Marine Pollution Bulletin xxx (2017) xxx–xxx

Contents lists available at ScienceDirect

Marine Pollution Bulletin

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

Baseline

Heavy metal concentrations in some gastropods and bivalves collected from the fishing zone of South India

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ARTICLE INFO

Article history:
Received 3 December 2016
Received in revised form 9 March 2017
Accepted 15 March 2017
Available online xxxx

Keywords:
Heavy metals
Fishing zone
Gastropods
Bivalves

ABSTRACT

The present study investigates heavy metal concentrations in gastropods and bivalves collected from major fishing centers in South India. Three gastropods, *Bursa spinosa*, *Tibia curta*, and *Murex trapa*, and two bivalves, *Perna viridis* and *Villoritta cyprinoids*, were collected for the analysis of heavy metals. The metals in the present study followed the order Mg > Ca > Zn > Fe > Cu > Mn > Cr > Pb > Ni > Co > Cd. Trace metal concentrations in the soft tissue of the molluscs varied as follows: for Cd: 0.04–5.33, Co: 0.09–0.87, Cr: 2.18–7.59, Cu: 9.54–37.02, Mn: 1.30–8.50, Ni: 0.94–3.21, Pb: 1.16–2.64 and Zn: 68.16–113.64 mg kg^{-1}. Metal concentrations in all the species were below the limits proposed by the World Health Organization, except for Pb and Cd. This baseline study suggests that the levels of toxic metals in *M. trapa, T. curta*, and *B. spinosa* should be continuously monitored to assess the fate and effects of these metals in this fragile ecosystem.

Heavy metal pollution has been a hot topic in marine environmental studies for many years. Although metals occur naturally in the environment, industrialization, agricultural land runoff, oil and gas production, tourism development, and heavy rainfall throughout the year have resulted in large quantities of metal toxicants in the marine environment (Li and Zhang, 2010; Varol et al., 2013; Zhang et al., 2016). Metals are nonbiodegradable, rapidly assimilate in the environment, and extend to toxic levels within a short period of time (Zhang et al., 2016). One of the problems associated with the persistence of heavy metals is the bioaccumulation, followed by bio-magnification, of these toxicants, which results in persistent hazards for both human health and the ecosystem (Rahman et al., 2012; Kalantzi et al., 2013). Health risk to humans from large exposure to trace elements through sea food consumption is commonly prominent in coastal areas (Li and Guo, 2011; Leung et al., 2014). The toxicity of heavy metals in seafood is a serious problem all over the world, especially in developing countries (Rumisha et al., 2012; Taweeln et al., 2013; Zhang et al., 2016).

All living organisms require small amounts of essential elements such as Ca, Mg, Fe, Mn, Cu, Ni, and Zn for their biological metabolism and growth (Kamaruzzaman et al., 2011; Yusoff and Long, 2011; Hossen et al., 2015). Metals such as Cd, Pb, and Cr are not essential for metabolic activities and become toxic even at relatively low concentrations (Kamaruzzaman et al., 2011). Although all organisms need these elements for the proper functioning of the body, these metals can have harmful effects when their concentrations exceed the standard limits (Beldi et al., 2006). Marine organisms, especially gastropods, bivalves, oysters, sponges, and sea cucumbers, have the ability to assimilate metals from their living environments (Roméo et al., 2005; Cervantes et al., 2009). Therefore, these organisms have been extensively used as bio-indicators of metal contamination in marine ecosystems (Martin and Richardson, 1991; Rainbow, 1995; Cantillo, 1998; Ribes et al., 1999; Turon et al., 2014). Many species of molluscs are used for the Mussel Watch Program because they fulfill the qualities of an ideal sentinel organism (Sures, 2004): they have a wide geographical distribution, are sensitive to many contaminants but tolerant to a large range of abiotic factors, can be maintained and experimented on the laboratory, and have a sedentary nature that helps in definitely represents the local pollution (Reiswig, 1971; Ribes et al., 1999; Perez et al., 2004; Genta-Jouve et al., 2012; Turon et al., 2014). The levels of all the elements in these species have great relevance because they can help to monitor the variation in the concentration and accumulation of all elements in the biota. In recent years, investigators have focused their attention on placing other possible organisms such as gastropods and bivalves for assessing trace metal pollution (Rainbow et al., 2000). In the past two decades, researchers have been using different gastropod molluscs, namely *B. nanum, D. trunculus*, and *C. gallina* (Gay and Maher, 2003; Usero et al., 2004), and bivalves, namely *P. grandis, C. angulata, S. plana, P. longirostris, U. tangeri, M. kerathurus, C. virginica, R. ovate, R. venosa,* and *N. didyma*, as sentinel organisms (Blasco et al., 1999; Gundacker, 2000; Apeti et al., 2005; Bonneris et al., 2005; Lee et al., 2006; Gupta and Singh, 2011).

