

EQS DATASHEET

ENVIRONMENTAL QUALITY STANDARD

ZINC

**On behalf of the
Federal Environment Agency
(Umweltbundesamt, UBA)
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ABBREVIATIONS

AA-EQS	Annual Average Environmental Quality Standard (long-term EQS)
ADI	Acceptable Daily Intake
AF	Assessment Factor
AOEL	Acceptable Operator Exposure Level
BCF	Bioconcentration Factor
BfR	Bundesanstalt für Risikobewertung (Germany)
BMF	Biomagnification Factor
bw	body weight
dm	dry matter
dw	dry weight
EC _x	Concentration at which x % effect is observed
EQS	Environmental Quality Standard
IUPAC	International Union of Pure and Applied Chemistry
LC _x	Concentration at which x % mortality is observed
LOEC	Lowest Observed Effect Concentration: lowest concentration tested at which the measured parameter shows significant inhibition relative to the control
MAC-EQS	Maximum Acceptable Concentration (short-term EQS)
NOAEL	No Observed Adverse Effect Level
NOEC	No Observed Effect Concentration: highest tested concentration for which the observed effect is not significantly different to the controls
PBT	Persistent, Bioaccumulative and Toxic Substances
PEC	Predicted Environmental Concentration
PNEC	Predicted No Effect Concentration
QS _{biota, hh, food}	Quality Standard for humans for the protection against adverse health effects from consuming fisheries products
QS _{biota, secpois}	Quality Standard for biota to protect against secondary poisoning of predators
QS _{fw, eco}	Quality Standard for freshwater community
QS _{sediment}	Quality Standard for the protection of freshwater benthic organisms
QS _{sw, eco}	Quality Standard for saltwater pelagic community (marine waters)
REACH	Registration Evaluation and Authorisation of Chemicals (Regulation (EC) No 1907/2006)
RfD	Reference dose
RIVM	National Institute for Public Health and the Environment (Netherlands)
SSD	Species Sensitivity Distribution
UQN	Umweltqualitätsnorm (German expression for EQS)
vPvB	very Persistent and very Bioaccumulative Substances
WHO	World Health Organisation
WFD	Water Framework Directive (2000/60/EC)
WRRL	Wasserrahmenrichtlinie (German expression for WFD)

1 ZUSAMMENFASSUNG

Chemische Identität

Name	Zink
Chemische Bezeichnung (IUPAC)	Zink (min.)
CAS Name	Zink
Chemische Klasse	Metall
CAS Nummer	7440-66-6
EC Nummer	231-175-3
Summenformel	Zn
SMILES	-
Strukturformel	-
Molekulare Masse (g.mol⁻¹)	65,38

Zink ist ein relativ häufiges Element und kommt in einer durchschnittlichen Konzentration von 76 mg.kg⁻¹ in der Erdkruste vor. In Böden findet man im allgemeinen Gehalte von 50 bis 100 mg.kg⁻¹. In Süßwasser sind die Hintergrundkonzentrationen meist zwischen 3 und 12 µg.l⁻¹ (Gesamtzink), in Sedimenten zwischen 70 und 90 mg.kg⁻¹. Natürliche Konzentrationen in Küstengewässern sind zwischen 0,5 und 1 µg.l⁻¹ berichtet. Die gelöste Hintergrundkonzentration im atlantischen Ozean ist mit 0,1±0,4 µg.l⁻¹ angegeben (European Union 2010).

In der EU werden jährlich über zwei Millionen Tonnen Zink verwendet. Davon werden 38,8 % zum Galvanisieren genutzt, 25,5 % für die Messingproduktion, 12,4 % für Gusslegierungen, 11,8 % für Zinklech und Draht und 2,9 % für Zinkpulver (European Union 2010).

Zink ist ein essentielles Spurenelement für sämtliche Organismen.

Bewertungen und regulatorische Informationen

Annex III UQN Richtlinie (2008/105/EC)	Nicht aufgeführt																																																
Altstoffverordnung (793/93/EC)	<p>Anhang 1 listet Zink und einige seiner Verbindungen:</p> <table border="1"> <thead> <tr> <th>Name</th> <th>Formel</th> <th>EU</th> <th>CAS</th> </tr> </thead> <tbody> <tr> <td>Zink</td> <td>Zn</td> <td>231-175-3</td> <td>7440-66-6</td> </tr> <tr> <td>Zinkoxid</td> <td>OZn</td> <td>215-222-5</td> <td>1314-13-2</td> </tr> <tr> <td>Zinkchlorid</td> <td>Cl₂Zn</td> <td>231-592-0</td> <td>7646-85-7</td> </tr> <tr> <td>Zinkbromid</td> <td>Br₂Zn</td> <td>231-718-4</td> <td>7699-45-8</td> </tr> <tr> <td>Zinksulfat</td> <td>H₂O₄S.Zn</td> <td>231-793-3</td> <td>7733-02-0</td> </tr> <tr> <td>Zinkchromat</td> <td>CrH₂O₄.Zn</td> <td>236-878-9</td> <td>13530-65-9</td> </tr> <tr> <td>Trizinkbis(orthophosphat)</td> <td>H₃O₄P.₃/2Zn</td> <td>231-944-3</td> <td>7779-90-0</td> </tr> <tr> <td>Naphthalinsäuren, Zinksalze</td> <td></td> <td>234-409-2</td> <td>12001-85-3</td> </tr> <tr> <td>Zinkdistearat</td> <td>C₁₈H₃₆O₂.½Zn</td> <td>209-151-9</td> <td>557-05-01</td> </tr> <tr> <td>Triammoniumpentachlorzinkat(3-)</td> <td>Cl₅Zn.3H₄N</td> <td>238-688-1</td> <td>14639-98-6</td> </tr> <tr> <td>Fritte, Chemikalien</td> <td></td> <td>266-047-6</td> <td>65997-18-4</td> </tr> </tbody> </table>	Name	Formel	EU	CAS	Zink	Zn	231-175-3	7440-66-6	Zinkoxid	OZn	215-222-5	1314-13-2	Zinkchlorid	Cl ₂ Zn	231-592-0	7646-85-7	Zinkbromid	Br ₂ Zn	231-718-4	7699-45-8	Zinksulfat	H ₂ O ₄ S.Zn	231-793-3	7733-02-0	Zinkchromat	CrH ₂ O ₄ .Zn	236-878-9	13530-65-9	Trizinkbis(orthophosphat)	H ₃ O ₄ P. ₃ /2Zn	231-944-3	7779-90-0	Naphthalinsäuren, Zinksalze		234-409-2	12001-85-3	Zinkdistearat	C ₁₈ H ₃₆ O ₂ .½Zn	209-151-9	557-05-01	Triammoniumpentachlorzinkat(3-)	Cl ₅ Zn.3H ₄ N	238-688-1	14639-98-6	Fritte, Chemikalien		266-047-6	65997-18-4
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Biozide (98/8/EC)	Anhang 1 listet Zink und einige seiner Verbindungen.																																																
PBT Substanzen	Nicht gekennzeichnet als PBT Substanz (gemäß Verordnung (EU) No. 253/2011 Annex XIII (European Union 2011))																																																
Substanzen mit besonderer Besorgnis (1907/2006/EC)	Nein																																																
POPs (Stockholm Konvention)	Nein																																																
Endokrine Wirkung	Nicht belegt, basierend auf den verfügbaren Informationen																																																

Verhalten in der Umwelt

Zink ist ubiquitär und für sämtliche Organismen essentiell. Die Bioverfügbarkeit von Zink und seinen Verbindungen in Gewässern wird durch physiko-chemische Parameter (gelöster organischer Kohlenstoff, Calcium-Konzentration, pH-Wert) bestimmt. Im Süßwasserkompartiment ist eine Einschätzung der Bioverfügbarkeit mittels Biotic Ligand Model (BLM) möglich. BLM berücksichtigt die geringere Bioverfügbarkeit und die damit reduzierte Toxizität von komplex gebundenem Zink. Zink und seine Verbindungen sind nicht flüchtig. Der Bioabbau ist für Metalle nicht relevant.

Ableitung der Umweltqualitätsnormen

Zum Schutz aquatischer Organismen nach WRRL, Anhang 5 WFD (2000/60/EC) wurde die niedrigste der Qualitätsnormen ($AA-QS_{\text{freshwater, eco}} 10,9 \mu\text{g.L}^{-1}$) als 'Gesamt' UQN vorgeschlagen. Es ist zu prüfen, ob zum Schutz des Rohwassers für die Trinkwassergewinnung ein separater Wert festzulegen ist.

