Supporting Information (SI)

Karin Veltman, Mark A.J. Huijbregts, Maurits van Kolck, Wen-Xiong Wang, A. Jan Hendriks

Metal bioaccumulation in aquatic species: quantification of uptake and elimination rate constants using physico-chemical properties of metals and physiological characteristics of species

This Supporting Information contains 5 Tables and 1 Figure.

Metal ion characteristics

Covalent indices ($\chi^2_m r$) were calculated using Pauling`s electronegativity values (χ_m) provided by Allred (1) and effective ionic radii (r) (in Ångstrom units) corresponding to octahedral coordination from Shannon and Prewitt (2,3). Electronegativity values for the correct oxidation state of the metal-ion were used, except for Cr (III) and Cu (II) as χ_m is provided for Cr (II) and Cu (I) only. For lead an ionic radius of 0.94 Å, corresponding to tetrahedral coordination, was used as the resulting covalent index is more in line with the known solution coordination chemistry of Pb^{2+} (4). Electronegativity data, ionic radii and covalent indices compiled per metal included in this study are presented in Table SI-S1.

Table SI-S1: Metal ion characteristics: electronegativity values, ionic radii and covalent indices

Metal	Ionic radius r (in Å)	Electronegativity χ_m	Covalent index $\chi^2_m r$
Ag^{+}	1.15	1.93	4.28
Cd^{2+}	0.95	1.69	2.71
Co^{2+}	0.75*	1.88	2.65
Cr^{3+}	0.62	1.66**	1.69
Cs^{+}	1.7	0.79	1.06
Cu^{2+}	0.73	1.9***	3.29
Hg^{2+}	1.02	2	4.08
Ni^{2+}	0.69	1.91	2.52
Pb^{2+}	0.94****	1.87	3.29
Zn^{2+}	0.74	1.65	2.01

* Ionic radius for high spin state of Co^{2+}, radius for low spin state is 0.65 Å

** Electronegativity value for Cr^{2+} instead of Cr^{3+}

*** Electronegativity value for Cu^{+} instead of Cu^{2+}

**** Ionic radius of Pb^{2+} for tetrahedral coordination instead of octahedral coordination (19)

Filtration rates

Absorption efficiencies for mollusks were preferentially calculated using filtration rates determined in the same study as the absorption rate constants. These filtration rates were available for the following studies: Shi and Wang (5,6) (*Ruditapes phillipinarum*, *Perna viridis*), Ng and Wang (7) (*Perna viridis*), Baines et al., (8) (*Mytilus edulis*), Wang and Fisher (9) (*Macoma balthica*, *Mytilus edulis*) and Wang et al. (10) (*Mytilus edulis*).

For other data, filtration rates from table SI-S2 were used. The filtration rate used for *Daphnia magna* is also provided in this table.

Table SI-S2. Species – specific filtration rates used

Species	**Filtration rate** $\mathbf{L{\cdot}kg^{-1}_{wet\ weight}{\cdot}d^{-1}}$		**References**
Perna viridis	$2.9{\cdot}10^{4}$	Geometric mean (n = 39), this study	5,7
Mytilus edulis	$1.8{\cdot}10^{4}$		11
Ruditapes phillipinarum	$6.9{\cdot}10^{3}$	Geometric mean (n = 2), this study	6
Dreissena polymorpha	$2.5{\cdot}10^{4}$		12
Macoma balthica	$9.0{\cdot}10^{3}$		9
Daphnia magna	$3.3{\cdot}10^{4}$	Geometric mean (n = 4), this study	13,14,15,16

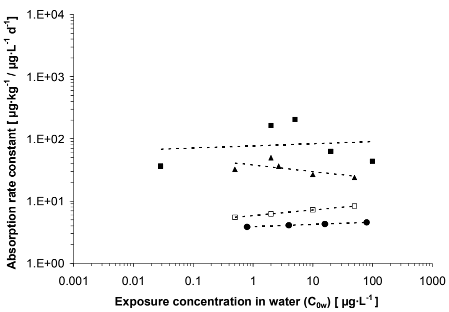
Absorption rate constants and exposure concentration in water

In our approach absorption rate constants determined at different exposure concentrations were combined to calculate mean species – specific absorption rate constants. This is only allowed if absorption rate constants are independent of the exposure concentration in water. We found that metal influx from the dissolved phase is generally linearly related to the dissolved metal concentration in water under laboratory conditions (Figure SI-S1, Table SI-S3). Absorption rate constants determined at different exposure concentrations can therefore be combined.

Figure SI-S1. Metal absorption rate constants ($k_{X,w,in}$ in $L \cdot kg^{-1} \cdot d^{-1}$) vs. exposure concentrations in water (C_{0w} in $\mu g \cdot L^{-1}$). Absorption rate constants are plotted against exposure concentration, if rate constants are determined at three or more exposure concentrations.

