2007-1-10 (3)

Available online at www.sciencedirect.com
ScienceDirect
Comparative Biochemistry and Physiology, Part C 145 (2007) 227–235
CBP
www.elsevier.com/locate/cbpc

Cadmium bioaccumulation and detoxification in the gill and digestive gland of the Antarctic bivalve *Laternula elliptica*

Heeseon J. Choi [1], Jungyoun Ji, Kyung-Ho Chung, In-Young Ahn *

Korea Polar Research Institute, Korea Ocean Research and Development Institute, 1270 Sa-2-dong, Sangrokgu, Ansan 426-744, Republic of Korea

Received 9 October 2006; received in revised form 8 December 2006; accepted 8 December 2006
Available online 15 December 2006

Abstract

Exposure to a sublethal concentration of cadmium (Cd; 50 μg L^{-1}) resulted in significantly increased Cd concentrations in the gill and digestive gland of the Antarctic bivalve *Laternula elliptica*. Continuous accumulation of Cd in the two organs during the 14-day exposure period was associated with sequestration of Cd to both the soluble cytosolic and insoluble particulate cell fractions. However, the contribution of each cell fraction to Cd sequestration differed between the two organs; in the gill, a larger portion of Cd was associated with the insoluble fraction, while in the digestive gland, both the soluble and insoluble fractions sequestered similar amounts of Cd. Metal-binding components in the insoluble cell fraction were not identified in this study. On the other hand, a metallothionein-like protein (MTLP) was the major Cd-detoxifying component in the soluble cell fraction of the gill and digestive gland. The amount of MTLP increased linearly with exposure time and the amount of Cd accumulated in the tissue, which suggests a potential utility of MTLP as a biomarker for exposure to Cd and possibly other metals.

Keywords: Antarctic; Cadmium; Detoxification; *Laternula elliptica*; Metal accumulation; Metallothionein-like protein

1. Introduction

Antarctica is one of the most pristine environments in the world. However, the condition of the Antarctic marine environment has been threatened by increasing human activities in the area, and long-range transport of contaminants from the rest of the world. Evidence from recent decades clearly shows an elevation in various toxic contaminants in some Antarctic marine organisms and environments, especially in some inshore areas where research stations have operated for years (e.g., Lee et al., 1990; Lenihan et al., 1990; Kennicutt et al., 1995; Lohan et al., 2001; Corsolini et al., 2002; Duquesne and Riddle, 2002; Sañudo-Wilhelmy et al., 2002). Understanding the biological significance of elevated contaminants is important to properly diagnosing the Antarctic coastal ecosystem (Abbott and Benninghoff, 1990; Walton et al., 2001; Riddle et al., 2003).

Cadmium (Cd), one of the most toxic heavy metals and a common environmental contaminant (US EPA, 1978; Nriagu, 1980), may be of particular concern in the Antarctic coastal environment, because its levels have already become elevated in the Antarctic marine environment via natural processes (Mauri et al., 1990; Ahn et al., 1996; Bargagli et al., 1996; Nigro et al., 1997; Vodopivez et al., 2001). In addition, the evolution of metal-resistant populations of marine organisms may reflect relatively rapid natural selection (Shirley and Sibly, 1999; Xie and Klerks, 2004). Therefore, it is possible that Antarctic organisms, which have survived in naturally Cd-elevated environments over a geologic timescale, may have developed efficient adaptive strategies to Cd elevation (Duquesne et al., 2000). Presence of Cd-binding metallothioneins (MTs) in some mollusk populations (Viarengo et al., 1993; Choi et al., 2001, 2003a) may be one such defensive mechanism against Cd toxicity. MTs are one of the most important metal-binding and detoxifying ligands in marine bivalve mollusks (Roesijadi, 1992; Viarengo and Nott, 1993; Mason and Jenkins, 1995; Langston et al., 1998), including Antarctic species (Viarengo et al., 1993, 1997; Ponzano et al., 2001; Choi et al., 2001, 2003a,b).

* Corresponding author. Tel.: +82 31 400 6421; fax: +82 31 408 5825.
E-mail addresses: iahn@kopri.re.kr, iahn@kordi.re.kr (I.-Y. Ahn).
[1] Present address: Geosystem Research Corp., 306 Hanlim Human Tower, 1-40 Geumjung-Dong, Gunpo City, Gyounggi-Do 435-824, Korea.

1532-0456/$ - see front matter © 2006 Elsevier Inc. All rights reserved.
doi:10.1016/j.cbpc.2006.12.005

other metals. Metal-binding components in the insoluble cell fraction, particularly in the gill, are to be characterized in future studies.