Vorläufige QN_{water}	Relevante Studie für QN Ableitung	Bewertungs-faktor	Vorläufige QN
$MAC_{\text{freshwater, eco}}$	'generische' HC5 von $10,9 \mu\text{g.L}^{-1}$ bioverfügbares Zn (UK Environment Agency 2010)	ACR = 3	$33 \mu\text{g.L}^{-1}$ bioverfügbares Zn
$MAC_{\text{marine waters, eco}}$	HC5 = $6,1 \mu\text{g.L}^{-1}$ (Bodar 2007)	AF = 2 ACR = 3	$9,0 \mu\text{g.L}^{-1}$ gelöstes Zn
$AA-QS_{\text{freshwater, eco}}$	'generische' HC5 von $10,9 \mu\text{g.L}^{-1}$ bioverfügbares Zn (UK Environment Agency 2010)	1	$10,9 \mu\text{g.L}^{-1}$ bioverfügbares Zn
$AA-QS_{\text{marine waters, eco}}$	HC5 = $6,1 \mu\text{g.L}^{-1}$ (Bodar 2007)	2	$3,0 \mu\text{g.L}^{-1}$ gelöstes Zn
$AA-QS_{\text{freshwater, sed.}}$	<i>Hyalella azteca</i> 6 w NOEC = $488000 \mu\text{g.kg}^{-1}_{\text{dw}}$ (European Union 2010, UK Environment Agency 2010)	10	$49000 \mu\text{g.kg}^{-1}_{\text{dw}}$
$AA-QS_{\text{marine waters, sed.}}$	---	---	Keine Daten

Daten zur chronischen Toxizität von Zink gegenüber Süßwasserorganismen liegen in ausreichender Qualität für 25 Spezies aus acht taxonomischen Gruppen vor: Algen, Amphibien, Kleinkrebse, Fische, Insekten, Mollusken, Rädertiere und Schwämme. Spezies-spezifische NOECs wurden nach Normalisierung hinsichtlich der physiko-chemischen Wasserparameter, die eine hohe Bioverfügbarkeit von Zink begünstigen ($0,52 \text{ mg.L}^{-1}$ gelöster organischer Kohlenstoff, mittlere Ca Konzentration von $1,6 \text{ mg.L}^{-1}$ und mittlerer pH von 6,29) in einer SSD verwendet. Dabei wurde eine 'generische' HC5 von $10,9 \mu\text{g.L}^{-1}$ bioverfügbares Zn berechnet, die 95 % der sensitiven Regionen schützt (UK Environment Agency 2010). Die Quantität der Daten, die taxonomische Diversität und die Berücksichtigung der Bioverfügbarkeit sowie entsprechende Daten aus Freiland und Mesokosmen zeigen, dass ein Bewertungsfaktor >1 nicht benötigt wird. Damit ist der vorgeschlagene $AA-QS_{\text{freshwater}} 10,9 \mu\text{g.L}^{-1}$.

Der MAC-QS_{freshwater} kann aus dem AA-EQS_{freshwater} als akut/chronisch Extrapolation berechnet werden. Mit dem AA-QS_{water} von 10,9 µg.L⁻¹ (UK Environment Agency 2010) und einem ACR von 3 wird ein extrapoliertes **MAC-QS_{water} von 33 µg.L⁻¹ bioverfügbares Zn** erhalten.

Daten zur chronischen Toxizität von Zink gegenüber marinen Spezies liegen in ausreichender Qualität für sechs taxonomische Gruppen vor: Algen, Anneliden, Hohltiere, Kleinkrebse, Stachelhäuter und Mollusken. Bodar (2007) nutzte 28 Spezies-spezifische NOECs um eine HC5 von 6,1 µg.L⁻¹ gelöstes Zink in Salzwasser zu berechnen. Weil chronische Daten für marine Fische fehlen, diese aber anhand der akuten Toxizitätsdaten als wenig sensitiv eingeschätzt werden können, wird ein Bewertungsfaktor von 2 als ausreichend angesehen für die Ableitung des **AA-QS_{marine water} von 3,0 µg.L⁻¹**.

Die Anwendung eines ACR von 3 auf den vorgeschlagenen AA-EQS_{marine water} von 3,0 µg.L⁻¹ (Bodar 2007) ergibt einen extrapolierten **MAC-QS_{marine water} von 9,0 µg.L⁻¹**.

Der niedrigste chronische NOEC für die benthische Spezies *Hyallela azteca* (488000 µg.kg⁻¹_{dw}) und ein Bewertungsfaktor von 10 resultiert für Süßwasser in einem **AA-QS_{sediment} von 49000 µg.kg⁻¹_{dw}**. Dieser Wert liegt jedoch im Bereich der geogenen Hintergrundkonzentration. In Deutschland wurde für unbelastete Bachsedimente ein Median von 93200 µg.kg⁻¹_{dw} ermittelt (Birke et al. 2006).

Es ist zu diskutieren ob der 'added risk approach' angewendet werden sollte. Weiterhin ist zu klären ob der vorgeschlagene AA-QS_{freshwater, eco} von 10.9 µg.L⁻¹ ausreichend protektiv für benthische Spezies ist oder ob zusätzlich ein EQS für Sediment und/oder Schwebstoffe benötigt wird.

Bioakkumulation und Anreicherung entlang von Nahrungsketten ist für Zink nicht relevant. Ein QS_{secpois} wurde nicht abgeleitet.

Es wurde keine Bewertung für Rückstände in aquatischen Biota im Hinblick auf die menschliche Gesundheit durchgeführt, da für Zink keine gentoxischen, karzinogenen oder reproduktionstoxischen Eigenschaften festgestellt wurden. Ein QS_{hh} wurde nicht abgeleitet.

Existierende UQN Vorschläge für Zink

PNEC aquatic für gelöstes Zink in Süßwasser	7,8 µg.L ⁻¹	European Union 2010
AA-UQN-Rhein für Süßwasser	7,8 µg.L ⁻¹	(IKSR 2009)
AA-EQS für Süßwasser	10,9 µg.L ⁻¹	(UK Environment Agency 2010)
AA-EQS für Meerwasser	3 µg.L ⁻¹	(Bodar 2007)
AA-UQN-Rhein für Meerwasser	3 µg.L ⁻¹	(IKSR 2009)
MAC-EQS für Süßwasser	23,4 µg.L ⁻¹	(European Union 2010)
MAC-EQS für Süßwasser	33 µg.L ⁻¹	(UK Environment Agency 2010)
Zielwert für SPM (Oberflächenwasser)	400 mg.kg ⁻¹	(Anonymous 2003)
AA-UQN für SPM (Oberflächenwasser)	800 mg.kg ⁻¹	(OGewV 2011)

2 CHEMICAL IDENTITY

Common name	Zinc
Chemical name (IUPAC)	Zinc (min.)
CAS name	Zinc
Chemical class	Metal
CAS number	7440-66-6
EC number	231-175-3
Molecular formula	Zn
SMILES	
Molecular structure	
Molecular weight (g.mol ⁻¹)	65.38

3 EXISTING EVALUATIONS AND REGULATORY INFORMATION

Annex III EQS Dir. (2008/105/EC)	Not included			
Existing Substances Reg. (793/93/EC)	Annex 1 lists Zinc and several of its compounds:			
	Name	Formula	EU	CAS
	Zinc	Zn	231-175-3	7440-66-6
	Zinc oxide	OZn	215-222-5	1314-13-2
	Zinc chloride	Cl ₂ Zn	231-592-0	7646-85-7
	Zinc bromide	Br ₂ Zn	231-718-4	7699-45-8
	Zinc sulphate	H ₂ O ₄ S.Zn	231-793-3	7733-02-0
	Zinc chromate	CrH ₂ O ₄ .Zn	236-878-9	13530-65-9
	Trizinc bis(orthophosphate)	H ₃ O ₄ P.3/2Zn	231-944-3	7779-90-0
	Naphthenic acids, zinc salts		234-409-2	12001-85-3
	Zinc distearate, pure	C ₁₈ H ₃₆ O ₂ .½Zn	209-151-9	557-05-01
	Triammonium pentachloro-zincate(3-)	Cl ₅ Zn.3H ₄ N	238-688-1	14639-98-6
	Frits, chemicals		266-047-6	65997-18-4
Pesticides (91/414/EEC)	Annex 1 lists Zinc and several of its compounds:			
	Number	Common name, identification numbers	IUPAC Name	
	54	Propineb CAS No 12071-83-9 (monomer), 9016-72-2 (homopolymer) CIPAC No: 177	Polymeric zinc 1,2-propylenebis (dithiocarbamate)	
	74	Ziram CAS No 137-30-4 CIPAC No 31	Zinc bis (dimethyldithiocarbamate)	
	115	Mancozeb CAS No 8018-01-7 (ehem. 8065-67-5) CIPAC No 34	Manganese ethylenebis (dithiocarbamate) (polymeric) complex with zinc salt	
	115	Metiram CAS No 9006-42-2 CIPAC No 478	Zinc ammoniate ethylenebis (dithiocarbamate) – poly [ethylenebis(thiuram-disulfide)]	
319	Zinkphosphid CAS No 1314-84-7 CIPAC No 69	Trizinc diphosphide		

