assessment

The European risk assessment for the use of several borates as wood preservative under the Biocides Directive 98/8/EC was finalised in 2008 (European Commission, 2008). The Netherlands acted as Rapporteur Member State. Competent Authority Reports (CAR) were prepared for boric acid, diboron trioxide, disodium tetraborate and disodium octaborate tetraborate. The toxicity data on boron involve a range of different boron compounds such as boric acid (H_3BO_3), anhydrous sodium tetraborate ($Na_2B_4O_7$), and hydrated sodium tetraborates ($Na_2B_4O_7.xH_2O$). Since all naturally occurring forms of boron are oxidised and are present as the boric acid species at the typically found (usual) environmental concentrations and acidity, boric acid was used as a model substance for risk assessment. Considering the fact that boron is the element that is relevant from an (eco)toxicological point of view, all endpoints were converted to concentrations of elemental boron (B).

1.4.2 Future developments

At the SETAC Conference in Götenborg, May 2009, an effects assessment for boron was presented by the Austrian Federal Environment Agency (Schoderboeck et al., 2009). This work was based on the data gathered under the former Existing Substances Regulation (793/93/EEC). A first draft risk assessment report (RAR) dating from October 2007[1] includes the draft biocides CAR of 2006, but the process was discontinued waiting for further developments under REACH (Registration, Evaluation, Authorisation and Restriction of Chemicals; European Commission, 2006). A representative of the notifier of the boron biocides dossier, present at the conference, provided information that boron is pre-registered under REACH and that a full dossier will be submitted within the near future. This dossier will probably be evaluated by Austria, as a follow-up of the RAR. Based on the (new) information submitted under REACH, member states may supplement and/or update the data for boric acid as prepared within the context of the Biocides Directive 98/8/EC, in order to derive a PNEC for biocide authorisation. An update of the ERLs as derived in the present report may then also be considered.

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[1] http://ecb.jrc.ec.europa.eu/DOCUMENTS/Existing-Chemicals/RISK_ASSESSMENT/REPORT/boricacidcrudereport423A.pdf

2 Methods

2.1 Data collection

The final Competent Authority Report (CAR) of boric acid (European Commission, 2008) produced to enable a decision to be made on the inclusion of boric acid in Annex I of Directive 98/8/EC was used as only source of physico-chemical and (eco)toxicity data. Information given in the CARs is checked thoroughly by European Union member states and afterwards approved by the Technical Meeting. Therefore, no additional evaluation of data is performed for the ERL derivation. Only valid data combined in an aggregated data table are presented in the current report. Occasionally, key studies are discussed when relevant for the derivation of a certain ERL.

In the aggregated data table only one effect value per species is presented. When for a species several effect data are available, the geometric mean of multiple values for the same endpoint is calculated where possible. Subsequently, when several endpoints are available for one species, the lowest of these endpoints (per species) is reported in the aggregated data table.

2.2 Methodology for derivation of environmental risk limits

The methodology for data selection and ERL derivation is described in Van Vlaardingen and Verbruggen (2007) which is in accordance with Lepper (2005). Some specific issues are discussed below.

2.2.1 Dealing with background concentrations

Since boron is a natural element, and so is boric acid, the added risk approach is applied in the CAR. In this approach, the specific ERLs as described below are the sum of the calculated addition and the background concentration C_b. The following formulas apply:

$$NC = C_b + NA; \qquad MPC = C_b + MPA; \qquad MAC_{eco} = C_b + MAA_{eco}; \qquad SRC_{eco} = C_b + SRA_{eco}$$

where C_b = background concentration and NA, MPA, MAA_{eco} and SRA_{eco} are the equivalents of NC, MPC, MAC_{eco} and SRC_{eco} (see 1.1) in terms of added concentrations. The background value and MPA (and NA, SRA) are independently derived values. With respect to ecotoxicity, it is assumed that any background concentration, either in laboratory tests or in the environment, does not have a negative impact on ecosystem health. The MPA and related risk limits are calculated using a similar approach as for substances having no natural background concentration, except for drinking water. The MPC_{dw} is always based on total concentrations in water and the background is always part of the MPC_{dw}. Further information on background concentrations of boron is presented in section 3.3.

2.2.2 Boron essentiality

Boron is a naturally occurring element that is essential to a variety of organisms. In plants, it is necessary for a variety of metabolic processes (*e.g.* nitrogen metabolism, nucleic acid metabolism and membrane integrity and stability). A beneficial effect to fish at low concentrations was shown for some fish species (Raymond and Butterwick, 1992). Evidence exists that it is essential for nitrogen fixation in some species of algae, fungi and bacteria, although that was questioned by others (Maier and Knight, 1991). The concentration-response curve for boron may be U-shaped, with adverse effects at very low

and very high concentrations, while no adverse effects are observed at the intermediate concentrations (Loewengart, 2001). Required levels may vary, especially among plants, such that essential levels for one species may be toxic to another (Eisler, 1990).
While evaluating the ecotoxicity data for the CAR, special attention was paid to this phenomenon and endpoints were only used when it was clear the observed effects were due to toxicity rather than to deficiency.

2.2.3 Drinking water abstraction

The INS-Guidance includes the MPC for surface waters intended for the abstraction of drinking water ($MPC_{dw,\ water}$) as one of the MPCs from which the lowest value should be selected as the general MPC_{water} (see INS-Guidance, section 3.1.6 and 3.1.7). According to the proposal for the daughter directive Priority Substances, however, the derivation of the AA-EQS (= MPC) should be based on direct exposure, secondary poisoning, and human exposure due to the consumption of fish. Drinking water was not included in the proposal and is thus not guiding for the general MPC_{water} value. The $MPC_{dw,\ water}$ is therefore presented as a separate value in this report.

The $MPC_{dw,\ water}$ is also used to derive the MPC_{gw}. For the derivation of the $MPC_{dw,\ water}$, a substance specific removal efficiency related to simple water treatment may be needed. Because there is no agreement as yet on how the removal fraction should be calculated, water treatment is not taken into account.

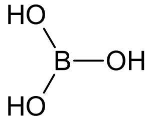
3 Derivation of environmental risk limits for boron

3.1 Substance identification, physico-chemical properties, fate and human toxicology

3.1.1 Identity

Boric acid is one of the natural forms of boron. The boron ion itself does not exist in the environment and all naturally occurring forms of boron are present as boric acid species. Boric acid is used as model substance for risk assessment in the CAR and therefore only the physico chemical properties for boric acid are given unless stated otherwise.