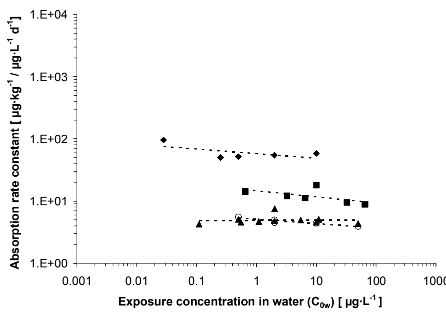
a. *Perna viridis*

(Cd, Zn, Cs, Cr (III))



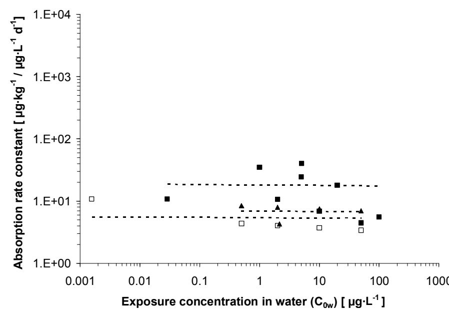
b. *Macoma balthica*

(Ag, Zn, Cd, Co)



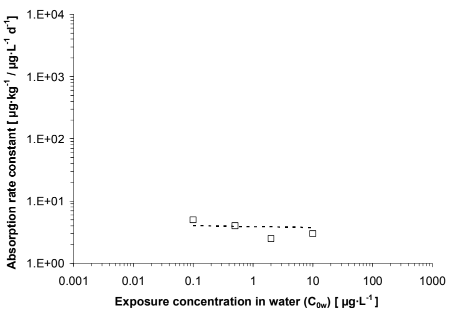
c. *Ruditapes phillipinarum*

(Cd, Zn, Cr (III))



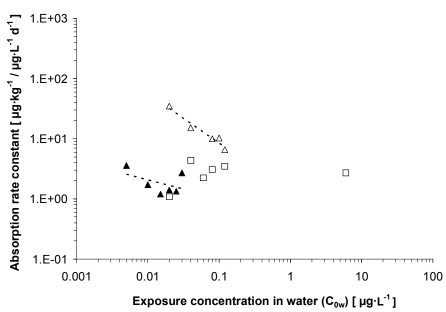
d. *Mytilus edulis*

(Cr (III))



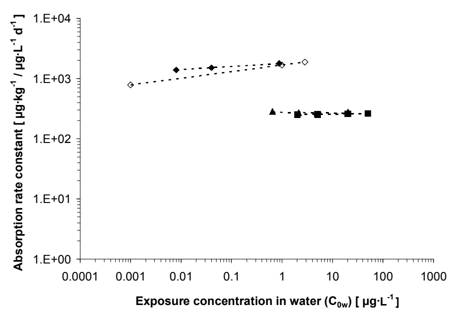
e. *Gammarus oceanicus*

(Pb, Cd, Cr (III))



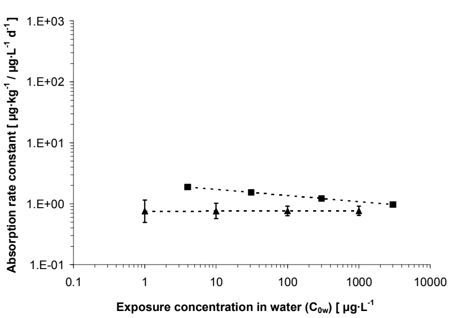
f. *Daphnia magna*

(Cd, Zn, Ag, Hg)



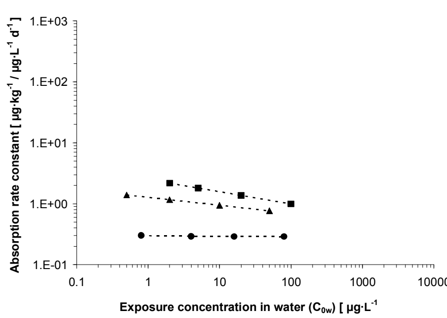
g. *Acanthopagrus schlegeli*

(Cd, Zn)



h. *Lutjanus argentimaculatus*

(Cd, Zn, Cs)



◆ Silver (Ag), ▲ Cadmium (Cd), □ Chromium (III) (Cr), ■ Zinc (Zn), ◇ Mercury (Hg), △ Lead (Pb), ● Cesium (Cs), × Copper (Cu), ○ Cobalt (Co)

Table SI-S3. Regression analysis of metal absorption rate constants ($k_{X,w,in}$ in $L \cdot kg^{-1} \cdot d^{-1}$) with exposure concentrations (C_{0w} in $\mu g \cdot L^{-1}$).

