Marine Pollution Bulletin 88 (2014) 180–187

Contents lists available at ScienceDirect

Marine Pollution Bulletin

journal homepage: www.elsevier.com/locate/marpolbul

# Response of the hairy mussel *Trichomya hirsuta* to sediment-metal contamination in the presence of a bioturbator

L.K. Lopez [a,*], P. Couture [b], W.A. Maher [c], F. Krikowa [c], D.F. Jolley [d], A.R. Davis [a]

[a] School of Biological Sciences, University of Wollongong, NSW 2522, Australia
[b] Institut National de La Recherche Scientifique, INRS—Centre Eau Terre Environnement, 490 de la Couronne, Quebec, QC G1K 9A9, Canada
[c] Ecochemistry Laboratory, Institute for Applied Ecology, Health, Design and Science, University of Canberra, Bruce, ACT 2601, Australia
[d] School of Chemistry, University of Wollongong, NSW 2522, Australia

ARTICLE INFO

*Article history:*
Available online 22 September 2014

*Keywords:*
Bivalve
Gastropod
Metal gradient
Cadmium
Zinc
Lead

ABSTRACT

The accumulation of metals in tissue compartments of bivalve biomonitors is expected to reflect the phases in which metals are most bioavailable. In concurrent field and laboratory experiments we measured Zn, Cd and Pb concentrations in the gills and digestive glands of mussels exposed to sediments from Lake Macquarie in NSW, Australia. Mussels in the laboratory were also exposed to the bioturbating gastropod *Batillaria australis*. Zn, Cd and Pb concentrations in gills and digestive glands of mussels from both experiments were accumulated in proportion with levels of metal contamination in the sediments. An interaction in the field between site and tissue type was found for Cd and Pb suggesting variation in the phases in which metals are most bioavailable. No effect of bioturbation on metal accumulation in the bivalve was detected and we conclude that it is unlikely to be a significant factor in metal uptake when these species interact.



## 1. Introduction

Metals are often present in high concentrations in many coastal regions as a result of industrial development and urbanisation (Bresler et al., 1999). The use of marine organisms to monitor these contaminants allows for the estimation of the bioavailable metal fraction in waters (Palmer and Rand, 1977; Uthe and Chou, 1987; Taylor and Maher, 2006) and was initially employed by Goldberg et al. (1983) as part of the United States of America Mussel Watch Program. Whilst phytoplankton, zooplankton, macrophytes, gastropod molluscs and fish have all been employed as bio-monitors, bivalve molluscs have been the most extensively used (Rainbow, 1995), particularly in temperate regions (Goldberg et al., 1983; Rainbow and Phillips, 1993).

Filter feeding organisms, such as bivalves, possess many attributes that make them ideal sentinels of marine contamination. As well as being ubiquitous and able to tolerate a wide range of temperatures, salinities, dissolved oxygen and suspended sediments (Anderson, 2001), some bivalves can detoxify and store metals for a significant length of time, without suffering lethal effects (Klumpp and Burden-Jones, 1982; Batley, 1987; Lukyanova et al., 1993; Birch and Hogg, 2011). Their sedentary lifestyle means they can also provide data on spatial variation of bioavailable metals in the environment (Rainbow, 1995; Warnau et al., 1998), with evidence that some species have tissue metal concentrations that reflect sediment-metal concentrations (Luoma et al., 1990; Burt et al., 2007; Taylor and Maher, 2012a,b).

The bioavailability of metals is dependent on the degree to which they are bound to particulate matter or are dissolved into the water column (Forbes et al., 1998). Generally, dissolved metals are more available than those adsorbed to particles (Atkinson et al., 2007). Suspension feeders, however, accumulate contaminants from both dissolved and particulate phases (Lukyanova et al., 1993; Hansen et al., 1995; Birch and Hogg, 2011) meaning they can assimilate metals from solution and in suspended materials (Luoma and Rainbow, 2008). Suspended materials may include phytoplankton, detritus, zooplankton and where disturbed, surficial sediments that have been re-suspended in the water column (Rainbow and Phillips, 1993). Metal uptake from both dissolved and particulate phases may subsequently be reflected in the tissue compartmentalisation of metals (Chapman and Wang, 2001). Dietary derived metals assimilated from the particulate phase by bivalves enter into the alimentary canal and pass through (and are potentially stored in) the digestive gland, while dissolved metals absorbed from the water column may be present at high concentrations in the mantle and gills (Chapman and Wang, 2001; George, 1980).