Table 3. Identification of boric acid.

Parameter	Name or number
Chemical name	orthoboric acid
Common/trivial/other name	boric acid
CAS number	10043-35-3 (natural boric acid[a] : 11113-50-1)
EC number	233-139-2 (natural boric acid[a]: 234-343-4)
Structural formula	
Molecular formula:	H_3BO_3
Smiles code	OB(O)O

a: natural boric acid is not assessed in the CAR.

3.1.2 Physico-chemical properties

Table 4. Physico-chemical properties of boric acid.

Parameter	Unit	Value	Remark
Molecular weight	[g.mol^{-1}]	61.83	
Water solubility[a]	[mg.L^{-1}]	48.37	20°C in water, pH of the solution: 3.61-3.62
		54.13	20°C in pH 7 KH_2PO_4 buffer, solution pH: 5.6-5.7
		62.95	20°C in pH 9 tris buffer, solution pH: 5.6-5.7
		66.38	20°C in pH 9 $(NH_4)_2CO_3$ buffer, solution pH: 6.0
log K_{OW}	[-]	-1.09	pH 7.5, 22°C[b]
K_{OC}	[L.kg^{-1}]		a Koc cannot be derived (see section 3.1.3.4)
Vapour pressure	[Pa]	$<10^{-5}$	at ambient temperature, experimental data
Melting point	[°C]	n.a.	decomposition at 97/96 °C
Boiling point	[°C]	n.a.	see melting point
Henry's law constant	[Pa.m^3.mol^{-1}]	n.a.	not applicable because of low volatility

n.a. = not applicable.

a: Water solubility studies at higher pH are not possible, because of the strong buffering capacity of boric acid solutions and ion-pair formation in the presence of alkali-metal ions like sodium and potassium.

b: in a $B(OH)_3$-$NaB(OH)_4$ or $B(OH)_3$-$KB(OH)_4$ system, undissociated boric acid is the only compound extracted into octanol. More values are reported in the CAR but these are for unknown pHs. The difference between log K_{ow} values obtained at different temperatures, different salinity, different concentration and different analysis, is only 0.5 log K_{ow} unit.

3.1.3 Behaviour in the environment

3.1.3.1 Biodegradation

Boron is an inorganic compound and therefore biodegradation is not a relevant pathway.

3.1.3.2 Hydrolysis

Boric acid does not have any chemical bonds prone to hydrolysis. Hydrolysis is therefore not a relevant degradation pathway under environmentally relevant conditions.

3.1.3.3 Photolysis in water

Boric acid is an inorganic compound without any light absorption characteristics in dilute solutions. It is therefore unlikely that the concentration of boric acid in water is influenced by light. Boric acid is therefore considered to be resistant to photochemical degradation.

3.1.3.4 Sorption

In the CAR a $Kp_{soil/solution}$ for boron of 2.6 L/kg is used in the calculations. This Kp is derived from Freundlich sorption coefficients (= K_F from the equation $C_{soil} = K_F$ x ($C_{solution}$^ (1/n)); Kp = K_F when the soil:solution ratio >0.3 and 0.7 < 1/n < 1.1). The Kp is not transformed into a K_{oc} because sorption of boron is highly variable. This is explained by the fact that K_F significantly correlates with not only organic carbon content but also with the clay content, cation exchange capacity, specific surface area and conductivity of the equilibrium solution. It is presumed that the Kp of 2.6 L/kg is also valid for suspended matter.

3.1.4 Bioconcentration and biomagnification

An overview of the bioaccumulation data for boron, is given in Table 5.

Table 5. Overview of bioaccumulation data for boron.

Parameter	Unit	Value	Remark
BCF (fish)	[$L.kg^{-1}$]	0.3	see below
BCF (pacific oyster)	[$L.kg^{-1}$]	1-1.5	see below
BMF	[$kg.kg^{-1}$]	1	Default value since the BCF is < 2000 $L.kg^{-1}$.

The value of 0.3 $L.kg^{-1}$ was determined by Suloway et al. (1983), who exposed fathead minnow (*Pimephales promelas*) and green sunfish (*Lepomis cyanella*) to components of coal fly ash extract containing boron at concentrations ranging from 1.23 to 91.7 $mg.L^{-1}$. The BCF of 1-1.5 $L.kg^{-1}$ for the pacific oyster (*Crassostrea gigas*) was determined in a flow-through experiment at boron concentrations of 1 $\mu g.L^{-1}$ and 10 $\mu g.L^{-1}$ on top of the background. Field data from the Lower San Joaquin River (California, United States) and its tributaries as reported in the CAR indicate that the BAF is < 10 L/kg for fish and < 30 L/kg for plankton and invertebrates.

3.1.5 Human toxicological threshold limits and carcinogenicity

In the CAR the proposed classification according to the 25th ATP of Directive 67/548/EEC is: T, R60, R61 and reproduction category 2. In the CAR a TDI of 0.096 mg $B.kg_{bw}^{-1}.d^{-1}$ is derived from a NOAEL of 9.6 mg $B.kg_{bw}^{-1}.d^{-1}$ disodium tetraborate decahydrate, using an assessment factor of 100.

3.2 Trigger values

This section reports on the trigger values for ERL_{water} derivation (as demanded in WFD framework).

Table 6. Boron/boric acid: collected properties for comparison to MPC triggers.

Parameter	Value	Unit	Method/Source
Log $K_{p,susp-water}$	0.4	[-]	$K_{p,\ susp-water} = Kp_{susp}$ [a]
BAF	10	[$L.kg^{-1}$]	worst case value
BMF	1	[$kg.kg^{-1}$]	
Log K_{OW}	-1.09	[-]	for boric acid
R-phrases	60, 61	[-]	
A1 value	1.0	[mg $B.L^{-1}$]	
DW standard[b]	1.0	[mg $B.L^{-1}$]	

a Since the sorption of boron is controlled by more than the organic carbon content, conversion to standard suspended matter on the basis of organic carbon is not realistic and $K_{p,\ susp-water}$ can be set equal to Kp_{susp}.

b Expressed in elemental boron.

