RELATING BIOACCUMULATION OF METALS TO THEIR TOXICITY IN LIGURIAN SEA COPEPODS

Nicholas S. Fisher* and Sharon E. Hook

Marine Sciences Research Center, State University of New York, Stony Brook, USA - nfisher@notes.cc.sunysb.edu

Abstract

Metals (Cd, Ag, and Hg) accumulated from phytoplankton food in marine copepods can significantly depress reproductive success at body concentrations that are only 2-fold (Cd), 3-fold (Ag), or 9-fold (Hg) higher than current metal concentrations in Ligurian Sea copepods. Sublethal toxicity is manifested in depressed egg production and hatching following dietary metal exposure. Metals accumulated from the dissolved phase have no effect at environmentally realistic concentrations.

key words: zooplankton; metals; toxicity

Results and discussion

Metals were taken up by the copepods from both dissolved and dietary pathways, but only the ingested metals consistently elicited a toxic response at body burden concentrations of metals close to environmentally realistic levels. For example, lethal concentrations (LC_{50} values) of Cd, Ag, and Hg were 300, 400, and 1000 nM, respectively following uptake from the dissolved phase. These concentrations are at least 2 orders of magnitude above surface seawater concentrations in the Ligurian Sea (7), suggesting that dissolved metals are unlikely to ever approach levels that are directly and acutely toxic to copepods. Concentration factors of these metals from the dissolved phase in the copepods following 12-h exposures were 1.0×10^3 for Cd, 3.0×10^3 for Ag, and 1.3×10^4 for Hg. These metals were bound principally to the exoskeleton (from 60% for Cd to 93% for Hg).

Metals accumulated in copepods from ingested diatoms were principally bound to internal tissues (ranging from 77% for Cd to 99% for Hg) and produced a sublethal toxic effect but had no acutely toxic effects at environmentally realistic concentrations. We found assimilation efficiencies of 62% for Cd, 15% for Ag, and 14% for Hg, comparable to previous studies (3). When the algal food was exposed to concentrations as low as 1 nM for Ag or Hg and as low as 5 nM for Cd, copepods feeding on this food produced significantly fewer eggs ($p < 0.05$) and many of these eggs did not hatch, leading to a pronounced decline in reproductive success. Toxic metal concentrations in phytoplankton (nmol g^{-1} dry wt, determined by measuring metal radioisotope uptake), which affected egg production were 64 for Cd, 39 for Ag, and 34 for Hg, or 1-2 orders of magnitude above background levels in phytoplankton in the Ligurian Sea (7). Table 1 presents the sublethal effects of the ingested metals as a function of the body burdens of these metals. The results suggest that concentrations of metals in Ligurian Sea copepods are within an order of magnitude, and generally within a factor of 2-3, of levels which can interfere with egg production and hatching. Toxicological studies clearly must consider sublethal effects and dietary pathways as well as solute uptake in assessing contaminant impacts on marine animal populations.

Table 1. Effects of metal accumulated from ingested diatoms on reproductive success in marine copepods. Dissolved Cd and Ag had no effect on egg production, whereas dissolved Hg significantly depressed egg production at body concentrations 11 times higher than those produced by ingestion of diatoms.

Metal	Lowest concentration in copepods (nmom g^{-1} dry wt whole body) that significantly affected egg production. Values in parentheses are concentrations in Ligurian Sea copepods (7,12).	Reproductive success relative to controls (considering egg production and hatching success rate).	Ratio of lethal to sublethal ambient metal concentrations (LC_{50} : EC_{50} values)
Cd	42.0 (22.1)	28%	1000 nM:5 nM = 200
Ag	4.3 (1.3)	57%	400 nM:1 nM = 400
HG	2.7 (0.3)	37%	300 nM:1 nM = 300

References

1. Fisher N.S., 1986. On the reactivity of metals for marine phytoplankton. *Limnol. Oceanogr.*, 31: 443-449.
2. Fisher N.S. and Reinfelder J.R., 1995. The trophic transfer of metals in marine systems. *In:* Tessier A., and Turner D.R. (eds.), Metal Speciation and Bioavailability in Aquatic Systems. John Wiley & Sons, Chichester, pp. 363-406.
3. Wang W.-X. and Fisher N.S., 1999. Assimilation efficiencies of chemical contaminants in aquatic invertebrates: a synthesis. *Environ. Toxicol. Chem.*, 18: 2034-2045.
4. Fisher N.S. and Fowler S.W., 1987. The role of biogenic debris in the vertical transport of transuranic wastes in the sea. *In:* O'Connor T.P., Burt W.V. and Duedall I.W. (eds.), Oceanic Processes in Marine Pollution, Vol. 2, Physicochemical Processes and Wastes in the Ocean. Krieger, Malabar, pp. 197-207.
5. Fisher N.S., Nolan C.V. and Fowler S.W., 1991. Assimilation of metals in marine copepods and its biogeochemical implications. *Mar. Ecol. Prog. Ser.*, 71: 37-43.
6. Fisher N.S., Nolan C.V. and Fowler S.W., 1991. Scavenging and retention of metals by zooplankton fecal pellets and marine snow. *Deep-Sea Res.*, 38: 1261-1275.
7. Fisher N.S., Stupakoff I., Sañudo-Wilhelmy S.A., Wang W.-X., Teyssié J.-L., Fowler S.W. and Crusius J., 2000. Trace metals in marine copepods: a field test of a bioaccumulation model coupled to laboratory uptake kinetics data. *Mar. Ecol. Prog. Ser.*, 194: 211-218.
8. Wang W.-X. and Fisher N.S., 1998. Accumulation of trace elements in a marine copepod. *Limnol. Oceanogr.*, 43: 273-283.
9. Reinfelder J.R. and Fisher N.S., 1994. Retention of elements absorbed by juvenile fish (*Menidia menidia, M. beryllina*) from zooplankton prey. *Limnol. Oceanogr.*, 39: 1783-1789.
10. Fisher N.S., Bjerregaard P. and Fowler S.W., 1983. Interactions of marine plankton with transuranic elements. III. Biokinetics of americium in euphausiids. *Mar. Biol.*, 75: 261-268.
11. Hook S.E. and Fisher N.S., In press. Reproductive toxicity of metals in calanoid copepods. *Mar. Biol.*
12. Fowler S.W., 1977. Trace elements in zooplankton particulate products. *Nature*, 269: 51-53.
13. Fisher N.S. and Reinfelder J.R., 1991. Assimilation of selenium in the marine copepod *Acartia tonsa* studied with a radiotracer ratio method. *Mar. Ecol. Prog. Ser.*, 70: 157-164.
14. Reinfelder J.R. and N.S. Fisher N.S., 1991. The assimilation of elements ingested by marine copepods. *Science*, 251: 794-796.
15. Wang W.-X., Reinfelder J.R., Lee B.-G. and Fisher N.S., 1996. Assimilation and regeneration of trace elements by marine copepods. *Limnol. Oceanogr.*, 41: 70-81.
16. Reinfelder J.R. and Fisher N.S., 1994. The assimilation of elements ingested by marine planktonic bivalve larvae. *Limnol. Oceanogr.*, 39: 12-20.
17. Hutchins D.A., Wang W.-X. and Fisher N.S., 1995. Copepod grazing and the biogeochemical fate of diatom iron. *Limnol. Oceanogr.*, 40: 989-994.
18. Hook S.E. and Fisher N.S., 2001. Sublethal effects of silver in zooplankton: importance of exposure pathways and implications for toxicity testing. *Environ. Toxicol. Chem.*, 20: 568- 574.