Species	**Metal**	**Log ($k_{x,w,in}$)**	**r^2**	**SE**	**p**	**n**
Perna viridis	Zn	$0.03 \cdot Log(C_{0w}) + 1.89$	0.02	0.39	0.83	5
Perna viridis	Cd	$-0.11 \cdot Log(C_{0w}) + 1.58$	0.42	0.11	0.24	5
Macoma balthica	Ag	$-0.07 \cdot Log(C_{0w}) + 1.76$	0.38	0.10	0.27	5
Macoma balthica	Cd	$0.003 \cdot Log(C_{0w}) + 0.69$	0	0.07	0.94	10
Macoma balthica	Zn	$-0.10 \cdot Log(C_{0w}) + 1.17$	0.36	0.10	0.21	6
Macoma balthica	Co	$-0.07 \cdot Log(C_{0w}) + 0.71$	0.89	0.022	0.02	5
Gammarus oceanicus	Pb	$-0.82 \cdot Log(C_{0w}) + 0.10$	0.95	0.07	0.005	5
Gammarus oceanicus	Cd	$-0.31 \cdot Log(C_{0w}) - 0.30$	0.19	0.19	0.34	6
Lutjanus argentimaculatus	Cs	$-0.009 \cdot Log(C_{0w}) - 0.52$	0.64	0.0051	0.13	4

Empirical absorption rate constants and elimination rate constants compiled

In Table SI-S4 species – specific geometric mean absorption rate constants per metal are given. 95% Confidence intervals represent the variability between organisms from one species. In Table SI-S5 all elimination rate constants compiled per species are provided. 95% Confidence intervals represent the variability between organisms from one species.

Table SI-S4: Species-specific and metal specific absorption rate constants and absorption efficiencies