- Boron has a log $K_{p,\ susp-water} < 3$; derivation of $MPC_{sediment}$ is not triggered.
- Boron has a log $K_{p,\ susp-water} < 3$; expression of the MPC_{water} as $MPC_{susp,\ water}$ is not required.
- Boron has a BCF < 100 $L.kg^{-1}$; assessment of secondary poisoning is not triggered.
- Boron has been proposed an R60/61 classification. Therefore, an MPC_{water} for human health via food (fish) consumption ($MPC_{hh\ food,\ water}$) should be derived.

3.3 Background concentrations

The information on background concentrations from the CAR is presented here, together with additional data from more recent sources.

3.3.1 Freshwater

According to Butterwick et al. (1989) boron concentrations in freshwater systems rarely exceed 1.0 mg $B.L^{-1}$ and are usually < 0.1 mg $B.L^{-1}$. For the United States, Parks and Edwards (2005) report a nationwide average boron concentration in freshwater of 0.076 mg $B.L^{-1}$. In a review of European monitoring data, Wyness et al. (2003) report ranges of < 0.001 to 7.5 mg $B.L^{-1}$, the mean 95-percentile concentration over 15 European countries ranges from 0.017 mg $B.L^{-1}$ in the United Kingdom to 0.632 mg $B.L^{-1}$ in Germany. In seven countries, the European drinking water standard of 1.0 mg $B.L^{-1}$ is exceeded in 0.004 to 11.6% of the cases. The data are presented in detail in Table 7.

The data for the Netherlands refer to nine monitoring points in the river Rhine and Meuse catchments. Generally, the concentration of boron in the river Rhine has varied between 0.05 and 0.15 mg $B.L^{-1}$, and between 0.04 and 0.2 mg $B.L^{-1}$ in the river Meuse (Wyness et al., 2003). It can be assumed that these values should not be considered as natural background, since influence of industrial and/or agricultural sources can be expected for these rivers.

Table 7. Boron concentrations in the European Union, copied from Wyness et al. (2003)