EC Directive 1107/2009	Not included
Biocides (98/8/EC)	Annex 1 lists Zinc and several of its compounds.
PBT substances	Not designated as PBT substance (according to Regulation (EU) No. 253/2011 Annex XIII (European Union 2011))
Substances of Very High Concern (1907/2006/EC)	No
POPs (Stockholm convention)	No
Endocrine disrupter	There are no indications based on available information

Existing EQS for zinc

PNEC aquatic for dissolved zinc in freshwater	7.8 µg.L ⁻¹	(European Union 2010)
AA-UQN-Rhine for freshwater	7.8 µg.L ⁻¹	(IKSR 2009)
AA-EQS for freshwater	10.9 µg.L ⁻¹	(UK Environment Agency 2010)
AA-EQS for marine water	3 µg.L ⁻¹	(Bodar 2007)
AA-UQN-Rhine for marine water	3 µg.L ⁻¹	(IKSR 2009)
MAC-EQS for freshwater	23.4 µg.L ⁻¹	(European Union 2010)
MAC-EQS for freshwater	33 µg.L ⁻¹	(UK Environment Agency 2010)
Target value for SPM (surface water)	400 mg.kg ⁻¹	(Anonymous 2003)
AA-UQN for SPM (surface water)	800 mg.kg ⁻¹	(OGewV 2011)

4 PROPOSED QUALITY STANDARDS (QS)

4.1 Environmental Quality Standard (EQS)

The AA-EQS (Annual Average Environmental Quality Standards) represent conditions of high bioavailability and so should be protective of sensitive areas. SCHER (Scientific Committee on Health and Environmental Risks) (2012) agrees on the way the AA-EQS for freshwater has been derived (10.9 µg/l bioavailable Zn) by the UK Environment Agency (2010).

Aiming at the protection of aquatic organisms in accordance with WFD Annex 5 the lowest (AA-QS_{freshwater, eco}) of the thresholds is proposed as an 'overall' EQS. It is to be verified whether a separate value for the protection of raw water for drinking water production is needed.

	Value	Comments
Proposed AA-EQS for freshwater [µg.L⁻¹] Proposed AA-EQS for marine waters [µg.L⁻¹]	10.9 3.0	Critical QS is AA-QS _{freshwater, eco} See section 8.3
Proposed MAC-EQS for freshwater [µg.L⁻¹] Proposed MAC-EQS for marine waters [µg.L⁻¹]	33 9.0	See section 8.2

4.2 Specific Quality Standard (QS)¹

Protection objective	Unit	Value	Comments
Pelagic community (freshwater)	[$\mu\text{g}\cdot\text{L}^{-1}$]	10.9	See section 8.3
Pelagic community (marine waters)	[$\mu\text{g}\cdot\text{L}^{-1}$]	3.0	
Benthic community (freshwater)	[$\mu\text{g}\cdot\text{kg}^{-1}_{\text{dw}}$]	49000	See section 8.4
Benthic community (marine)	[$\mu\text{g}\cdot\text{kg}^{-1}_{\text{dw}}$]	No data available	
Predators (secondary poisoning)	[$\mu\text{g}\cdot\text{l}^{-1}$]	Not relevant	See section 8.5
Human health via consumption of fishery products	[$\mu\text{g}\cdot\text{L}^{-1}$]	Not relevant	See section 8.6
Human health via consumption of water	[$\mu\text{g}\cdot\text{L}^{-1}$]	Not relevant	See section 8.6

A substantial body of laboratory ecotoxicity data is available for zinc. Chronic freshwater ecotoxicity data of adequate quality are available for 25 species from eight taxonomic groups: algae (2 species of unicellular and 1 species of multicellular), amphibians (1 species), crustaceans (4 species), fish (8 species), insects (1 species), molluscs (2 species), rotifers (2 species) and sponges (4 species). The species NOECs have been used as input data to an SSD after normalization to a target water of physico-chemical conditions that favour high bioavailability (0.52 mg.L⁻¹ dissolved organic carbon, mean Ca concentration of 1.6 mg.L⁻¹ and mean pH of 6.29). To provide 95 % protection for the most sensitive region, a ‘generic’ HC5 of 10.9 $\mu\text{g}\cdot\text{L}^{-1}$ bioavailable Zn has been proposed (UK Environment Agency 2010). Based on quantity of data, taxonomic diversity and consideration of bioavailability as well as evaluation of field and mesocosm data there is no evidence that there is a need for an AF>1. Thus, the **proposed AA-QS_{freshwater} is 10.9 $\mu\text{g}\cdot\text{L}^{-1}$.**

The MAC-QS_{freshwater} may be derived from the high quality AA-EQS_{freshwater} based on an ACR of 3. With the AA-QS_{water} value of 10.9 $\mu\text{g}\cdot\text{L}^{-1}$ (UK Environment Agency 2010) and an ACR of 3, an extrapolated **MAC-QS_{water} of 33 $\mu\text{g}\cdot\text{L}^{-1}$ bioavailable Zn** is obtained.

Marine species are also well-represented with chronic NOECs for saltwater species from six taxonomic groups: algae (unicellular and multicellular), annelids, coelenterates, crustaceans, echinoderms, and molluscs. Bodar (2007) used a large number (28) of species mean values from various taxonomic groups to calculate a median 5th percentile value of 6.1 $\mu\text{g}\cdot\text{L}^{-1}$ for dissolved zinc in saltwater. Because chronic data for fish are lacking in the marine data set, but on the other hand acute toxicity for marine fish indicate that they have a rather low sensitivity to zinc compared to other species being sufficiently covered in the marine data set, an assessment factor of 2 is considered appropriate for the derivation of the marine AA-QS, resulting in a **AA-QS_{marine water} value of 3.0 $\mu\text{g}\cdot\text{L}^{-1}$.**

¹ Please note that as recommended in the Technical Guidance for deriving EQS, “EQSs [...] are not reported for ‘transitional and marine waters’, but either for freshwater or marine waters”. If justified by substance properties or data available, QS for the different protection objectives are given independently for transitional waters or coastal and territorial waters.

Application of an ACR of 3 to the tentative AA-EQS_{marine water} of 3 µg.L⁻¹ (Bodar 2007) results in an extrapolated **MAC-QS_{marine water} of 9.0 µg.L⁻¹**.

For freshwater sediments the lowest chronic NOEC for the benthic species *Hyallela azteca* (488000 µg.kg⁻¹_{dw}; based on single-species laboratory studies) and an AF of 10 results in an **AA-QS_{sediment} of 49000 µg.kg⁻¹_{dw}**. This value is in the range of geogenic background concentration. In Germany a median of 93,200 µg.kg⁻¹_{dw} was determined for sediments of unpolluted brooks and streams (Birke et al. 2006).

Secondary poisoning is considered to be not relevant in the effect assessment of zinc. An assessment for secondary poisoning was not performed. A QS_{secpois} was not derived.

Zinc and zinc compounds do not meet the criteria for classification and labelling for carcinogenic, mutagenic, reproduction and/or high chronic toxicity. QS_{biota, hh} and QS_{dw, hh} assessments were not performed within this project. A QS_{hh} was not derived.

5 MAJOR USES AND ENVIRONMENTAL EMISSIONS

Zinc occurs naturally in average concentrations of 76 mg.kg⁻¹ in the earth crust. Generally, soil contents range between 50 and 100 mg.kg⁻¹. The background concentrations of total zinc are usually between 3 and 12 µg.l⁻¹ in freshwaters and between 70 and 90 mg.kg⁻¹ in sediments. Reported values for the natural concentrations in coastal seas are 0.5 and 1 µg.l⁻¹. The dissolved background concentration for the Atlantic Ocean is reported to be 0.1±0.4 µg.l⁻¹ (European Union 2010). Zinc is an essential element for many species.