Metal	Species	Weight kg	$k_{X,w,in}$ $L \cdot kg^{-1} \cdot d^{-1}$	95%CI	5% CI	n	$p_{X,w,in}$	References
argentum	Perna viridis	1.3E-03	1.2E+03	1.6E+03	8.5E+02	33	4.11%	5,7,17
mercury	Perna viridis	1.3E-03	7.7E+02	2.4E+03	2.5E+02	4	2.69%	5,18,19
copper	Perna viridis	1.3E-03	1.7E+02			1	0.56%	20
cadmium	Perna viridis	1.3E-03	4.5E+01	6.2E+01	3.2E+01	25	0.15%	5,7,20,21,22,23,24,25
cesium	Perna viridis	1.3E-03	4.2E+00	4.7E+00	3.7E+00	4	0.01%	26,27
chromium (III)	Perna viridis	1.3E-03	6.7E+00	8.9E+00	5.1E+00	5	0.02%	24
zinc	Perna viridis	1.3E-03	1.4E+02	2.1E+02	9.0E+01	24	0.46%	5,7,21,22,23,24
lead	Perna viridis	1.3E-03	2.0E+01			1	0.06%	20
argentum	Mytilus edulis	1.9E-04	2.7E+02	1.1E+03	6.8E+01	6	0.46%	8,9,10
cadmium	Mytilus edulis	1.9E-04	5.5E+01	1.3E+02	2.4E+01	9	0.16%	8,9,10,28
chromium (III)	Mytilus edulis	1.9E-04	3.5E+00	5.7E+00	2.1E+00	4	0.02%	11
zinc	Mytilus edulis	1.9E-04	1.4E+02	2.5E+02	7.3E+01	9	0.44%	8,9,10,28
cobalt	Mytilus edulis	1.9E-04	2.0E+01	3.1E+01	1.3E+01	8	0.07%	8,9,28
cesium	Mytilus edulis	1.9E-04	3.0E+00			1	0.02%	29
argentum	Ruditapes philippinarum	1.6E-03	2.3E+02			1	0.25%	30
zinc	Ruditapes philippinarum	1.6E-03	1.0E+01	1.7E+01	6.0E+00	14	0.07%	6,22,24,30
chromium (III)	Ruditapes philippinarum	1.6E-03	4.7E+00	8.5E+00	2.6E+00	5	0.01%	22,24
mercury	Ruditapes philippinarum	1.6E-03	2.4E+02	2.4E+02	2.4E+02	1	2.12%	30
cadmium	Ruditapes philippinarum	1.6E-03	7.6E+00	8.7E+00	6.6E+00	14	0.06%	6,22,24,30
chromium	Dreissena polymorpha	5.9E-03	1.4E+02			1	0.47%	31,32
argentum	Dreissena polymorpha	5.9E-03	5.5E+02			1	1.87%	31,32
mercury	Dreissena polymorpha	5.9E-03	3.5E+02			1	1.17%	31,32
cadmium	Dreissena polymorpha	5.9E-03	3.0E+02			1	1.02%	31,32
cadmium	Macoma balthica	1.4E-03	4.9E+00	5.5E+00	4.4E+00	10	0.05%	9,33,34,35
zinc	Macoma balthica	1.4E-03	1.2E+01	1.6E+01	9.0E+00	6	0.13%	9,35
argentum	Macoma balthica	1.4E-03	6.0E+01	8.4E+01	4.3E+01	5	0.67%	9,33,34,35
cobalt	Macoma balthica	1.4E-03	4.6E+00	5.5E+00	3.9E+00	5	0.05%	9,33,34,35
copper	Chaetogammarus marinus		2.1E+02	8.4E+02	5.0E+01	3		36
lead	Chaetogammarus marinus		4.5E+01	2.8E+02	7.1E+00	3		36
cobalt	Chaetogammarus marinus		7.0E+00	8.4E+00	5.8E+00	2		36
nickel	Chaetogammarus marinus		5.9E+00	1.8E+01	1.9E+00	3		36
cadmium	Chaetogammarus marinus		1.7E+01	2.1E+01	1.3E+01	3		36
lead	Gammarus oceanicus		1.3E+01	2.8E+01	5.9E+00	5		37
cadmium	Gammarus oceanicus		1.8E+00	2.9E+00	1.2E+00	6		37
nickel	Gammarus oceanicus		1.1E+00	1.1E+00	1.1E+00	1		37
copper	Gammarus oceanicus		3.8E+01	3.8E+01	3.8E+01	1		37
cadmium	Temora longicornis	1.0E-06	1.4E+02	1.6E+02	1.2E+02	4		38
cobalt	Temora longicornis	1.0E-06	1.2E+02	1.4E+02	1.0E+02	4		38
argentum	Temora longicornis	1.0E-06	2.1E+03	3.0E+04	1.5E+02	2		38
zinc	Temora longicornis	1.0E-06	6.5E+02	9.5E+02	4.4E+02	4		38
cadmium	Daphnia magna	1.4E-06	3.2E+02	4.4E+02	2.4E+02	9	0.83%	39
zinc	Daphnia magna	1.4E-06	2.1E+02	3.4E+02	1.3E+02	8	0.54%	39
argentum	Daphnia magna	1.4E-06	1.6E+03	2.8E+03	8.7E+02	6	3.98%	40
mercury	Daphnia magna	1.4E-06	1.4E+03	4.4E+03	4.2E+02	3	3.47%	41
cadmium	Acanthopagrus schlegelii	3.8E-04	9.3E-01	1.2E+00	7.2E-01	26	0.06%	42,43,44
zinc	Acanthopagrus schlegelii	3.8E-04	1.7E+00	2.4E+00	1.2E+00	22	0.12%	42,43
argentum	Acanthopagrus schlegelii	4.0E-04	8.3E+00	7.1E+01	9.6E-01	4	0.58%	44
cesium	Lutjanus argentimaculatus	3.7E-04	2.9E-01	3.0E-01	2.8E-01	4	0.02%	45
cadmium	Lutjanus argentimaculatus	3.7E-04	1.0E+00	1.6E+00	6.9E-01	4	0.07%	46
zinc	Lutjanus argentimaculatus	3.7E-04	1.5E+00	2.6E+00	8.9E-01	4	0.11%	46
cadmium	Terapon jarbua	1.4E-03	3.9E-01	3.0E+03	5.2E-05	2	0.04%	42
zinc	Terapon jarbua	1.4E-03	1.3E+00	2.9E+02	5.9E-03	2	0.13%	42
cadmium	Oncorhynchus mykiss	1.8E-01	3.8E-01	2.6E+00	5.5E-02	5	0.12%	47
argentum	Pleuronectes platessa	4.5E-02	7.4E+00			1	1.71%	48
mercury	Pleuronectes platessa	4.3E-02	4.3E+00			1	0.98%	49
zinc	Gambusia affinis	4.1E-04	7.4E-01	1.9E+00	2.8E-01	6	0.05%	50
mercury	Lepomis microlophys	8.5E-04	8.8E+00	5.7E+01	1.4E+00	2	0.75%	51
zinc	Oncorhynchus mykiss	5.5E-03	2.0E+00	2.0E+00	2.0E+00		0.27%	52
mercury	Gambusia affinis	4.1E-04	1.3E+01	1.7E+02	9.7E-01	2	0.91%	51
cadmium	Periophthalmus cantonensis	3.0E-03	5.0E-01	8.0E-01	3.2E-01	4	0.06%	53
zinc	Periophthalmus cantonensis	3.0E-03	1.2E+00	3.6E+00	3.9E-01	4	0.14%	53

Table SI-S5: Species - specific and metal - specific elimination rate constants and weight-corrected elimination rates