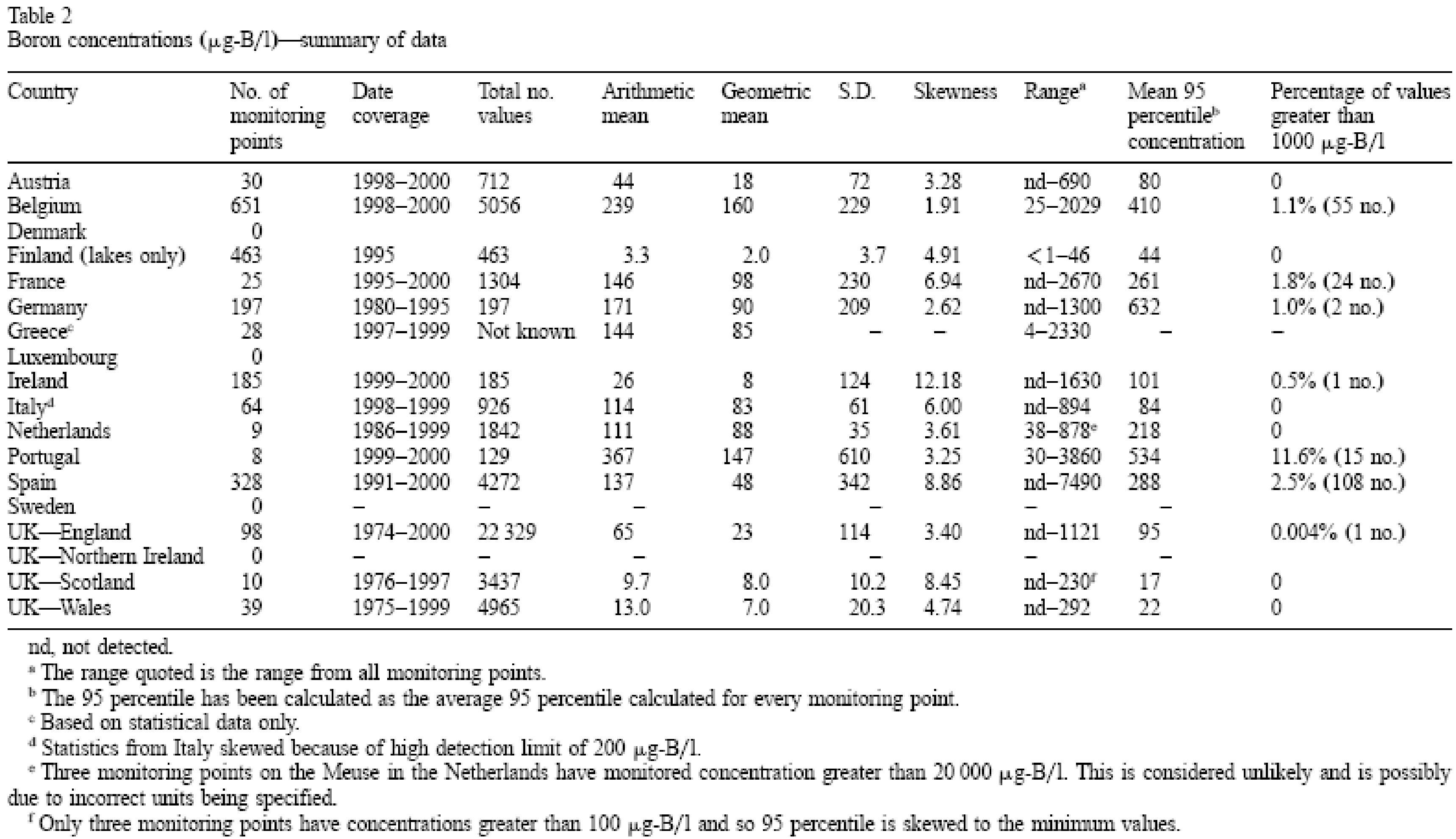


Table 2
Boron concentrations (μg-B/l)—summary of data

Country	No. of monitoring points	Date coverage	Total no. values	Arithmetic mean	Geometric mean	S.D.	Skewness	Range[a]	Mean 95 percentile[b] concentration	Percentage of values greater than 1000 μg-B/l
Austria	30	1998–2000	712	44	18	72	3.28	nd–690	80	0
Belgium	651	1998–2000	5056	239	160	229	1.91	25–2029	410	1.1% (55 no.)
Denmark	0									
Finland (lakes only)	463	1995	463	3.3	2.0	3.7	4.91	<1–46	44	0
France	25	1995–2000	1304	146	98	230	6.94	nd–2670	261	1.8% (24 no.)
Germany	197	1980–1995	197	171	90	209	2.62	nd–1300	632	1.0% (2 no.)
Greece[c]	28	1997–1999	Not known	144	85	–	–	4–2330	–	–
Luxembourg	0									
Ireland	185	1999–2000	185	26	8	124	12.18	nd–1630	101	0.5% (1 no.)
Italy[d]	64	1998–1999	926	114	83	61	6.00	nd–894	84	0
Netherlands	9	1986–1999	1842	111	88	35	3.61	38–878[e]	218	0
Portugal	8	1999–2000	129	367	147	610	3.25	30–3860	534	11.6% (15 no.)
Spain	328	1991–2000	4272	137	48	342	8.86	nd–7490	288	2.5% (108 no.)
Sweden	0	–	–	–		–		–	–	
UK—England	98	1974–2000	22 329	65	23	114	3.40	nd–1121	95	0.004% (1 no.)
UK—Northern Ireland	0	–	–	–		–		–	–	
UK—Scotland	10	1976–1997	3437	9.7	8.0	10.2	8.45	nd–230[f]	17	0
UK—Wales	39	1975–1999	4965	13.0	7.0	20.3	4.74	nd–292	22	0

nd, not detected.

[a] The range quoted is the range from all monitoring points.

[b] The 95 percentile has been calculated as the average 95 percentile calculated for every monitoring point.

[c] Based on statistical data only.

[d] Statistics from Italy skewed because of high detection limit of 200 μg-B/l.

[e] Three monitoring points on the Meuse in the Netherlands have monitored concentration greater than 20 000 μg-B/l. This is considered unlikely and is possibly due to incorrect units being specified.

[f] Only three monitoring points have concentrations greater than 100 μg-B/l and so 95 percentile is skewed to the minimum values.

Kot (2009) also gives an overview of boron concentrations in water (see Table 8). It appears that the mean 95th percentile of 0.218 mg B.L^{-1} as reported by Wyness et al. (2003) for the Rhine and Meuse rivers (see Table 7) is similar to the lower range found in agricultural regions in the United Kingdom (0.193 mg.L^{-1}) and only two times higher than the upper levels found in rural regions in the UK (0.096 mg.L^{-1}). The upper range given for pristine waters in China of 0.51 mg.L^{-1} is even about 2.5 times higher than the 95th percentile for the rivers Rhine and Meuse. This might be interpreted as an indication that the Rhine and Meuse rivers are not so much influenced by human activities, but it is much more likely that there are large differences between countries and/or regions as to what can be considered as natural background levels.

Table 8. Boron concentrations in natural and contaminated waters, copy from Table 4 in Kot (2009)