* Corresponding author.

http://dx.doi.org/10.1016/j.marpolbul.2014.09.008
0025-326X/

Re-suspension events such as bioturbation, tidal flushing and dredging can significantly increase levels of bioavailable contaminants (Atkinson et al., 2007; Hedge et al., 2009). This process alters the contaminant partitioning in deeper anoxic sediments, potentially oxidising metal-sulfides and liberating metals into the dissolved phase increasing the flux of bioavailable metals within the sediment and across the sediment–water interface (Chapman and Wang, 2001; Simpson et al., 2002, 2012, 2014, 2011). Hedge et al. (2009) documented this effect on the oyster *Saccostrea glomerata* following a dredging event which resulted in a significant increase in contamination in the water column and in the oysters.

Bioturbation arises from the activity of organisms inhabiting the sediment or its surface and has been demonstrated to increase metal concentrations including cadmium, iron and manganese in the overlying water column (Hirst and Aston, 1983; Prause et al., 1985; Calmano et al., 1994). Peters et al. (1999) reported increased selenium bioavailability due to sediment bioturbation by a polychaete (*Marphysa sanguinea)* and a bivalve (*Spisula trigonella*). Another study by Atkinson et al. (2007) reported that sediments bioturbated by the deposit-feeding bivalve *Tellina deltoidalis* caused metal release from the pore waters and higher concentrations of iron and manganese in overlying waters than in non-bioturbated sediments. In addition, *T. deltoidalis* accumulated significantly higher tissue concentrations of zinc, cadmium and lead from the metal contaminated sediments compared to controls. This suggests that despite lead and zinc likely being bound as sulfide phases in deeper sediments, the metals maintain their bioavailability because of the continued cycling between pore waters and surface sediments due to physical mixing and bioturbation. Only one previous study (Ciutat and Boudou, 2003), however, has examined the effect of a bioturbator, the larvae of the Mayfly *Hexagenia rigida,* on metal uptake in a non-bioturbating organism, the bivalve *Corbicula fluminea.*

Consequently, information is lacking regarding the bioavailability of resuspended metals to other benthic fauna as a result of bioturbation. It is likely that metals liberated during disturbance events (such as bioturbation) become more available to other organisms through water exposure (from increased dissolved metals) or dietary uptake (increase in metal accumulation in microalgae, or metal adsorption onto suspended particles) (Hedge et al., 2009). Yet it is also possible that bioturbation will decrease metal uptake by producing increased fine suspended sediments that clog or disturb the filtration activities of suspension feeders. Considering the prevalence of bioturbating organisms in marine and freshwater sediments it is important to assess whether their activities alter the accumulation of metals in sentinel species. If bioturbation is a significant factor then the relevance and accuracy of some field and laboratory contamination studies, which do not consider bioturbation, may be questioned.

In the current study, we first sought to determine the accumulation of zinc, cadmium and lead in tissue compartments, specifically the digestive glands and gills of the Hairy Mussel, *Trichomya hirsuta* (Lamark), (Mytilidae) collected across a sediment-metal contamination gradient in Lake Macquarie. Although past studies have established this species to be an effective biomonitor of metals (Batley, 1987; Klumpp and Burden-Jones, 1982), metal contamination has only been recorded on a whole organism basis. By comparing metal concentrations in the digestive glands and gills we sought to establish in which phase, dissolved or particulate, metals are most bioavailable to mussels. We predicted that tissue concentrations of zinc, cadmium and lead would conform to the established sediment-metal concentration gradient and yet this would differ between tissue compartments. Subsequently, we conducted a laboratory study to determine the effect of the bioturbating benthic gastropod *Batillaria australis* on metal uptake in *T. hirsuta* and the condition of bivalves previously not exposed to high levels of sediment-metal contamination. We predicted that metal uptake by the suspension feeding *T. hirsuta* would increase in the presence of *B. australis* as sediment-bound metals would become more bioavailable due to bioturbation-induced changes in sediment-metal partitioning.