5.1 Summary of uses and quantities

The International lead and zinc study group (2013) (ILZSG) released data for world zinc supply and demand during 2012:

000 tonnes	2007	2008	2009	2010	2011	2011 2012		2012			
						Jan -	Dec	Sep	Oct	Nov	Dec
Mine production	11201	11882	11608	12486	12948	12948	13604	1186.4	1167.5	1168.6	1198.1
Metal production	11345	11772	11282	12885	13120	13120	12660	1015.3	1078.0	1105.1	1147.3
Metal Usage	11229	11574	10920	12637	12754	12754	12395	1033.5	1064.6	1024.1	1093.4

Source: ILZSG

The International lead and zinc study group (2013) also reported annual data for Europe:

000 tonnes	2008	2009	2010	2011	2012	Change 2012-2011	
							%
Mine production	1061	1010	1008	1034	1055	21	2.1%
Refined production	2476	2050	2382	2437	2404	-32	-1.3%
Refined consumption	2626	1939	2488	2525	2352	-173	-6.8%

5.2 Summary of estimated environmental emissions

Environmental emission data for the Netherlands indicate that the emissions from agriculture to surface waters account for ~ 30 % of total emissions, and qualify as discharges of “significant quantities”, as described by the WDF Annex VIII for pollutants.

Zinc emissions to water, soil and air in the Netherlands in t/yr in 2000, 2005 and 2007.

Source: Deltares, 2009. www.prtr.nl

Year	Source	Waste water	Surface water	Soil	Air
2000	Agriculture	1.2	145	1.548	0.0049
	Industry	22	33		56
	Waste treatment	9.1	0.9	2.3	0.12
	Traffic	38	175	113	35
	Consumers	192	1.9	4.2	5.0
	Trade and services	32	0.4	9.1	
	Effluents STP		101		
	Nature	57	324	70	
	Others	0.19	32	3.2	0.0006
	Total		352.06	813.80	1.749.82
Year		Waste water	Surface water	Soil	Air
2005	Agriculture	2.3	97	917	8
	Industry	23	22		38
	Waste treatment	5.2	0.6	2.3	0.01
	Traffic	42	177	110	38
	Consumers	208	0.8	3.7	4.8
	Trade and services	33	0.25	8.9	0.02
	Effluents STP		85		
	Nature	35	200	65	
	Others	0.13	30	5.0	0.0003
	Total		348.82	613.17	1.112.46
Year		Waste water	Surface water	Soil	Air
2007	Agriculture	2.1	156	822	9.0
	Industry	15	14		42
	Waste treatment	5	0.7	2.3	0.26
	Traffic	43	178	107	39
	Consumers	206	0.38	3.3	4.8
	Trade and services	29	0.01	7.8	0.03
	Effluents STP		84		
	Nature	34	192	50	
	Others	0.06	29	6.6	0.0003
	Total		333.55	654.02	999.43

6 ENVIRONMENTAL BEHAVIOUR

6.1 Environmental distribution

		Master reference
Water solubility (g.L⁻¹)	Insoluble as solid metal. Hence, only the results of tests with soluble zinc salts are used.	(European Union 2010)
Volatilisation		
Vapour pressure (Pa)	31 Pa at 450°C	(European Union 2010)
Henry's Law constant (Pa.m³.mol⁻¹)	Not applicable	(European Union 2010)
Adsorption		
Organic carbon – water partition coefficient (K_{oc})	Not applicable	
Suspended matter – water partition coefficient (K_{susp-water})	K _{susp-water} = 110000 L.kg ⁻¹	(European Union 2010)
Sediment – water partition coefficient (K_{susp-water})	K _{sed-water} = 73000 L.kg ⁻¹	(European Union 2010)
Bioaccumulation		
Octanol-water partition coefficient (log K_{ow})	Not applicable	

CF (measured)	<p>Bioaccumulation and biomagnification (i.e. accumulation and transfer through the food chain, possibly causing secondary poisoning) of zinc in animals is considered to be not relevant in the effect assessment of zinc. Major decision points for this conclusion are the following. The accumulation of zinc, an essential element, is regulated in animals of several taxonomic groups, for example in molluscs, crustaceans, fish and mammals. In mammals, one of the two target species for secondary poisoning, both the absorption of zinc from the diet and the excretion of zinc, are regulated. This allows mammals, within certain limits, to maintain their total body zinc level (whole body homeostasis) and to maintain physiologically required levels of zinc in their various tissues, both at low and high dietary zinc intakes. The results of field studies, in which relatively small differences were found in the zinc levels of small mammals from control and polluted sites, are in accordance with the homeostatic mechanism. These data indicate that the bioaccumulation potential of zinc in both herbivorous and carnivorous mammals will be low. Based on the above data, evaluation of quality standards for protection of top predators from secondary poisoning and protection of human health from consumption of fishery products are deemed not relevant.</p>	(Bodar 2007, European Union 2010, UK Environment Agency 2010)
BCF (calculated)	Not applicable	

6.2 Abiotic and biotic degradations

Abiotic and biotic degradation are not relevant parameters for the environmental fate of metals.

		Master reference
Hydrolysis	Not applicable	
Photolysis	Not applicable	
Biodegradation	Not applicable	

7 AQUATIC ENVIRONMENTAL CONCENTRATIONS

7.1 Background concentrations

The concentrations of zinc in surface waters (both marine waters and freshwater) are dependent on natural conditions: it is almost impossible to determine experimentally a natural background concentration in Europe. Due to geochemical differences, the natural background concentrations differ around Europe. In addition, since the concentrations that are measured in the environment are the sum of anthropogenic and 'natural' sources, one cannot simply distinguish the 'natural' part from the anthropogenic part. Hence, background concentrations are not measured, but estimated or determined with other methods (European Union 2010, UK Environment Agency 2010).

		Master reference
Surface open ocean	Range 0.001 – 0.06 µg.L ⁻¹	(European Union 2010, UK Environment Agency 2010)
Dissolved concentration in deep Atlantic Ocean water	0.1 ± 0.4 µg.L ⁻¹	
Coastal seas	Range 0.5 – 1 µg.L ⁻¹	
European Freshwater	3 – 12 µg total Zn.L ⁻¹	
Freshwater Sediment	Range: 70-175 mg.kg ⁻¹ _{dw}	
Germany, Background Freshwater	Median: 3 µg Zn.L ⁻¹ 90-percentile: 15.7 µg Zn.L ⁻¹	(Birke et al. 2006)
Germany, Background Freshwater Sediment	Median: 93,2 mg.kg ⁻¹ _{dw} 90-percentile: 267 mg.kg ⁻¹ _{dw}	

Examples of estimates of average region specific bioavailability factors are given in the following Table (UK Environment Agency 2010).²

River basin or Region	Average Zinc Bioavailability
Meuse River (Belgium/Netherlands)	0.8
Elbe	0.5
Main	0.7
Mosel	0.7
Flanders Region (Belgium)	0.6
Walloon Provinces Region (Belgium)	0.7
Netherlands Region	0.3
Rhine Meuse region (France)	0.6
Rhone Region (France)	0.9
UK (England & Wales) – average of 86 rivers	0.56

² Average bioavailability factors taken from EU RA except for UK which is calculated from 86 river sites monitored for compliance against the Freshwater Fish directive.

7.2 Estimated concentrations

The EU RAR gives calculated PECs in a theoretical EU-region and the Netherlands (NL) region (European Union 2010).

	EU-region	NL-region
Compartment		
PEC air	0.01 $\mu\text{g}\cdot\text{m}^{-3}$	0.006 $\mu\text{g}\cdot\text{m}^{-3}$
PEC water	16.8 $\mu\text{g}\cdot\text{L}^{-1}$ (total)	12.2 $\mu\text{g}\cdot\text{L}^{-1}$ (total)
PEC sediment	268 $\text{mg}\cdot\text{kg}^{-1}_{\text{ww}}$	194 $\text{mg}\cdot\text{kg}^{-1}_{\text{ww}}$
PEC soil agricultural	56.8 $\text{mg}\cdot\text{kg}^{-1}_{\text{ww}}$	56.5 $\text{mg}\cdot\text{kg}^{-1}_{\text{ww}}$
PEC soil natural	0.9 $\text{mg}\cdot\text{kg}^{-1}_{\text{ww}}$	0.5 $\text{mg}\cdot\text{kg}^{-1}_{\text{ww}}$
PEC soil industrial	86 $\text{mg}\cdot\text{kg}^{-1}_{\text{ww}}$	38 $\text{mg}\cdot\text{kg}^{-1}_{\text{ww}}$

Assuming 15 $\text{mg}\cdot\text{L}^{-1}$ suspended solids, the PEC for total Zn in water, calculated for EU-region, of 16.8 $\mu\text{g}\cdot\text{L}^{-1}$ was used to derive a freshwater PEC of 6.3 $\mu\text{g}\cdot\text{L}^{-1}$ added dissolved zinc (UK Environment Agency 2010).