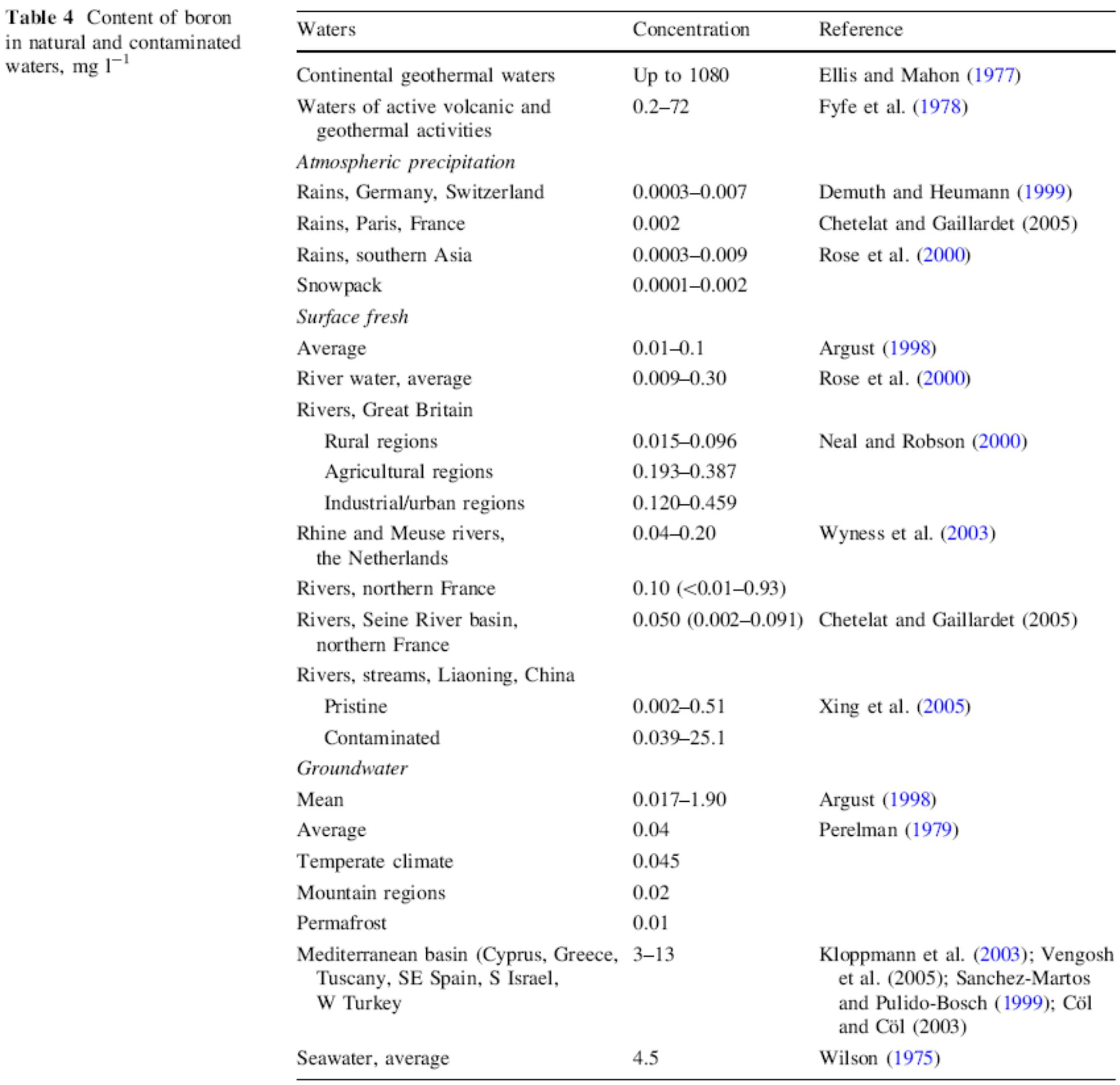


Table 4 Content of boron in natural and contaminated waters, mg l^{-1}

Waters	Concentration	Reference
Continental geothermal waters	Up to 1080	Ellis and Mahon (1977)
Waters of active volcanic and geothermal activities	0.2–72	Fyfe et al. (1978)
Atmospheric precipitation		
Rains, Germany, Switzerland	0.0003–0.007	Demuth and Heumann (1999)
Rains, Paris, France	0.002	Chetelat and Gaillardet (2005)
Rains, southern Asia	0.0003–0.009	Rose et al. (2000)
Snowpack	0.0001–0.002	
Surface fresh		
Average	0.01–0.1	Argust (1998)
River water, average	0.009–0.30	Rose et al. (2000)
Rivers, Great Britain		
Rural regions	0.015–0.096	Neal and Robson (2000)
Agricultural regions	0.193–0.387	
Industrial/urban regions	0.120–0.459	
Rhine and Meuse rivers, the Netherlands	0.04–0.20	Wyness et al. (2003)
Rivers, northern France	0.10 (<0.01–0.93)	
Rivers, Seine River basin, northern France	0.050 (0.002–0.091)	Chetelat and Gaillardet (2005)
Rivers, streams, Liaoning, China		
Pristine	0.002–0.51	Xing et al. (2005)
Contaminated	0.039–25.1	
Groundwater		
Mean	0.017–1.90	Argust (1998)
Average	0.04	Perelman (1979)
Temperate climate	0.045	
Mountain regions	0.02	
Permafrost	0.01	
Mediterranean basin (Cyprus, Greece, Tuscany, SE Spain, S Israel, W Turkey	3–13	Kloppmann et al. (2003); Vengosh et al. (2005); Sanchez-Martos and Pulido-Bosch (1999); Cöl and Cöl (2003)
Seawater, average	4.5	Wilson (1975)

To gain more insight in the levels of boron that may be considered as background for the Netherlands, the database with monitoring information from Dutch Ministry of Transport, Public Works and Water Management (www.waterbase.nl) was consulted (date of search 17 July 2009). Data for boron in filtered and unfiltered samples are present as from 1978, but it appears that boron concentrations declined over time. This may be indicative of anthropogenic sources of boron in the past and therefore, only the more recent data from 2005-2008 were selected. Since boron is not a metal, the MPA$_{water}$

represents total concentrations (see INS-guidance, section 3.1.7.1, point 2), and therefore the data for unfiltered samples were used. For 2005-2008, data are present for 29 locations. An overview of minimum, maximum and geometric mean values per sampling station is given in Table 9 below. Most sampling locations are located large waterbodies or canals, either located in urbanised areas or in regions with a high agricultural activity, and are thus not the type of locations one would refer to as typical for determining the natural background. Since seawater contains much higher boron levels than freshwater, this may influence the measured boron concentrations. Therefore, salinity data are also reported. Locations with a salinity > 0.5 ‰ are considered as brackish or saline and indicated in italics.

Table 9. Total boron concentrations in unfiltered samples over 2005-2008, extracted from www.waterbase.nl. Locations with salinity > 0.5 ‰ are indicated in italics.

	Sampling station	**Location**	**Salinity[a] [‰][a]**	**Boron concentration [µg B.L^{-1}]**			
				min	**max**	**geomean**	**n**
1	*Amsterdam*	*IJ*	*3.0*	*250*	*720*	*458*	*26*
2	*Beerkanaal*	*Maasvlakte*	*15*	*1800*	*3300*	*2418*	*6*
3	Belfeld	River Meuse	0.061	20	83	45	52
4	Bovensluis	Hollandsch Diep	0.12	32	110	56	27
5	Brienenoord	Nieuwe Waterweg	0.17	36	260	64	52
6	Eemmeerdijk	Lake Eem	0.15	64	120	90	27
7	Eijsden ponton	River Meuse	0.056	10	82	33	209
8	Genemuiden	Zwartewater	0.10	33	110	58	39
9	Gouda	River Hollandsche IJssel	0.18	60	380	112	51
10	Haringvlietsluis	Haringvliet	0.14	27	130	57	53
11	*IJmuiden*	*North Sea-canal*	*7.8*	*620*	*1800*	*1062*	*51*
12	Kampen	River IJssel	0.14	32	100	61	39
13	Keizersveer	River Bergsche Maas	0.065	16	110	51	52
14	Ketelmeer	Lake Ketel	0.14	43	91	65	39
15	Lobith ponton	River Rhine	0.14	32	350	62	155
16	*Maassluis*	*Nieuwe Waterweg*	*1.5*	*1*	*1100*	*237*	*104*
17	Markermeer	Lake Markermeer	0.20	96	300	123	39
18	Nederweert	Zuid Willemsvaart	0.065	23	110	49	39
19	Nieuwegein	Lekcanal	0.13	31	97	60	39
20	Nieuwersluis	Amsterdam-Rhine canal	0.093	48	88	62	13
21	Puttershoek	Dordtsche Kil	0.13	27	120	58	53
22	*Sas van Gent*	*Canal Gent - Terneuzen*	*1.2*	*67*	*1100*	*263*	*33*
23	*Schaar van Ouden Doel*	*River Scheldt*	*6.2*	*260*	*2100*	*1052*	*104*
24	*Steenbergen*	*Volkerak*	*0.76*	*120*	*240*	*170*	*33*
25	Stevensweert	River Meuse	0.061	11	74	36	39
26	Veluwemeer	Lake Veluwe	0.25	99	170	127	28
27	Vrouwezand	Lake IJssel	0.19	58	98	74	52
28	Wiene	Twenthe-canal	0.10	38	120	64	39
29	Wolderwijd	Wolderwijd	0.26	110	180	133	27

a: based on geometric mean Cl--values for 2008; converted to ‰ according to section 2.2.3.11 of the INS-guidance; Cl-data provided by Helpdesk Water on 24 and 30 July, 2009.