Metal	Species	weight kg	$k_{x,ex}$ d^{-1}	95%CI	5% CI	n	Weight-corrected $k_{X,ex}$ $kg^{\kappa} \cdot d^{-1}$	95%CI	5% CI	n	References
argentum	Perna viridis	1.3E-03	1.9E-02	2.0E-02	1.0E-02	16	3.8E-03	7.0E-03	2.0E-03	16	7,17
cadmium	Perna viridis	1.3E-03	1.3E-02	1.4E-02	8.4E-03	6	2.3E-03	3.8E-03	1.4E-03	6	7,24
cesium	Perna viridis	1.3E-03	1.5E-01			1	3.0E-02			1	26,27
chromium (III)	Perna viridis	1.3E-03	2.9E-02			1	6.1E-03			1	24
zinc	Perna viridis	1.3E-03	3.1E-02	3.3E-02	1.9E-02	6	5.7E-03	8.9E-03	3.7E-03	6	7,21,24
argentum	Mytilus edulis	1.9E-04	4.5E-02	4.6E-02	3.1E-02	5	4.7E-03	7.2E-03	3.1E-03	5	8,10
cadmium	Mytilus edulis	1.9E-04	6.9E-02	6.9E-02	2.4E-02	8	6.0E-03	1.8E-02	2.0E-03	8	8,10,28
chromium (III)	Mytilus edulis	1.9E-04	1.1E-02	1.1E-02	8.7E-03	3	2.3E-03	3.0E-03	1.8E-03	3	11
zinc	Mytilus edulis	1.9E-04	5.4E-02	5.4E-02	2.3E-02	8	4.7E-03	9.7E-03	2.3E-03	8	8,10,28
cobalt	Mytilus edulis	1.9E-04	8.7E-02	8.8E-02	2.6E-02	7	7.6E-03	2.0E-02	2.9E-03	7	8,11
zinc	Ruditapes philippinarum	1.6E-03	1.7E-02	1.9E-02	5.1E-03	3	3.6E-03	1.1E-02	1.2E-03	3	6,24
chromium (III)	Ruditapes philippinarum	1.6E-03	2.3E-02			1	5.0E-03			1	24
cadmium	Ruditapes philippinarum	1.6E-03	2.0E-02	2.2E-02	4.5E-03	3	4.2E-03	1.7E-02	1.0E-03	3	6,24
argentum	Dreissena polymorpha	5.9E-03	8.8E-02			1	9.0E-03			1	31
cadmium	Dreissena polymorpha	5.9E-03	1.1E-02			1	1.1E-03			1	31
cadmium	Macoma balthica	1.4E-03	2.0E-02	2.2E-02	4.3E-03	2	4.0E-03	2.3E-02	6.8E-04	2	34,35
zinc	Macoma balthica	1.4E-03	1.2E-02			1	2.3E-03			1	35
argentum	Macoma balthica	1.4E-03	9.6E-03			1	1.9E-03			1	34
cobalt	Macoma balthica	1.4E-03	2.6E-02			1	5.2E-03			1	34
copper	Chaetogammarus marinus		3.4E-01	8.5E-01	1.4E-01	3					36
lead	Chaetogammarus marinus		1.3E-01								36
cobalt	Chaetogammarus marinus		1.8E-01			2					36
nickel	Chaetogammarus marinus		1.5E-01	3.0E-01	7.5E-02	3					36
cadmium	Chaetogammarus marinus		2.9E-01	3.5E-01	2.3E-01	3					36
lead	Gammarus oceanicus		3.6E-01	6.1E-01	2.2E-01	5					37
cadmium	Gammarus oceanicus		1.7E-01	2.6E-01	1.1E-01	6					37
nickel	Gammarus oceanicus		4.7E-01			1					37
copper	Gammarus oceanicus		1.2E+00			1					37
cadmium	Temora longicornis	1.0E-06	2.2E-01	7.1E-01	6.7E-02	3	6.9E-03	2.2E-02	2.1E-03	3	38
cobalt	Temora longicornis	1.0E-06	2.7E-01	4.6E-01	1.6E-01	3	8.7E-03	1.4E-02	5.2E-03	3	38
argentum	Temora longicornis	1.0E-06	2.2E-01	4.6E-01	1.0E-01	2	6.8E-03	1.4E-02	3.2E-03	3	38
zinc	Temora longicornis	1.0E-06	7.0E-02	1.7E-01	2.9E-02	3	2.2E-03	5.3E-03	9.2E-04	3	38
cadmium	Daphnia magna	1.4E-06	6.5E-02	1.4E-01	3.1E-02	3	2.2E-03	4.7E-03	1.0E-03	3	54
zinc	Daphnia magna	1.4E-06	2.9E-01	3.0E-01	2.7E-01	3	9.8E-03	1.0E-02	9.3E-03	3	54
argentum	Daphnia magna	1.4E-06	2.8E-01	3.2E-01	2.5E-01	4	9.6E-03	1.1E-02	8.6E-03	4	40
mercury	Daphnia magna	1.4E-06	5.1E-02	7.6E-02	3.5E-02	3	1.8E-03	2.6E-03	1.2E-03	3	41
cadmium	Acanthopagrus schlegelii	3.8E-04	8.9E-02			1	1.3E-02			1	55
zinc	Acanthopagrus schlegelii	3.8E-04	1.6E-02			1	2.2E-03			1	55
cesium	Lutjanus argentimaculatus	3.7E-04	2.1E-02			1	3.0E-03			1	45
cadmium	Lutjanus argentimaculatus	3.7E-04	2.5E-02			1	3.5E-03			1	46
zinc	Lutjanus argentimaculatus	3.7E-04	1.5E-02			1	2.1E-03			1	46
cadmium	Terapon jarbua	1.4E-03	3.0E-02	5.1E-02	1.7E-02	3	4.7E-03	8.0E-03	2.7E-03	3	56
argentum	Terapon jarbua	6.0E-04	3.4E-02	4.7E-02	2.5E-02	5	5.3E-03	7.4E-03	3.8E-03	3	56
cadmium	Oncorhynchus mykiss	1.8E-01	1.1E-02	4.0E-02	3.0E-03	5	7.0E-03	2.6E-02	1.9E-03	5	47
argentum	Pleuronectes platessa	4.5E-02	2.3E-02				1.0E-02			1	48
mercury	Pleuronectes platessa	4.3E-02	3.7E-03				1.7E-03			1	49
mercury	Gambusia affinis	5.9E-04	1.7E-02	8.9E-02	3.1E-03	5	1.7E-02	8.9E-02	3.1E-03	5	51
mercury	Lepomis microlophys	8.5E-04	1.2E-02	2.9E-01	5.1E-04	2	2.1E-03	5.0E-02	8.6E-05	2	51