Acknowledgments

We thank the reviewers for their valuable comments on this manuscript and to the diver Seung Goo Ra and the members of the 15th Korea Antarctic Research Program for their support in conducting the experiment. This study was a part of the Monitoring on Environmental Changes at the Korean Arctic and Antarctic Stations (PE06040) program, and supported by the Korea Science and Engineering Foundation (No. R03-2000-000-00004-0) and the Korea Polar Research Institute (KOPRI) of the Korea Ocean Research and Development Institute (KORDI).

References

Abbott, S.B., Benninghoff, W.S., 1990. Orientation of environmental change studies to the conservation of Antarctic ecosystems. In: Kerry, K.R., Hempel, G. (Eds.), Antarctic Ecosystems: Ecological Change and Conservation. Springer-Verlag, Berlin, pp. 394–403.

Ahn, I.-Y., 1993. Enhanced particle flux through the biodeposition by the Antarctic suspension-feeding bivalve *Laternula elliptica* in Marian Cove, King George Island. J. Exp. Mar. Biol. Ecol. 171, 75–90.

Ahn, I.-Y., 1997. Feeding ecology of the Antarctic lamellibranch *Laternula elliptica* (Laternullidae) in Marian Cove and vicinity, King George Island, during one austral summer. In: Battaglia, B., Valencia, J., Walton, D.W.H. (Eds.), Antarctic Communities: Species, Structure and Survival. Cambridge University Press, Cambridge, pp. 142–151.

Ahn, I.-Y., Lee, S.H., Kim, K.T., Shim, J.H., Kim, D.Y., 1996. Baseline heavy metal concentrations in the Antarctic clam, *Laternula elliptica* (King and Broderip) in Maxwell Bay, King George Island, Antarctica. Mar. Pollut. Bull. 32, 592–598.

Ahn, I.-Y., Chung, H., Choi, K.S., 2001a. Some ecological features of the Antarctic clam, *Laternula elliptica* (King and Broderip) in a nearshore habitat on King George Island. Ocean Polar Res. 23, 419–424.

Ahn, I.-Y., Kang, J., Kim, K.-W., 2001b. The effect of body size on metal accumulations in the bivalve *Laternula elliptica*. Antarct. Sci. 13, 355–362.

Ahn, I.-Y., Chung, K.H., Choi, H.J., 2004. Influence of glacial runoff on baseline metal accumulation in the Antarctic limpet *Nacella concinna* from King George Island. Mar. Pollut. Bull. 49, 119–141.

Bargagli, R., Nelli, L., Ancora, S., Focardi, S., 1996. Elevated cadmium accumulation in marine organisms from Terra Nova Bay (Antarctica). Polar Biol. 16, 513–520.

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

Bordin, G., McCourt, J., Raposo, F.C., Rodriguez, A., 1996. Trace metals in the marine bivalve *Macoma balthica* in the Wetserschelde estuary, The Netherlands. part 3: variability of the role of cytosol in metal uptake by the clams. Sci. Total Environ. 180, 241–255.

Brown, M.T., Depledge, M.H., 1998. Determinants of trace metal concentrations in marine organisms. In: Langston, W.J., Bebianno, M.J. (Eds.), Metal metabolism in aquatic environments. Ecotoxicology Series, vol. 7. Chapman and Hall, London, pp. 185–217.

Choi, H.J., Ahn, I.-Y., Ryu, S.-K., Lee, Y.-S., Lee, I.-S., Jeong, K.-H., 2001. Preliminary evidence for a metallothionein-like Cd-binding protein in the kidney of the Antarctic clam *Laternula elliptica*. Ocean Polar Res. 23, 337–345.

Choi, H.J., Ahn, I.-Y., Kim, K.-W., Kim, H.-A., Lee, I.-S., 2003a. Subcellular distribution of naturally elevated cadmium in the Antarctic clam *Laternula elliptica*. Bull. Environ. Contam. Toxicol. 71, 83–89.

Choi, H.J., Ahn, I.-Y., Kim, K.-W., Lee, Y.-S., Lee, I.-S., Jeong, K.-H., 2003b. Subcellular accumulation of Cu in the Antarctic bivalve *Laternula elliptica* from a naturally Cu-elevated bay of King George Island. Polar Biol. 26, 601–609.

Corsolini, S., Romeo, R., Ademollo, N., Greco, S., Focardi, S., 2002. POPs in key species of marine Antarctic ecosystem. Microchem. J. 73, 187–193.

Cosson, R.P., 2000. Bivalve metallothionein as a biomarker of aquatic ecosystem pollution by trace metals: limits and perspectives. Cell. Mol. Biol. 46, 295–309.