The high salinity of the IJ in Amsterdam is most likely due to seepage. At some freshwater locations, such as Lake Markermeer and Lake Veluwe, relatively high boron levels are measured. It is not known to what extent local inputs of boron from industrial activities or agriculture play a role. Therefore, it is considered most appropriate to use the median of the geometric mean values of the non-saline sampling points (salinity ≤ 0.5 ‰), which is **62 µg.L^{-1}** (0.062 mg B.L^{-1}), as a background concentration for the purpose of standard setting. It is recognised that this may not represent a true “natural” background, but in the absence of other data it is considered to be an acceptable estimate.

3.3.2 Marine waters

Raymond and Butterwick (1992) state that oceans have a natural level of boron of about 5 mg B.L^{-1}. Kot (2009) cites a level of 4.5 mg B.L^{-1} (see Table 8). The data for the Maasvlakte, which is partly influenced by freshwater input via the Nieuwe Waterweg (see Table 9), indicate that for the Dutch marine environment similar levels may be expected. However, data are scarce, and since no marine ERLs are derived (see below, section 3.4.1), deciding on a natural background level for marine waters is not necessary at this stage.

3.3.3 Soil

Boron concentrations in soil are highly variable, Eisler (1990) reports a range of 4 to 200 mg B.kg^{-1}, mostly as unavailable earth mineral (tourmaline) and a usual level of 45-124 mg B.kg$_{dwt}^{-1}$. In the Environmental Health Criteria on boron (WHO, 1998), a range of 10 – 300 mg B.kg^{-1} is reported with an average background concentration of about 30 mg B.kg^{-1}. Since the data are rather outdated and no specific information is available for the Netherlands, it is not considered justified to set a single natural background level for Dutch soil at this stage.

3.3.4 Groundwater

Boron levels in European groundwaters are presented in the WHO report of 1998. For the Netherlands, concentrations range from 0.08 to 0.6 mg B.L^{-1}. According to Weinthal et al. (2005), groundwater concentrations are most likely influenced by anthropogenic sources. They mention domestic sewage as one of the potential sources, probably because of the addition of boron to detergents. According to the WHO, the close similarity of boron concentrations in groundwater, fresh surface water, and drinking water indicates that boron is not removed in the treatment of groundwater and fresh surface water used for drinking water. The reported groundwater concentrations of 0.08 to 0.6 mg B.L^{-1} for the Netherlands as reported by the WHO seem to be rather high in view of the more recent values for surface water as presented in section 3.3.1. This suggests that the WHO-data refer to contaminated groundwater rather than to natural background levels, and the values should thus not be used as such..
For natural springs (“sprengen”) sampled in 1996 at the Veluwe in the Netherlands, Meinardi et al. (2003) report an average boron concentration of 3.3 µg.L^{-1} for 12 sites with pH > 6. These springs relate to deep groundwater, that has entered the soil before 1945. From this, they calculate a so-called “basic value” for fresh groundwater of 7.0 µg.L^{-1}, which according to their conclusions can be regarded as the natural background concentration for that particular area. Boron was only measured in the Veluwe springs, while for other elements also data from the national and provincial groundwater surveys were available. For those elements that can be compared, concentrations in the Veluwe springs are generally a factor of two lower than those obtained for groundwater, which has entered more recently. This can be explained by the difference in landscape characteristics of the Veluwe at the time the spring water entered the soil, and the current landscape in the rest of the Netherlands. This indicates that the value of 7.0 µg.L^{-1} is most likely not representative for groundwater in general.
The observation that the concentrations in the Veluwe springs are lower than average is confirmed by data from the groundwater monitoring network over 1997 (“Landelijk Meetnet Grondwater”; by courtesy of Herman Prins, RIVM). Data include saline, brackish, and fresh groundwater from several soil type uses (forest, agricultural land, residential areas etc.). Boron concentrations in forest groundwater range from 3.2 to 112 µg B.L^{-1} (n=35; freshwater only), with a median value of 12 µg.L^{-1} and geometric mean of 14 µg.L^{-1}.
It is proposed to use the median boron level in forest groundwater of **12 µg.L^{-1}** (0.012 mg.L^{-1}) as the natural background level for groundwater.

3.4 Toxicity data and derivation of ERLs for water

An overview of the selected freshwater toxicity data for boric acid species as reported in the CAR is given in Table 10. More studies are presented in the CAR. These additional studies were not submitted as part of the dossier, and have not been evaluated in the CAR. Because they would not result in a lower PNEC, they were eventually not used for derivation of the PNEC. Therefore, these studies are not reported in Table 10. Marine toxicity data are not reported in the CAR.

Table 10. Boron: selected freshwater toxicity data for ERL derivation expressed in elemental boron.

Taxonomic group	Chronic NOEC/EC$_{10}$ (mg B.L^{-1})	Acute L(E)C$_{50}$ (mg B.L^{-1})
Algae		
Pseudokirchneriella subcapitata	17.5	44.6
Crustacea		
Daphnia magna	10	141
Pisces		
Catostomus latipinnis		125
Danio rerio	1.8	

3.4.1 Treatment of fresh- and saltwater toxicity data

No marine toxicity data are presented in the CAR, and a PNEC$_{marine}$ is not derived. Boron is a metalloid and in the INS-guidance no specific instructions are given on metalloids. According to Kot (2009), boron has many similarities to carbon and silicon and it can be present in many forms. It is not known whether or not the environmental behaviour of boron should be considered as being comparable to metals. Background concentrations of boron in marine water are much higher than in freshwater (see section 3.3.2), and it is expected that this somehow influences the sensitivity. In view of the above, ERLs for the marine environment are not derived.

3.4.2 Mesocosm studies

No mesocosm studies are reported in the CAR.

3.4.3 Derivation of MPC$_{water}$

3.4.3.1 MPA$_{eco, water}$ and MPC$_{eco, water}$

In the CAR a PNEC$_{add, water}$ of 0.18 mg B.L^{-1} is derived for elemental boron using an assessment factor of 10. The MPA$_{eco, water}$ is set equal to the PNEC$_{add, water}$: 0.18 mg B.L^{-1}. Addition of the background value of 0.062 mg B.L^{-1} results in an MPC$_{eco, water}$ of 0.24 mg B.L^{-1}.