References

1. Allred, A.L. Electronegativity values from thermodynamical data. *J. Inorganic Nucl. Chem*. **1961**, *17*, 215 – 221

2. Shannon, R.D.; Prewitt, C.T. Effective ionic radii in oxides and fluorides. *Acta Crystallogr. B.* **1969**, *25*, 925 – 946

3. Shannon, R.D.; Prewitt, C.T. Revised values of effective ionic radii. *Acta Crystallogr. B.* **1970**, *26*, 1046 – 1048

4. Nieboer, E.; Richardson, D.H.S. The replacement of the nondescript term ‘heavy metals’ by a biologically and chemically significant classification of metal ions. *Environ. Poll.* **1980**, *1*, 3 – 26

5. Shi, D.; Wang, W.-X. Modification of trace metal accumulation in the green mussel Perna viridis by exposure to Ag, Cu, and Zn. *Environ. Poll.* **2004a**, *132*, 265 - 277

6. Shi, D.; Wang, W.-X. Understanding the differences in Cd and Zn bioaccumulation and subcellular storage among different populations of marine clams. *Environ. Sci. Technol.* **2004b**, *38*, 449 – 456

7. Ng, T.-Y.; Wang, W.-X. Subcellular controls of silver biokinetics in the green mussel *Perna viridis* from two hydrographic zones. *Mar. Ecol. Prog. Ser.* **2005**, *299*, 193 - 204

8. Baines, S.B.; Fisher, N.S.; Kinney, E.L.; Effects of temperature on uptake of aqueous metals by blue mussels *Mytilus edulis* from Arctic and temperate waters. *Mar. Ecol. Prog. Ser.* **2006**, *308*, 117 – 128

9. Wang, W.-X.; Fisher, N.S. Effects of calcium and metabolic inhibitors on trace element uptake in two marine bivalves. *J. Exp. Mar. Biol. Ecol.* **1999**, *236*, 149 - 164

10. Wang, W.-X.; Fisher, N.S.; Luoma, S.N. Kinetic determinations of trace element bioaccumulation in the mussel *Mytilus edulis*. *Mar. Ecol. Prog. Ser.* **1996**, *140*, 91 - 113

11. Wang, W.-X.; Griscom, S.B.; Fisher, N.S. Bioavailability of Cr (III) and Cr (VI) to marine mussels from solute and particulate pathways. *Environ. Sci. Technol.* **1997**, *31*, 603 - 611

12. Roditi, H.A.; Caraco, N.F.; Cole, J.J.; Strayer, D.L. Filtration of Hudson river water by the zebra mussel (*Dreissena polymorpha*). *Estuaries.* **1996**, *19*, 824 - 832

13. Egloff, D.A.; Palmer, D.S. Size relations of the filtering area of two Daphnia species. *Limnol. Oceanogr.* **1971**, *16*, 900 - 905

14. Ferrando, M.D.; Andreu, E. Feeding behavior as an index of copper stress in *Daphnia magna* and *Brachionus calyciflorus*. *Compar. Biochem. Physiol. C.* **1993**, *106*, 327 - 331

15. Fernandez-Casalderrey, A.; Ferrando, M.D.; Andreu-Moliner, E. Effect of sublethal concentrations of pesticides in the feeding behavior of *Daphnia magna*. *Ecotoxicol. Environ. Saf.* **1994**, *27*, 82 – 89

16. Flickinger, A.L.; Bruins, R.J.F.; Winner, R.W.; Skillings, J.H. Filtration and phototactic behavior as indices of chronic copper stress in *Daphnia magna* straus. *Arch. Environ. Contam. Toxicol.* **1982**, *11*, 391 - 520