Danielsson, L., Magnausson, B., Westerlund, S., 1978. An improved metal extraction procedure for the determination of trace metals in seawater by atomic absorption spectrometry with electrothermal atomization. Anal. Chem. Acta 98, 47–57.

Duquesne, S., Riddle, M.J., 2002. Biological monitoring of heavy-metal contamination in coastal waters off Casey Station, Windmill Islands, East Antarctica. Polar Biol. 25, 206–215.

Duquesne, S., Riddle, M., Schulz, R., Liess, M., 2000. Effects of contaminants in the Antarctic environment — potential of the gammarid amphipod crustacean *Paramorea walkeri* as a biological indicator for Antarctic ecosystems based on toxicity and bioaccumulation of copper and cadmium. Aquat. Toxicol. 49, 131–143.

Ellman, G.L., 1958. A colorimetric method for determining low concentrations of mercaptans. Arch. Biochem. Biophys. 74, 443–450.

Geret, F., Cosson, R.P., 2002. Induction of specific isoforms of metallothionein in mussel tissues after exposure to cadmium or mercury. Arch. Environ. Contam. Toxicol. 42, 36–42.

Jenkins, K.D., Mason, A.Z., 1988. Relationship between subcellular distributions of cadmium and perturbations in reproduction in the polychaete *Neanthes arenaceodendata*. Aquat. Toxicol. 12, 229–244.

Kennicutt II, M.C., McDonald, S.J., Sericano, J.L., Boothe, P., Oliver, J., Safe, S., Presley, B.J., Hong, Liu, Wolfe, D., Wade, T.L., Crockett, A., Bockus, D., 1995. Human contamination of the marine environment—Arthur Harbor and McMurdo Sound, Antarctica. Environ. Sci. Technol. 29, 1279–1287.

King, C.K., Riddle, M.J., 2001. Effects of metal contaminants on the development of the common Antarctic sea urchin *Sterechinus neumayeri* and comparisons of sensitivity with tropical and temperate echinoids. Mar. Ecol., Prog. Ser. 215, 143–154.

Langston, W.J., Bebianno, M.J., Mingjiang, Z., 1989. A comparison of metal-binding proteins and cadmium metabolism in the marine mollusks, *Littorina littorea* (Gastropoda), *Mytilus edulis* and *Macoma balthica* (Bivalvia). Mar. Environ. Res. 28, 195–200.

Langston, W.J., Bebianno, M.J., Burt, G.R., 1998. Metal handling strategies in mollusks. In: Langston, W.J., Bebianno, M.J. (Eds.), Metal metabolism in aquatic environments. Chapman and Hall, London, pp. 219–283.

Lee, S.H., Kim, K.T., Kim, S.H., 1990. Trace metals in the surface waters of Maxwell Bay, King George Island, Antarctica. Korean J. Polar Res. 1, 11–15 (in Korean with English abstract).

Lenihan, H.S., Oliver, J.S., Oakden, J.M., Stephenson, M.D., 1990. Intense and localized benthic marine pollution around McMurdo Station, Antarctica. Mar. Pollut. Bull. 21, 422–430.

Lohan, M.C., Statham, P.J., Peck, L., 2001. Trace metals in the Antarctic soft-shelled clam *Laternula elliptica*: implications for metal pollution from Antarctic research stations. Polar Biol. 24, 808–817.

Mackay, E.A., Overnell, J., Dunbar, B., 1993. Complete amino acid sequences of five dimeric and four monomeric forms of metallothionein from the edible mussel *Mytilus edulis*. Eur. J. Biochem. 218, 183–194.

Mason, A.Z., Jenkins, K.D., 1995. Metal detoxification in aquatic organisms. In: Tessier, A., Turner, D.R. (Eds.), Metal speciation and bioavailability in aquatic systems. John Wiley and Sons, Chichester, pp. 479–603.

Mauri, M., Orlando, E., Nigro, M., Regoli, F., 1990. Heavy metals in the Antarctic scallop *Adamussium colbecki*. Mar. Ecol., Prog. Ser. 67, 27–33.

Mercuri, G., Iken, K., Ledesma, B., Dubois, R.F., 1998. On the distribution pattern and density of the Antarctic infaunal bivalve *Laternula elliptica* in Potter Cove, King George Island. In: Wiencke, C., Ferreyra, G., Arntz, W., Rinaldi, C. (Eds.), The Potter Cove coastal ecosystem, Antarctica. Ber Polarforsch, pp. 137–143.

Nigro, M., Regoli, F., Rocchi, R., Orlando, E., 1997. Heavy metals in Antarctic mollusks. In: Battaglia, B., Valencia, J., Walton, D.W.H. (Eds.), Antarctic