7.3 Measured concentrations

Most recent information about monitored zinc data, with details by country, by water body type (river Water, lake water, transitional water, coastal water) and by fraction (benthos, whole fish, fish liver, macro invertebrate, molluscs, mussel, water dissolved fraction, whole water, SPM, sediment fraction <2mm, <63 μm , <20 μm) are available online (Office International de l'Eau 2013).

8 EFFECTS AND QUALITY STANDARDS

A Risk Assessment Report (RAR) for Zinc and Zinc compounds has been prepared and published (European Union 2010), reflecting the status of May 2008. Based on a rich data base, the PNEC is based on extrapolation using an SSD using 18 chronic NOECs normalised to physico-chemistry relating to water quality conditions that reflect protection of 95 % of European watercourses. The derivation resulted in a median 5th percentile value (HC5) of 15.6 $\mu\text{g}\cdot\text{L}^{-1}$ and justified the use of an assessment factor of 2. The PNEC_{aquatic} of 7.8 $\mu\text{g}\cdot\text{L}^{-1}$ for dissolved zinc in freshwater was considered sufficiently protective for the most sensitive species and for the field situation.

In 2010, the UK conducted a review (UK Environment Agency 2010), which modified the conclusions drawn in the RAR in the light of new information. It developed a 'generic' EQS for zinc that aims to afford protection to waters in which zinc is highly bioavailable. The approaches taken in the EU RAR and by UK have much in common i.e. both take account of bioavailability of zinc but differ in the input data, the way in which bioavailability is dealt with and the levels of protection afforded.

Bioavailability of zinc (UK Environment Agency 2010): Zinc exists in the +2 oxidation state in forms that are dependent on physicochemical parameters, particularly pH, hardness and the

content of dissolved organic carbon. Bioavailability and toxicity may be affected by organic and inorganic complexation, with anions such as chloride (Cl^-) and carbonate (CO_3^{2-}), and by the competition of cations (e.g. Ca^{2+} , Mg^{2+} , Na^+ and H^+) with zinc at biological receptors. These abiotic factors may vary considerably in freshwater environments.

Biotic Ligand Models (BLMs) have been developed for zinc which account for the effects of these factors, reducing substantially the observed variation in ecotoxicity to organisms when tests are carried out in different waters.

The UK tiered approach to EQS implementation (UK Environment Agency 2010): Because of variations in key water quality characteristics, the bioavailability of zinc will vary across different locations. This means that a risk may exist at one location but the same concentration of dissolved zinc does not pose a risk at another location because much less of the zinc is actually in a form that is bioavailable.

For an EQS that can be applied across all MSs, the 'generic' EQS should be protective even under 'worst case' conditions, i.e. 100 % bioavailability. Measured total zinc concentrations below the 'generic' EQS pass the compliance check at the first tier. If the measured zinc concentration exceeds the 'generic' EQS, bioavailability is taken into account at subsequent tiers using BLMs³ (initially screening versions of BLMs in conjunction with local measurements of key water quality parameters (pH, DOC and [Ca]), or default values where these are not available). If a sample still exceeds the 'generic' EQS after bioavailability is accounted for, then local background levels of zinc may be considered. If these steps do not help to meet the zinc EQS, good chemical status may not have been achieved and remedial measures may be needed.

8.1 Acute and chronic aquatic ecotoxicity

Toxicity data were taken from the EU RAR (European Union 2010), as also used by IKS (2009) and Bodar (2007), and the UK EQS dossier (UK Environment Agency 2010). The toxicity data were not subjected to additional quality assessment as experts had already assessed these.

A substantial body of laboratory ecotoxicity data is available for zinc. Chronic freshwater ecotoxicity data of adequate quality are available for 25 species from eight taxonomic groups: algae (2 species of unicellular and 1 species of multicellular), amphibians (1 species), crustaceans (4 species), fish (8 species), insects (1 species), molluscs (2 species), rotifers (2 species) and sponges (4 species). Not all these data were available in 2008 when the RAR was carried out. Marine species are also well-represented with chronic NOECs for saltwater species from six taxonomic groups: algae (unicellular and multicellular), annelids, coelenterates, crustaceans, echinoderms and molluscs.

³ 'Full' BLMs take account of all water quality factors that affect zinc bioavailability whilst 'screening' BLMs are restricted to the main factors (DOC, pH and hardness). Estimates of bioavailable concentrations of zinc using the 'screening' BLMs tend to be more conservative (lower) than those derived using the 'full' BLMs.

ACUTE EFFECTS

			Master reference
Algae & aquatic plants	Freshwater	<i>Selenastrum capricornutum</i> 72 h ErC50 = 136 µg.L ⁻¹ (lowest value still valid after revision of dataset (UK Environment Agency 2010))	(European Union 2010)
	Marine	No data	
Invertebrates	Freshwater	<i>Daphnia magna</i> 48 h LC50 = 70 µg.L ⁻¹	(European Union 2010)
		<i>Daphnia magna</i> 48 h LC50 = 76 µg.L ⁻¹	(UK Environment Agency 2010)
		<i>Daphnia magna</i> 48 h LC50 species geomean = 244 µg.L ⁻¹ (n=9; data obtained under most sensitive conditions)	(UK Environment Agency 2010)
	Marine	EC50: 170 – 950000 µg.L ⁻¹	(European Union 2010)
	Sediment	No data	
Fish	Freshwater	<i>Oncorhynchus mykiss</i> 96 h LC50 = 136 µg.L ⁻¹	(European Union 2010)
		<i>Oncorhynchus mykiss</i> 96 h LC50 = 170 µg.L ⁻¹	(UK Environment Agency 2010)
	Marine	EC50: 190 – 83000 µg.L ⁻¹ (majority: 3000 – 30000)	(European Union 2010)

LONG-TERM EFFECTS

			Master reference
Algae & aquatic plants	Freshwater	<i>Pseudokirchneriella subcapitata</i> 72 h NOEC: 4.9 – 124 µg.L ⁻¹ Geometric mean (n = 25) = 17 µg.L ⁻¹	(European Union 2010)
		<i>Pseudokirchneriella subcapitata</i> 72 h NOEC: 4.9 – 65 µg.L ⁻¹ Geometric mean (n = 5) = 25.5 µg.L ⁻¹ (high bioavailability conditions)	(UK Environment Agency 2010)
		<i>Cladophora glomerata</i> 3 d NOEC = 60 µg.L ⁻¹ (C _{nominal})	(European Union 2010)
		<i>Chlorella sp</i> 48h NOEC/EC10: 4.9 µg.L ⁻¹	(UK Environment Agency 2010)
	Marine	<i>Amphidinium carteri</i> 9 d NOEC = 100 µg.L ⁻¹ (C _{nominal})	(European Union 2010)
		<i>Asterionella japonica</i> 72 h NOEC: 7 – 40 µg.L ⁻¹ Geometric mean (n = 7) = 15 µg.L ⁻¹ (C _{nominal})	(European Union 2010)
		<i>Chaetoceros compressum</i> 72 h NOEC = 10 µg.L ⁻¹ (C _{nominal})	(European Union 2010)
		<i>Gymnodinium splendens</i> 5 w NOEC = 500 µg.L ⁻¹ (C _{nominal})	(European Union 2010)
		<i>Nitzschia closterium</i> 72 h NOEC: 10 - 40 µg.L ⁻¹ Geometric mean (n = 2) = 20 µg.L ⁻¹ (C _{nominal})	(European Union 2010)
		<i>Phaeodactylum tricorutum</i> 2 w NOEC = 500 – 10000 µg.L ⁻¹ Geometric mean (n = 3): 2700 µg.L ⁻¹ (C _{nominal})	(European Union 2010)
		<i>Prorocentrum micans</i> 5 w NOEC = 100 µg.L ⁻¹ (C _{nominal})	(European Union 2010)