17. Shi, D.; Blackmore, G.; Wang, W.-X. Effects on aqueous and dietary pre-exposure and resulting body-burden on silver biokinetics in the green mussel *Perna viridis*. *Environ. Sci. Technol.* **2003**, *37,* 936 - 94

18. Pan, J.-F.; Wang, W.-X. Uptake of Hg(II) and methylmercury by the green mussel Perna viridis under different organic carbon conditions. *Mar. Ecol. Prog. Ser.* **2004**, *276*, 125 – 136

19. Wang, W.-X.; Wong, R.S.K.; Wang, J.; Yen, Y.-F. Influences of different selenium species on the uptake and assimilation of Hg(II) and methylmercury by diatoms and green mussels. *Aquat. Toxicol.* **2004**, *68*, 39 – 50

20. Chan, H.M. Accumulation and tolerance to cadmium, copper, lead and zinc by the green mussel *Perna viridis*. *Mar. Ecol. Prog. Ser.* **1988**, *48*, 295 - 303

21. Blackmore, G.; Wang, W.-X. Uptake and efflux of Cd and Zn by the green mussel *Perna viridis* after metal pre-exposure. *Environ. Sci. Technol.* **2002**, *36*, 989 - 995

22. Wang, W.-X. Comparison of metal uptake rate and absorption efficiency in marine bivalves. *Environ. Toxicol. Chem*. **2001**, *20*, 1367 – 1373

23. Blackmore, G.; Wang, W.-X. Comparison of metal accumulation in mussels at different local and global scales. *Environ. Toxicol. Chem.* **2003**, *22*, 388 – 395

24. Chong, K.; Wang, W.-X. Comparative studies on the biokinetics of Cd, Cr and Zn in the green mussel *Perna viridis* and the manila clam *Ruditapes phillipinarum*. *Environ. Poll.* **2001**, *115*, 107 - 121

25. Wang, W.-X. Cd and Se aqueous uptake and exposure of green mussels *Perna viridis*: influences of seston quality. *Mar. Ecol. Prog. Ser.* **2002**, *226*, 211 – 221

26. Wang, W.-X.; Ke, C.; Yu, K.N.; Lam, P.K.S. Modeling radiocesium bioaccumulation in a marine food chain. *Mar. Ecol. Prog. Ser.* **2000**, *208*, 41 - 50

27. Ke, C.; Yu, K.N.; Lam, P.K.S.; Wang, W.-X. Uptake and depuration of cesium in the green mussel *Perna viridis*. *Mar. Biol*. **2000**, *137*, 567 - 575

28. Wang, W.-X.; Fisher, N.S. Modeling the influence of body size on trace element accumulation in the mussel *Mytilus edulis*. *Mar. Ecol. Prog. Ser.* **1997**, *161*, 103 - 115

29. Nolan, C.; Dahlgaard, H. Accumulation of metal radiotracers by *Mytilus edulis*. *Mar. Ecol. Prog. Ser.* **1991**, *70,* 165 - 174

30. Ng, T.-Y.; Wang, W.-X. Detoxification and effects of Ag, Cd and Zn pre-exposure on metal uptake kinetics in the clam *Ruditapes phillipinarum*. *Mar. Ecol. Prog. Ser.* **2004**, *268*, 161 - 172

31. Roditi, H.A.; Fisher, N.S. Rates and routes of trace element uptake in zebra mussels. *Limnol. Oceanogr.* **1999**, *44*, 1730 - 1749

32. Roditi, H.A.; Fisher, N.S.; Sanudo-Wilhelmy, S.A. Field testing a metal bioaccumulation model for zebra mussels. *Environ. Sci. Technol.* **2000**, *34*, 2817 - 2825

33. Griscom, S.B.; Fisher, N.S. Uptake of dissolved Ag, Cd and Co by the clam, *Macoma balthica*: Relative importance of overlying water, oxic pore water and burrow water. *Environ. Sci. Technol.* **2002**, *36*, 2471 - 2478

34. Griscom, S.B.; Fisher, N.S.; Luoma, N.S. Kinetic modeling of Ag, Cd and Co bioaccumulation in the clam *Macoma balthica*: quantifying dietary and dissolved sources. *Mar. Ecol. Prog. Ser.* **2002**, *240*, 127 – 141

35. Lee, B.-G.; Wallace, W.G.; Luoma, S.N. Uptake and loss kinetics of Cd, Cr and Zn in the bivalves *Potamocorbula amurensis* and *Macoma balthica*: effects of size and salinity. *Mar. Ecol. Prog. Ser.* **1998**, *75*, 177 - 189

36. Clason, B.; Langston, W.J.; Zauke, G.-P. Bioaccumulation of trace metals in the amphipod *Chaetogammarus marinus* (Leach, 1815) from the Avon and Tamar estuaries (UK): comparison of two-compartment and hyperbolic toxicokinetic models. *Mar. Environ. Research*. **2004a**, *57*, 171 - 195