3.4.3.2 MPC$_{sp, water}$

Boron has a BCF < 100 L.kg^{-1}, thus assessment of secondary poisoning is not triggered.

3.4.3.3 MPC$_{hh food, water}$

Derivation of MPC$_{hh food, water}$ is performed according to the method described in Van Vlaardingen and Verbruggen (2007). For this calculation the TDI of 0.096 mg B.kg$_{bw}$$^{-1}$.d^{-1} is used together with the maximum BAF of 10 L.kg^{-1} for fish (see section 3.1.4). The latter replaces the BCF x BMF in equation 16 of the INS-guidance. Since the added-risk approach is not applied for the derivation of the human-toxicological threshold value and the BAF also includes background levels of boron, the calculations refer to total concentrations, including the background. The $MPC_{hh, food}$ = 0.1 * 0.096*70/0.115 = 5.8 mg $B.kg_{food}^{-1}$. The resulting $MPC_{hh food, water}$ is then 5.8 / (10) = 0.58 mg $B.L^{-1}$.

3.4.4 Selection of the MPC_{water}

The lowest value available is the $MPC_{eco, water}$. The MPC_{water} is 0.24 mg $B.L^{-1}$.

3.4.5 Derivation of $MPC_{dw, water}$

A1 and DW standards are available for boron both of 1.0 mg $B.L^{-1}$. According the INS guidance this value should be used to calculate the $MPC_{dw, water}$. As described in section 2.2 water treatment is currently not taken into account. Also the added risk approach does not apply for the $MPC_{dw, water}$. Therefore the $MPC_{dw, water}$ is equal to the drinking water guideline value and becomes: 1.0 mg $B.L^{-1}$.

3.4.6 Derivation of $MAA_{eco, water}$ and $MAC_{eco, water}$

The MAA_{eco} is based on the lowest L(E)C50. This is the algae *Pseudokirchneriella subcapitata* with an L(E)C50 of 44.6 mg $B.L^{-1}$ (see Table 7). An assessment factor of 100 is applied since boron has no potential to bioaccumulate. This sets the $MAA_{eco, water}$ to 0.45 mg $B.L^{-1}$, addition of the background of 0.062 mg $B.L^{-1}$, results in a $MAC_{eco, water}$ of 0.51 mg $B.L^{-1}$.

3.4.7 Derivation of NA_{water} and NC_{water}

The NA_{water} is set a factor of 100 lower than the $MPA_{eco, water}$: 1.8 x 10^{-3} mg $B.L^{-1}$. Addition of the background concentration of 0.062 mg $B.L^{-1}$ results in a NC_{water} of 6.4 x 10^{-2} mg $B.L^{-1}$.

3.4.8 Derivation of $SRA_{eco, water}$ and $SRC_{eco, water}$

For derivation of the $SRA_{eco, aquatic}$ both chronic and acute data are available as presented in Table 10. The geometric mean of the acute values divided by 10 (9.2 mg $B.L^{-1}$) is higher than the geometric mean of the chronic values (6.8 mg $B.L^{-1}$). Therefore the $SRA_{eco, aquatic}$ is the geometric mean of all chronic values with an assessment factor of 1: 6.8/1 = 6.8 mg $B.L^{-1}$. Addition of the background concentration of 0.062 mg $B.L^{-1}$ results in a $SRC_{eco, aquatic}$ of 6.9 mg $B.L^{-1}$. In view of the uncertainty related to behaviour, toxicity and background concentrations in marine waters, the $SRC_{eco, aquatic}$ is only valid for the freshwater environment.

3.5 Toxicity data and derivation of ERLs for sediment

The log $K_{p, susp-water}$ of boron is below the trigger value of 3, according to the INS guidance (Van Vlaardingen en Verbruggen 2007), ERLs need not be derived for sediment. However in the CAR a $PNEC_{add, sed}$ is derived of 0.24 mg $B.kg_{wwt}^{-1}$, based on equilibrium partitioning. Since derivation of ERLs for sediment is not triggered, this ERL is not taken over in this report.

3.6 Toxicity data and derivation of ERLs for soil

An overview of the selected soil toxicity data for boric acid species is given in Table 11.

Table 11. Boron: selected soil toxicity data for ERL derivation expressed in elemental boron.

Taxonomic group	Chronic NOEC/EC_{10} (mg $B.kg_{dwt}^{-1}$)	Acute L(E)C_{50} (mg $B.kg_{dwt}^{-1}$)
Micro-organisms		
dehydrogenase activity		152
nitrification	54	
Macrophyta		
Agropyrion riparium	4 (EC_{20})	
Helianthus annuus		6.74
Hordeum vulgare	2	
Medicago sativa	11	
Sorghum vulgare sudanense	5	
Annelida		
Eisenia andrei	54	609
Eisenia fetida		693
Lumbricus terrestris		473
Insecta		
Folsomia candida	14	
Onychiurus folsomi	31	

3.6.1 Derivation of MPA_{soil}

Because a natural background concentration for soil cannot be established (see section 3.3.3), it is not possible to derive an MPC_{soil}, and only the MPA_{soil} can be derived.

3.6.1.1 $MPA_{eco, soil}$

In the CAR a $PNEC_{add, terrestrial}$ of 0.4 mg $B.kg_{dwt}^{-1}$ is derived. This PNEC is based on de chronic NOEC for *Hordeum vulgare* with an assessment factor of 5. The reasoning for lowering the assessment factor to 5 is discussed in detail in the CAR and is briefly summarised here. Most importantly, from the available data for plants as a group, it appears that the NOEC for *H. vulgare* is at the lower end of the range of toxicity data obtained for sensitive plant species, while there are also boron tolerant plants that show optimum growth at much higher levels (see also 2.2.2). Moreover, in other tests with *H. vulgare*, adverse effects appeared only at much higher concentrations. It was thus considered that the lowest NOEC of 2 $mg.kg^{-1}$ is most likely protective for any other species. This was confirmed by the fact that the $PNEC_{add, terrestrial}$ obtained by equilibrium partitioning using the $PNEC_{add, aquatic}$, is higher. The $MPA_{eco, soil}$ is set equal to the $PNEC_{add, terrestrial}$: 0.4 mg $B.kg_{dwt}^{-1}$. Conversion to Dutch standard soil is not preferred since the sorption of boron to soil is determined by more parameters than organic carbon.