		<i>Rhizosolenia spp.</i> 12/24-h NOEC = 15 µg.L ⁻¹ (C _{nominal})	(European Union 2010)
		<i>Schroederella schroederi</i> 11 d NOEC = 10 µg.L ⁻¹ (C _{nominal})	(European Union 2010)
		<i>Scrippsiella faeroense</i> 7 w NOEC = 100 µg.L ⁻¹ (C _{nominal})	(European Union 2010)
		<i>Skeletonema costatum</i> 10 d NOEC = 7 – 200 µg.L ⁻¹ Geometric mean (n = 9): 32 µg.L ⁻¹ (C _{nominal})	(European Union 2010)
		<i>Thalassiosira pseudonana</i> 9/14 d NOEC = 100 – 200 µg.L ⁻¹ Geometric mean (n = 2): 140 µg.L ⁻¹ (C _{not reported})	(European Union 2010)
		<i>Thalassiosira rotula</i> 14 d NOEC = 10 µg.L ⁻¹ (C _{nominal})	(European Union 2010)
		<i>Thalassiosira guillardii</i> 10/14-d NOEC = 200 µg.L ⁻¹ (C _{not reported})	(European Union 2010)
		<i>Laminaria hyperborea</i> 4 w NOEC = 100 µg.L ⁻¹ (C _{nominal})	(European Union 2010)
Invertebrates	Freshwater crustaceans	<i>Ceriodaphnia dubia</i> 7 d NOEC = 14 – 100 µg.L ⁻¹ Geometric mean (n = 13): 37 µg.L ⁻¹ (C _{nominal})	(European Union 2010)
		<i>Daphnia magna</i> 21 d NOEC = 31 – 420 µg.L ⁻¹ Geometric mean (n = 27): 88 µg.L ⁻¹ (C _{analysed})	(European Union 2010)
		<i>Daphnia longispina</i> NOEC = 70.5 µg.L ⁻¹	(UK Environment Agency 2010)
		<i>Hyalella azteca</i> NOEC = 42 µg.L ⁻¹ (C _{analysed})	(European Union 2010)
	Freshwater insects	<i>Chironomus tentans</i> 8 w NOEC = 137 µg.L ⁻¹ (analysed-C _{background})	(European Union 2010)
	Freshwater molluscs	<i>Dreissena polymorpha</i> 10 w NOEC = 400 µg.L ⁻¹ (C _{nominal})	(European Union 2010)
		<i>Potamopyrgus jenkinsi</i> 16 w NOEC = 75 µg.L ⁻¹ (C _{nominal})	(European Union 2010)
	Freshwater rotifers	<i>Anuraeopsis fissa</i> NOEC = 48 µg.L ⁻¹	(UK Environment Agency 2010)
		<i>Brachionus rubens</i> NOEC = 24 µg.L ⁻¹	(UK Environment Agency 2010)
	Freshwater sponges	<i>Ephydatia fluviatilis</i> 7 d NOEC = 43 µg.L ⁻¹ (C _{nominal})	(European Union 2010)
		<i>Ephydatia muelleri</i> 7 d NOEC = 43 µg.L ⁻¹ (C _{nominal})	(European Union 2010)
		<i>Spongilla lacustris</i> 7 d NOEC = 65 µg.L ⁻¹ (C _{nominal})	(European Union 2010)
		<i>Eunapius fragilis</i> 7 d NOEC = 43 µg.L ⁻¹ (C _{nominal})	(European Union 2010)
	Marine annelids	<i>Capitella capitata</i> 25/40 d ? NOEC = 320 µg.L ⁻¹ (C _{not reported})	(European Union 2010)
		<i>Ctenodrilus serratus</i> 21-31 d NOEC: 100 µg.L ⁻¹ Geometric mean (n = 2) = 100 µg.L ⁻¹ (C _{nominal})	(European Union 2010)
		<i>Nereis arenaceodentata</i> 4 m ? NOEC = 100 µg.L ⁻¹ (C _{not reported})	(European Union 2010)
		<i>Ophryotrocha diadema</i>	(European Union 2010)

		3-4 w NOEC: 100 µg.L ⁻¹ Geometric mean (n = 2) = 100 µg.L ⁻¹ (C _{nominal})	Union 2010)
	Marine coelenterates	<i>Eirene viridula</i> 3 m NOEC = 300 µg.L ⁻¹ (C _{nominal})	(European Union 2010)
	Marine crustaceans	<i>Callianassa australiensis</i> 14 d NOECs = 440 µg.L ⁻¹ (C _{not reported})	(European Union 2010)
		<i>Holmesimysis costata</i> 7 w NOEC = 18 µg.L ⁻¹ (C _{analysed})	(European Union 2010)
		<i>Mysidopsis bahia</i> NOEC = 120 µg.L ⁻¹ (C _{not reported})	(European Union 2010)
	Marine echinoderms	<i>Arbacia lixula</i> 4 d NOEC = 10 µg.L ⁻¹ (C _{not reported})	(European Union 2010)
	Marine molluscs	<i>Crassostrea gigas</i> 5 d NOEC = 50 µg.L ⁻¹ (C _{nominal})	(European Union 2010)
		<i>Haliotis refescens</i> 9 d NOEC = 19 µg.L ⁻¹ (C _{not reported})	(European Union 2010)
		<i>Mercenaria mercenaria</i> 8 d NOEC = 50 µg.L ⁻¹ (C _{nominal})	(European Union 2010)
		<i>Scrobicularia plana</i> 14 d NOECs = 1000 µg.L ⁻¹ (C _{nominal})	(European Union 2010)
	Sediment oligochaetes	<i>Tubifex tubifex</i> 4 w NOEC = 1135000 µg.kg ⁻¹ _{dw} (C _{analysed})	(European Union 2010)
	Sediment crustaceans	<i>Hyalella azteca</i> 6 w NOEC = 488000 µg.kg ⁻¹ _{dw} (analysed-C _{background})	(European Union 2010)
	Sediment insects	<i>Chironomus tentans</i> 8 w NOEC = 850000 µg.kg ⁻¹ _{dw} (C _{analysed})	(European Union 2010)
		<i>Chironomus tentans</i> 3 w NOEC = 639000 µg.kg ⁻¹ _{dw} (C _{analysed})	(European Union 2010)
Fish	Freshwater	<i>Brachidanio rerio</i> 2 w NOEC = 180 – 2900 µg.L ⁻¹ Geometric mean (n = 9): 660 µg.L ⁻¹ (C _{nominal})	(European Union 2010)
		<i>Jordanella floridae</i> 14 w NOEC = 26 – 75 µg.L ⁻¹ Geometric mean (n = 2): 44 µg.L ⁻¹ (C _{analysed})	(European Union 2010)
		<i>Oncorhynchus mykiss</i> 30 d NOEC = 25 – 974 µg.L ⁻¹ Geometric mean (n = 15): 189 µg.L ⁻¹ (C _{analysed})	(European Union 2010)
		<i>Phoxinus phoxinus</i> 5 m NOEC = 50 µg.L ⁻¹ (C _{analysed})	(European Union 2010)
		<i>Pimephales promelas</i> 8 m NOEC = 78 µg.L ⁻¹ (C _{analysed})	(European Union 2010)
		<i>Salvelinus fontinalis</i> 3 y NOEC = 530 µg.L ⁻¹ (C _{analysed})	(European Union 2010)
		<i>Salmo trutta</i> NOEC = 76 µg.L ⁻¹	(UK Environment Agency 2010)
		<i>Cottus bairdii</i> NOEC = 170 µg.L ⁻¹	(UK Environment Agency 2010)
	Marine	No data	
Amphibian	Freshwater	<i>Rhinella arenarum</i> NOEC = 840 µg.L ⁻¹	(UK Environment Agency 2010)

C_{nominal}: Nominal zinc concentration in test water.

C_{background}: Background zinc concentration in test water.

C_{analysed}: Analysed zinc concentration in test water.

C_{not reported}: Unknown; reported NOEC from review, without data on analysis of zinc in test water.

UK Environment Agency (2010) processed the available aquatic ecotoxicity data to obtain species NOEC values:

- The geometric mean of NOECs or EC10 values was taken if several studies of comparable exposure duration and endpoint for the same species were available⁴.
- If differences in EC10 and NOEC values for the same species were due to differences in water quality, sensitive (i.e. high bioavailability) tests from each study were identified and a species geometric mean was derived only from the selected tests⁵.