37. Clason, B.; Gulliksen, B.; Zauke, G.P. Assessment of two-compartment models as predictive tools for the bioaccumulation of trace metals in the amphipod *Gammarus oceanicus*, Segerstråle, 1947 from Grunnfjord (Northern Norway). *Sci. Tot. Environ.* **2004b**, *323,* 227 - 241

38. Wang, W.-X.; Fisher, N.S. Accumulation of trace elements in a marine copepod. *Limnol. Oceanogr.* **1998**, *43*, 273 - 283

39. Yu, R.-Q.; Wang, W.-X. Kinetic uptake of bioavailable cadmium, selenium and zinc by *Daphnia magna*. *Environ. Toxicol. Chem*. **2002**, *21*, 2340 - 2355

40. Lam, I.K.S.; Wang, W.-X. Accumulation and elimination of aqueous and dietary silver in *Daphnia magna*. *Chemosphere*. **2006**, *64*, 26 - 35

41. Tsui, M.T.K.; Wang, W.-X. Uptake and elimination routes of inorganic mercury and methylmercury in *Daphnia magna*. *Environ. Sci. Technol.* **2004**, *38*, 808 - 816

42. Zhang, L.; Wang, W.-X. Effects of Zn pre-exposure on Cd and Zn bioaccumulation and metallothionein levels in two species of marine fish. *Aquat. Toxicol.* **2005**, *73*, 353 - 369

43. Zhang, L.; Wang, W.-X. Alteration of dissolved cadmium and zinc uptake kinetics by metal pre-exposure in the black sea bream (*Acanthopagrus schlegeli*). *Environ. Toxicol. Chem*. **2006**, *25*, 1312 – 1321

44. Long, A.; Wang, W.-X. Assimilation and bioconcentration of Ag and Cd by the marine black bream after waterborne and dietary metal exposure. *Environ. Toxicol. Chem.* **2005**, *24*, 709 - 716

45. Zhao, X.; Wang, W.-X.; Yu, K.N.; Lam, P.K.S. Biomagnification of radiocesium in a marine piscivorous fish. *Mar. Ecol. Prog. Ser.* **2001**, *232*, 227 - 237

46. Xu, Y.; Wang, W.-X. Exposure and potential food chain transfer factor of Cd, Se and Zn in marine fish *Lutjanus argentimaculatus*. *Mar. Ecol. Prog. Ser.* **2002**, *238*, 173 – 186

47. Calamari, D.; Gaggino, G.F.; Pacchetti, G. Toxicokinetics of low levels of Cd, Cr, Ni and their mixture in long-term treatment on *Salmo gairdneri*. *Chemosphere.* **1982**, *11*, 59 - 70

48. Pentreath, R.J. The accumulation of ^{110m}Ag by the plaice *Pleuronectes platessa* L. and the thornback ray, *Raja clavata* L. *J. Exp. Mar. Biol.* **1977**, *29,* 315 - 325

49. Pentreath, R.J. The accumulation of inorganic mercury from seawater by the plaice, *Pleuronectes platessa* L. *J. Exp. Mar. Biol. Ecol.* **1976**, *24*, 103 – 119

50. Newman, M.C.; Mitz, S.V. Size dependence of zinc elimination and uptake from water by the mosquitofish, Gambusia affinis. *Aquat. Toxicol.* **1988**, *12*, 17 - 32

51. Pickhardt, P.C.; Stepanova, M.; Fisher, N.S. Contrasting uptake routes and tissue distributions of inorganic and methylmercury in mosquitofish (*Gambusia affinis*) and redear sunfish (*Lepomis microlophus*). *Environ. Toxicol. Chem.* **2006**, *25*, 2132 - 2142

52. Alsop, D.H.; Wood, C.M. Influence of waterborne cations on zinc uptake and toxicity in rainbow trout, *Oncorhynchus mykiss*. *Can. J. Fish. Aquat. Sci.* **1999**, *56*, 2112 - 2119

53. Ni, I.-H.; Chan, S.M.; Wang, W.-X. Influences of salinity on the biokinetics of Cd, Se and Zn in the intertidal mudskipper *Periophthalmus cantonensis*. *Chemosphere*. **2005**, *61*, 1607 - 1617

54. Guan, R.; Wang, W.-X. Dietary assimilation and elimination of Cd, Se, and Zn by *Daphnia magna* at different metal concentrations. *Environ. Toxicol. Chem*. **2004**, *23*, 2689 - 2698

55. Zhang, L.; Wang, W.-X. Size-dependence of the potential for metal biomagnification in early life stages of marine fish. *Environ. Toxicol. Chem.* **2007**, *26*, 787 - 794

56. Long, A.; Wang, W.-X. Metallothionein induction and bioaccumulation kinetics of Cd and Ag in the marine fish *Terapon jarbua* challenged with dietary or waterborne Ag and Cu. *Mar. Ecol. Prog. Ser.* **2005**, *291*, 215 - 226