## 2. Materials and methods

### *2.1. Study species and study locations*

The endemic Hairy Mussel, *T. hirsuta* (Lamark), is distributed along the East Coast of Australia. It is found in a variety of habitats, including rocky reefs and soft substrata where it often forms clumps. As suggested by its common name the periostracum of this species is covered in short bristles. *B. australis* is an endemic gastropod found in saline lakes, estuaries and mudflats from Queensland to Tasmania as well as Western Australia where it is an invasive species (Thomsen et al., 2010). It is known to be highly tolerant of a wide range of salinity and temperatures (Ewers, 1965, 1966). Animals used in this study were collected under DPI permit number F295. All experiments were undertaken in accordance with Australian animal ethics guidelines.

To assess the effect of sediment-metal concentration on the tissue distribution of the metals Pb, Cd and Zn, *T. hirsuta* were collected along a sediment-metal concentration gradient in Lake Macquarie NSW, Australia. Lake Macquarie, located approximately 100 km north of Sydney, is the largest coastal lake in Eastern Australia with a catchment area of about 622 $km^2$ (AWACS, 1995). The lake is physically divided into two sections due to the easterly projection of Wangi–Wangi Point and the shallows of Swansea (Jolley et al., 2004). This is responsible for the limited mixing of sediment between the north and south as well as heightened accumulation of metals and other contaminants in both sections of the lake (Batley, 1987). Almost all shores of the lake have been affected by industrialisation, urbanisation or both. The major industrial sources of metal in the north are discharges from a lead zinc smelter (which commenced operation in 1897 and ceased in 2003), collieries, sewage treatment works and a steel foundry (Batley, 1987) resulting in elevated lead and cadmium levels in sediments. The southern section of the lake has two coal fired power plants at Eraring and Vales Point where high concentrations of selenium have been reported owing to discharges from ash wash dams (Roy and Crawford, 1984; Batley, 1987). Previous studies have recorded *T. hirsuta* to be widespread in Lake Macquarie (Batley, 1987; Furner, 1979).

*T. hirsuta* were collected in winter from five sites which were selected based on the findings of previous studies (Batley, 1987; Burt et al., 2007) which have established the presence of a latitudinal gradient in Zn, Cd and Pb concentrations in sediments. From north to south these sites were: Cockle Creek (CC: 32°57′′45.87″S, 151°36′58.90″E), Warners Bay (WB: 32°58′28.57″S, 151°38′24.36″E), South Belmont (SB: 33°04′17.07″, 151°37′43.52″E), Nords Wharf (NW: 33°08′18.58″S, 151°36′30.44″E), and Vales Point (VP: 33°08′36.12″S, 151°32′14.04″E) (Fig. 1). At each site a minimum of ten *T. hirsuta* individuals were collected in shallow water (0.7 m and within 15 m of the shore) and where possible mussels were collected from a number of separate clumps in order to maximise the spatial scale of sampling within each location. Shell lengths of the collected specimens ranged from 20.7 to 50.1 mm with an average of 41.4 ± 1.2 mm (mean ± SE). Sediment samples were collected from the surface sediment layer (<5 cm) and kept frozen until metal analysis.

*T. hirsuta* used in the laboratory component of this study were collected near the entrance to Lake Conjola (35°16′05.39″S, 150°29′34.23″E), on the south coast of NSW, Australia. This site was chosen because it has less industry and urbanisation and experiences greater, although intermittent, tidal flushing and