This approach yielded the **species NOECs** (UK Environment Agency 2010) listed in the following Table:

SPECIES	NOEC [$\mu\text{g}\cdot\text{L}^{-1}$]
Algae (unicellular)	
<i>P. subcapitata</i> *	25.5
<i>Chlorella</i> sp.	4.9
Algae (multicellular)	
<i>C. glomerata</i>	60
Sponges	
<i>E. fluviatilis</i>	43
<i>E. muelleri</i>	43
<i>S. lacustris</i>	65
<i>E. fragilis</i>	43
Molluscs	
<i>D. polymorpha</i>	400
<i>P. jenkinsi</i>	75
Crustaceans	
<i>C. dubia</i> *	36.9
<i>D. magna</i> *	90.1
<i>D. longispina</i>	70.5
<i>H. azteca</i>	42
Insects	
<i>C. tentans</i>	137
Rotifers	
<i>A. fissa</i>	48
<i>B. rubens</i>	24
Fish	
<i>D. rerio</i> *	666.1
<i>J. floridae</i> *	44.2
<i>P. phoxinus</i>	50
<i>P. promelas</i>	78
<i>O. mykiss</i> *	189.3
<i>S. fontinalis</i>	530
<i>S. trutta</i>	76.4
<i>C. bairdi</i>	169
Amphibians	
<i>R. arenarum</i>	840

* Geometric mean values

⁴ 29 individual test results were available for the green alga *Pseudokirchneriella subcapitata*, with EC10 or NOEC values ranging from 4.9 to 124 $\mu\text{g}\cdot\text{L}^{-1}$.

⁵ In the case of these algal tests, there are 5 test results performed under 'high bioavailability' conditions giving rise to NOECs of 4.9, 24, 28, 50 and 65 $\mu\text{g}\cdot\text{L}^{-1}$ zinc. The geometric mean of these values is 25.5 $\mu\text{g}\cdot\text{L}^{-1}$ zinc. The geometric mean of all the algal data (29 values) is 19.7 $\mu\text{g}\cdot\text{L}^{-1}$ zinc, but this is made up of values spanning a range of water qualities.

8.2 Derivation of the MAC-QS_{WATER}

In contrast to the chronic data, the set for acute toxicity does not meet the criteria for applying a species sensitivity distribution (number of taxonomic groups is too low: only one algae species, only cladocerans for invertebrates). As the TGD assessment factor method does not result in a reliable MAC-QS_{water} and the use of the SSD-method is not valid for the MAC-QS_{water}, an alternative method is used that is based on acute-to-chronic toxicity ratios (ACR). Despite the various limitations (Bodar 2007, IKSR 2009) ACRs for zinc appear to be well below 10. A more conservative ACR of 2 (Bodar 2007, IKSR 2009) or an ACR of 3 (UK Environment Agency 2010) can be used to extrapolate the 'unknown' MAC-QS_{water} value (acute) from the well-founded AA-QS_{water} value (chronic).

Freshwater environment

The MAC-QS_{freshwater} may be derived from the high quality AA-EQS_{freshwater} based on an ACR of 3. With the AA-QS_{water} value of 10.9 µg.L⁻¹ (UK Environment Agency 2010), see section 8.3, and an ACR of 3, an extrapolated **MAC-QS_{water} of 33 µg.L⁻¹ bioavailable Zn** is obtained.

Marine environment

Application of an ACR of 3 to the tentative AA-EQS_{marine water} of 3.0 µg.L⁻¹ (Bodar 2007), see section 8.3, results in an extrapolated **MAC-QS_{marine water} of 9.0 µg.L⁻¹**.

8.3 Derivation of the AA-QS_{WATER}

The AA-EQS (Annual Average Environmental Quality Standards) represent conditions of high bioavailability and so should be protective of sensitive areas. SCHER (Scientific Committee on Health and Environmental Risks) (2012) agrees on the way the AA-EQS for freshwater has been derived (10.9 µg/l bioavailable Zn) by the UK Environment Agency (2010).

Freshwater environment

The species NOECs shown in section 8.1 have been used as input data to an SSD after normalization to a target water of physico-chemical conditions that favour high bioavailability (UK Environment Agency 2010). The target water conditions were selected as follows: North West Region in the UK is the most sensitive of the 10 Regions in Great Britain (six in England, one in Wales and three in Scotland) for which data are available, followed by Wales and the South West⁶. HC5 values were calculated from SSDs constructed for approximately 100 sites from each Region in the UK by normalising the species NOECs to the actual water quality at each of those 100 sites/Region. For each site, the annual averages of pH (mean), DOC (median) and Ca (mean) of at least six samples were used⁷.

This process gave rise to around 100 HC5 values for each Region from which various percentiles of the calculated Zn HC5 for individual sites across the whole of Great Britain (n = 916) and the North West Region (n = 103) could be estimated. The Table below shows the frequency distribution of Zn HC5 values [µg.L⁻¹] for Great Britain and North West Region (UK Environment Agency 2010):

⁶ Predominantly upland areas of igneous geology

⁷ The Environment Agency monitoring data was collected in 2007 to 2008 for Scotland and 2000 to 2009 for England and Wales. The use of the mean is consistent with requirements under the WFD, whereas a median value for DOC was chosen as it is less likely to be sensitive to outliers and skewed data.

Percentile	Great Britain	North West
5 th	14.15	10.92
10 th	16.56	11.59
15 th	18.29	12.01
25 th	21.85	12.85
50 th	31.01	23.46
75 th	41.21	41.35
90 th	54.61	57.78
95 th	64.47	63.50

The 'generic' HC5 of 14.2 µg.L⁻¹ for the whole of Great Britain represents a rather lower level of protection (approximately only 68 %) in the North West Region. To provide 95 % protection for the most sensitive region – which would ensure a high level of protection if applied on a UK basis - a **'generic' HC5 of 10.9 µg.L⁻¹ bioavailable Zn has been proposed (UK Environment Agency 2010)**. This corresponds to water conditions of 0.52 mg.L⁻¹ dissolved organic carbon, a mean Ca concentration of 1.6 mg.L⁻¹ and a mean pH of 6.29.

The selected bioavailability conditions also provide a high level of protection to other regions across Europe, including those with upland, igneous geology. Comparison of the percentiles of estimated PNEC [µg.L⁻¹] from NW UK with those calculated for several other European datasets is shown in the Table below (UK Environment Agency 2010). The data in the table clearly show that the HC5 at the 5th percentile of sites from North West Region in the UK is the lowest of those estimated.

Dataset	5 th percentile	10 th percentile
Austria* (n = 1779)	9.29	10.55
Sweden [#] (n = 3997)	15.34	18.24
Northern France [#] (n = 144)	16.68	17.29
North West Region (UK) [∞] (n = 103)	8.56 ⁸	9.05

* <http://wisa.lebensministerium.at>

[#] Data from EIONET

[∞]These data are annual averages and annual medians

The same principles, in terms of DOC complexation and competition from major ions, are responsible for affecting zinc toxicity across a wide range of water qualities, including soft waters. Therefore, there did not appear to be a need for a separate softwater EQS because the proposed 'generic' HC5 applies across a wide range of waterbodies, including soft waters (UK Environment Agency 2010).

To account for residual uncertainty, an assessment factor between 1 and 5 should be applied to the 50 % confidence value of the 5th percentile value (i.e. EQS = HC5/AF). Based on quantity of data, taxonomic diversity and consideration of bioavailability as well as evaluation of field and mesocosm data there is **no evidence that there is a need for an AF>1** in order to ensure adequate protection of sensitive aquatic organisms from zinc toxicity (UK Environment Agency 2010). Thus, the **proposed AA-QS_{freshwater} is 10.9 µg.L⁻¹, i.e. the generic HC5 of with an AF = 1 (UK Environment Agency 2010)**. The UK Environment Agency (2010) AA-QS_{freshwater} of 10.9 µg.L⁻¹ is slightly higher than the European Union (2010) AA-QS_{freshwater} of 7.8 µg.L⁻¹. The UK Environment Agency (2010) AA-QS_{freshwater} of 10.9 µg.L⁻¹ represents conditions of high

⁸ The value of 8.56 µg.L⁻¹ is lower than the proposed HC5 of 10.9 µg/l due to the use of a more conservative Screening Tool rather than the 'full' ZnBLM. However, the relative difference shown in the table between the PNEC at the 5th percentile of the NW data and the other datasets provide a robust indication that this will be protective of the other regions/Member states listed.

bioavailability and should be protective of sensitive areas. A bioavailability correction needs to be made to compensate for local conditions when undertaking a compliance check.

The results of a recent study 'Effects of zinc in freshwater microcosms' on behalf of the International Zinc Association (Rand et al. 2012) with lowest NOEC of $14 \mu\text{g.L}^{-1}$ and lowest LOEC of $21 \mu\text{g.L}^{-1}$ are very well in line with the proposed AA-QS_{freshwater} of $10.9 \mu\text{g.L}^{-1}$ (UK Environment Agency 2010). Indeed, the lowest LOEC with an AF = 2 would result in the same AA-QS_{freshwater}.