3.6.1.2 $MPA_{sp, soil}$

Boron has a BCF < 100 $L.kg^{-1}$and therefore secondary poisoning is not triggered.

3.6.1.3 $MPA_{human, soil}$

The formulas to derive an $MPA_{human, soil}$ are all log K_{ow}-driven. Since a log K_{ow} is not relevant to boron, the $MPA_{human, soil}$ cannot be derived.

3.6.1.4 Selection of the MPA_{soil}

The only MPA_{soil} is the $MPA_{eco, soil}$. This sets the MPA_{soil} at 0.4 mg $B.kg_{dwt}^{-1}$.
Although no background concentration is available, it is clear from the data presented in section 3.3.3 that the $MPA_{eco, soil}$ is most likely very small as compared to natural background levels. In practice this means that any addition of boron to soil should be avoided.

3.6.2 Derivation of NA_{soil}

The NA_{soil} is set a factor 100 lower than the MPA_{soil}: 4.0×10^{-3} mg $B.kg_{dwt}^{-1}$.

3.6.3 Derivation of $SRA_{eco, soil}$

For derivation of the $SRA_{eco, soil}$ both chronic and acute data are available as presented in Table 11. The geometric mean of the acute values divided by 10 (18.3 mg $B.kg_{dwt}^{-1}$) is higher than the geometric mean of the chronic values (10.9 mg $B.kg_{dwt}^{-1}$). Therefore the $SRA_{eco, soil}$ is the geometric mean of all chronic values with an assessment factor of 1 = 10.9/1 = 10.9 mg $B.kg_{dwt}^{-1}$. Conversion to Dutch standard soil is not preferred since the sorption of boron to soil is determined by more parameters than organic carbon.

3.7 Derivation of ERLs for groundwater

3.7.1 Derivation of MPC_{gw}

3.7.1.1 $MPA_{eco, gw}$ and $MPC_{eco, gw}$

Since groundwater-specific ecotoxicological data are absent, the surface water $MPA_{eco, water}$ of 0.18 mg $B.L^{-1}$ is taken as a substitute for the $MPA_{eco, gw}$. As explained in section 3.3.4, the background concentration for groundwater is set to 0.012 $mg.L^{-1}$. The resulting $MPC_{eco, gw}$ is 0.19 mg $B.L^{-1}$.

3.7.1.2 $MPC_{human, gw}$

The $MPC_{human, gw}$ is set equal to the $MPC_{dw, water}$: Therefore the $MPC_{human, gw}$ = $MPC_{dw, water}$ = 1.0 mg $B.L^{-1}$.

3.7.1.3 Selection of the MPC_{gw}

The lowest MPC_{gw} is the $MPC_{eco, gw}$. This sets the MPC_{gw} at 0.19 mg $B.L^{-1}$..

3.7.2 Derivation of NC_{gw}

The NA_{gw} is a factor of 100 lower than the MPA_{gw}: 1.8×10^{-3} mg $B.L^{-1}$. With the background concentration of 0.012 mg $B.L^{-1}$, the NC_{gw} is 1.4×10^{-2} mg $B.L^{-1}$.

3.7.3 Derivation of $SRC_{eco, gw}$

The $SRA_{eco, gw}$ is set equal to the $SRA_{eco, aquatic}$: 6.8 mg $B.L^{-1}$. With the background concentration of 0.012 mg $B.L^{-1}$, the $SRC_{eco, gw}$ is 6.8 mg $B.L^{-1}$.

3.8 Derivation of ERLs for air

In the CAR is considered that because of the low vapour pressure, release of boron to air will be minimal. Therefore no $PEC_{add, air}$ and no $PNEC_{add, air}$ are derived in the CAR. For the same reason no ERLs will be derived in this report.

3.9 Comparison of derived ERLs with monitoring data

The available monitoring data have been presented in Table 9 above. In the non-saline waters, the maximum concentrations do not exceed the $MAC_{eco,\ water}$ of 0.51 mg $B.L^{-1}$. Since Table 9 shows geometric means over 2005-2008 instead of annual average concentrations, a direct comparison with the MPC_{water} is not possible. The data, however, indicate that MPC_{water} of 0.24 mg $B.L^{-1}$ will not be exceeded in freshwater.

4 Conclusions

In this report, environmental the risk limits (ERLs) are derived for boron in water and groundwater. The following ERLs are considered: Negligible Concentration (NC), Maximum Permissible Concentration (MPC), Maximum Acceptable Concentration for ecosystems (MAC_{eco}), and Serious Risk Concentration for ecosystems (SRC_{eco}). For soil, only ERLs based on added concentrations could be derived, since there is not enough information to establish a natural background concentration. No ERLs were derived for the air compartment because release of borates to air will be minimal, while the trigger to derive ERLs for sediment is not breached.

The environmental risk limits expressed as additions are summarised in Table 12. Risk limits including background concentrations for water, drinking water and groundwater are given in Table 13.

Table 12. Derived MPA, NA, MAA_{eco}, and SRA_{eco} values for additions of boron in water and soil.

Compartment	Unit	Environmental Risk Limit			
		MPA	NA	MAA_{eco}	SRA_{eco}
water	mg $B.L^{-1}$	0.18	1.8×10^{-3}	0.45	6.8
drinking water	mg $B.L^{-1}$	n.a.	n.a.	n.a.	n.a.
groundwater	mg $B.L^{-1}$	0.18	1.4×10^{-2}	n.a.	6.8
soil	mg $B.kg_{dwt}^{-1}$	0.40	4.0×10^{-3}	n.a.	10.9

Table 13. Derived MPC, NC, MAC_{eco}, and SRC_{eco} values for boron in water (including background).

Compartment	Unit	Environmental Risk Limit			
		MPC	NC	MAC_{eco}	SRC_{eco}
water[a]	mg $B.L^{-1}$	0.24	6.4×10^{-2}	0.51	6.9
drinking water	mg $B.L^{-1}$	1.0	n.a.	n.a.	n.a.
groundwater[b]	mg $B.L^{-1}$	0.19	1.4×10^{-2}	n.a.	6.8

a: based on a background concentration of 0.062 mg $B.L^{-1}$.
b: based on a background concentration of 0.012 mg $B.L^{-1}$.

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RIVM

National Institute
for Public Health
and the Environment

P.O. Box 1
3720 BA Bilthoven
The Netherlands
www.rivm.com