Marine environment

The database on toxicity to saltwater organisms meets the criteria on number of species and taxonomic diversity allowing the use of statistical extrapolation. Bodar (2007) used a large number ($n = 28$) of species mean values from various taxonomic groups to calculate a median 5th percentile value of $6.1 \mu\text{g.L}^{-1}$ for dissolved zinc in saltwater (lower 95 % C.I. is 2.6 and higher 95 % C.I. is 11.6).

Chronic fish data are lacking in the marine data set. This is of course a shortcoming, but on the other hand acute toxicity for marine fish indicate that they have a rather low sensitivity to zinc compared to other species being sufficiently covered in the marine data set. In addition, read across to the freshwater data set also points to a lower zinc sensitivity for fish compared to algae and invertebrates (Bodar 2007).

Bodar (2007) considered an assessment factor of 2 most appropriate for the derivation of the marine AA-QS, resulting in a **AA-QS_{marine water} value of $3.0 \mu\text{g.L}^{-1}$** .

The European Union (2010) presented natural background concentrations of zinc for marine environments. On average, natural background concentrations of zinc in marine waters tend to be lower than freshwater concentrations. The background concentration for the North Sea is estimated to be $1 \mu\text{g.L}^{-1}$ and used for the AA-QS_{marine water} for zinc, resulting in an overall marine AA-QS value of $3.0 \mu\text{g.L}^{-1} + 1 \mu\text{g.L}^{-1} = 4.0 \mu\text{g.L}^{-1}$ (Bodar 2007).

8.4 Derivation of the AA-QS_{SEDIMENT}

Freshwater and marine environment

The available freshwater benthic studies for zinc with *Hyalloa azteca*, *Chironimus tentans* and *Tubifex tubifex* represent three taxonomic groups of invertebrates with different living and feeding conditions. They have been used to derive AA-QS_{sediment} (Bodar 2007, European Union 2010) and are still the most current data base (UK Environment Agency 2010). Therefore, it is recommended to adopt the AA-QS_{sediment} described in the EU RAR (European Union 2010). After detailed discussion of the wet or dry weight normalized PNEC approach, the Acid-Volatile Sulphide (AVS) hypothesis, consideration of regional bioavailability and evaluation of results of field studies, it was emphasised that the Equilibrium Partition (EP) method has limitations for the derivation of a reliable AA-QS_{sediment}, especially for metals (European Union 2010). Preference is given to the application of an assessment factor of 10 on the lowest chronic NOEC for the benthic species *Hyalloa azteca* ($488000 \mu\text{g.kg}^{-1}_{\text{dw}}$; based on single-species laboratory studies). Based on the above data, an AF of 10 is considered to be justified, leading to an **AA-QS_{sediment} of $49000 \mu\text{g.kg}^{-1}_{\text{dw}}$** .

For saltwater benthic organisms no chronic toxicity data for Zn-spiked sediments are available and no PNEC_{sediment} could be derived for the marine environment.

Tentative QS _{water}	Relevant study for derivation of QS	Assessment factor	Tentative QS
MAC _{freshwater, eco}	'generic' HC5 of 10.9 µg.L ⁻¹ bioavailable Zn (UK Environment Agency 2010)	ACR = 3	33 µg.L ⁻¹ bioavailable Zn
MAC _{marine waters, eco}	HC5 = 6.1 µg.L ⁻¹ (Bodar 2007)	AF = 2 ACR = 3	9.0 µg.L ⁻¹ dissolved Zn
AA-QS _{freshwater, eco}	'generic' HC5 of 10.9 µg.L ⁻¹ bioavailable Zn (UK Environment Agency 2010)	1	10.9 µg.L ⁻¹ bioavailable Zn
AA-QS _{marine waters, eco}	HC5 = 6.1 µg.L ⁻¹ (Bodar 2007)	2	3.0 µg.L ⁻¹ dissolved Zn
AA-QS _{freshwater, sed.}	<i>Hyalella azteca</i> 6 w NOEC = 488000 µg.kg ⁻¹ _{dw} (European Union 2010)	10	49000 µg.kg ⁻¹ _{dw}
AA-QS _{marine waters, sed.}	---	---	No data available

8.5 Secondary poisoning

Bioaccumulation and biomagnification (i.e. accumulation and transfer through the food chain, possibly causing secondary poisoning) of zinc in animals is considered to be not relevant in the effect assessment of zinc (Bodar 2007, IKSr 2009, European Union 2010, UK Environment Agency 2010). An assessment for secondary poisoning was not performed. A QS_{secpois} was not derived.

Tentative QS _{biota}	Relevant study for derivation of QS	Assessment factor	Tentative QS
QS _{secpois}	---	---	Not relevant

8.6 Human health

Zinc and zinc compounds do not meet the criteria for classification and labelling for carcinogenic, mutagenic, reproduction and/or high chronic toxicity. $QS_{\text{biota, hh}}$ and $QS_{\text{dw, hh}}$ assessments were not performed within this project.

Human health via consumption of fishery products		Master reference
Mammalian oral toxicity	Upper limits of safe intake (female >18 years): 35 mg.d ⁻¹	(WHO 1996b)
	Upper limits of safe intake (male >18 years): 45 mg.d ⁻¹	(WHO 1996b)
	RfD (oral reference dose): 15 mg	(US EPA 2005)
	RDI (recommended daily intake): 0.3 mg/kg/day	(US EPA 2005)
	NOAEL: 50 mg.d ⁻¹	(European Food Safety Authority 2006)
CMR	---	

A QS_{hh} assessment was not performed within this project.

Tentative $QS_{\text{biota, hh}}$	Relevant study for derivation of $QS_{\text{biota, hh}}$	Assessment Factor	Tentative $QS_{\text{biota, hh}}$
Human health	Not required	-	-

Human health via consumption of drinking water		Master reference
Existing drinking water standard(s)	Derivation of a health-based guideline value is not required.	(WHO 1996a)
	Drinking-water containing zinc at levels above 3 mg.L ⁻¹ tends to be opalescent, develops a greasy film when boiled, and has an undesirable astringent taste.	(WHO 1996a)

8.7 Mode of action

Zinc is an essential metal which is important to nutritional health. Zinc is necessary for the function of various enzymes and plays an essential role in DNA, RNA and protein synthesis.

Following high-level oral exposure, zinc appears to exert adverse health effects primarily through interaction with copper. Specifically, high levels of zinc can result in a saturation of the carrier-mediated pathway of zinc absorption and a shift to metallothionein-mediated absorption. It is believed that the copper deficiency results from a zinc-induced decrease in copper absorption. Zinc-induced copper deficiency is consistent with numerous reports of effects of zinc

on various biomarkers of copper nutritional status following exposures to elevated levels of zinc in humans and animals, as well as by reports indicating that copper supplementation can result in an attenuation of zinc-induced toxicity (US EPA 2005).

9 IDENTIFICATION OF ISSUES RELATING TO UNCERTAINTY IN RELATION TO THE QSS DERIVED

The **AA-QS_{sediment} of 49000 µg.kg⁻¹_{dw}** for the protection of benthic freshwater species is in the range of geogenic background levels. It has to be discussed if the added risk approach should be used. Furthermore, it should be debated if the proposed AA-QS_{freshwater, eco} of 10.9 µg.L⁻¹ is already protective for benthic species or if additionally an EQS for sediment and/or suspended matter should be set.

10 IDENTIFICATION OF ANY POTENTIAL IMPLEMENTATION ISSUES IN RELATION TO THE QSS DERIVED

The UK tiered approach to EQS implementation (UK Environment Agency 2010): Because of variations in key water quality characteristics, the bioavailability of zinc will vary across different locations. This means that a risk may exist at one location but the same concentration of dissolved zinc does not pose a risk at another location because much less of the zinc is actually in a form that is bioavailable. The concept underlying the zinc EQS is based on a single 'generic' EQS coupled with a tiered approach that takes account of the factors that mitigate bioavailability.

For an EQS that can be applied across all MSs, the 'generic' EQS should be protective even under 'worst case' conditions, i.e. 100 % bioavailability. Measured total zinc concentrations below the 'generic' EQS pass the compliance check at the first tier. If the measured zinc concentration exceeds the 'generic' EQS, bioavailability is taken into account at subsequent tiers using BLMs (initially screening versions of BLMs in conjunction with local measurements of key water quality parameters (pH, DOC and [Ca]), or default values where these are not available). If a sample still exceeds the 'generic' EQS after bioavailability is accounted for, then local background levels of zinc may be considered. If these steps do not help to meet the zinc EQS, good chemical status may not have been achieved and remedial measures may be needed.

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