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http://dx.doi.org/10.1016/j.marpolbul.2017.03.029
0025-326X/

The Ashtamudi lagoon is the second largest estuary in Kerala, South India, and is included in the list of wetlands of international importance, as defined by the Ramsar Convention for the conservation and sustainable utilization of wetlands. It is a palm-shaped extensive water body with a water spread area of approximately 32 km^2. The Ashtamudi estuary opens to the Arabian Sea at Neendakara, an area of frequent sea erosion that is severely polluted by major and minor industrial effluents (Sujatha et al., 2009; Cheriyan et al., 2015). Neendakara is a famous fishing center in South India, and fishery is a major source of income for the fishing community here. According to Robin et al. (2013), the average marine production from the state of Kerala is approximately 25% of the country's marine production, and fisheries contribute approximately 3% to the state's economy. Kerala's estimated value of marine fishery potential is about 7.95 lakh tons (Robin et al., 2013). The Ashtamudi estuary contains heavy mineral deposits due to the input of mineral-rich sand from the sea by tidal currents, especially during upwelling periods. Based on the chlorophyll content, the Ashtamudi estuary is a mesotrophic productive ecosystem, and it is suitable for the growth and survival of fishery (Pirnie, 2005). Approximately 90% of the overall bivalves exported from India are from the Ashtamudi estuary. The estimated standing stock biomass of bivalves in the Ashtamudi estuary during March 2011 was 24,191.6 tons in an estimated bed area of 173.29 ha (Mohamed et al., 2013). Various economic activities have created numerous environmental and ecological problems in Ashtamudi and Neendakara, including fishing operations, discharging untreated effluents, harbor activities, agricultural activities, and expanding tourism on the shores. Bivalves and gastropods are found in the inter-tidal sandy shores of the Ashtamudi lagoon and are well-known accumulators of heavy metals. Moreover, they have been widely used as sentinel organisms for monitoring trace metal pollution in the aquatic environment. The aim of the present study was to (1) determine the concentrations of heavy metals in gastropods and bivalves from major fishing zones in South India, (2) compare the results of the present study with the permissible limits of toxic metals, and (3) evaluate the correlation between metal concentrations in the tissues of the gastropods and bivalves to identify exogenic sources.

The gastropods *Tibia curta*, *Murex trapa,* and *Bursa spinosa* and bivalves *Perna viridis* and *Villorita cyprinoids* (Fig. 1) were collected from five different stations (S1, S2, S3, S4, and S5) of the Ashtamudi estuary situated in Kollam district, Kerala, India. S1 lies in the barmouth region (Needakkara) (Latitude: 8° 56′ 40″N. Longitude: 76° 32′ 25″E), and S2 is the old Neendakara fishing harbor (Latitude: 8° 56′ 13.1″N. Longitude: 76° 32′ 30.9″E). S3 is located in Sakthikulangara barmouth (Latitude: 8° 55′ 30″N. Longitude: 76° 33′ 22″E); oil spillage from mechanized boat is a major source of pollution in this site. S4 and S5 were located in Dalavapuram (Latitude: 8° 94′ 87"N. Longitude: 76° 55′ 03″E) and Chavara Thekumbhagom (Latitude: 8° 96′ 67″N. Longitude: 76° 56′ 33″E), respectively (Fig. 2).

The bivalves (*P. viridis* and *V. cyprinoids*) and gastropods (*T. curta, B. spinosa* and *M. trapa*) collected from the sampling sites were washed in water. A second wash was given with distilled water, and the soft tissues were removed from the shells. All the soft tissues were freeze dried. The dried samples were crushed by using a mortar and pestle and were shaken vigorously to produce homogeneity (Yap et al., 2002).

Approximately 2 g of dried samples were digested with a mixture of concentrated HNO_3 (AnalaR grade; BDH 69%) and $HClO_4$ (AnalaR grade; BDH 60%) in the ratio 5:1. The samples were heated in a hot-block digester first at low temperature (40 °C) for 1 h and then fully digested at 140 °C for at least 3 h. After digestion, the samples were evaporated, and the residue was washed with milli-Q water and filtered through Whatman 40 filter paper (Yap et al., 2002, 2003). The sample volume was adjusted to 25 mL, and the samples were then analyzed for heavy metals by flame atomic absorption spectrophotometry (Perkin Elmer 3110). Metal concentrations were presented in mg kg^{-1}. All analyses were conducted in triplicate, and the mean ± standard deviations are reported. The accuracy and precision of analysis were checked with TORT-2, LobsteZ Hepatopancreas, National Research Council, Canada, and the triplicate measurements showed recovery between 96% and 99.3% for all the metals.

Pearson correlation analysis was performed to determine the degree of relationship within trace metals. This analysis helps to identify the origin and migration of these elements. For example, high correlation between two metals implies that these two elements share similar pollution sources or analogous transformation and migration processes in certain circumstances (Zhang et al., 2016).

Metal concentrations from the five mollusc species are given in Table 1. The metals in the present study generally followed the order Mg > Ca > Zn > Fe > Cu > Mn > Cr > Pb > Ni > Co > Cd, and their concentrations are expressed in mg kg^{-1} dry wt. Ca and Mg were predominant in all species because of their biological role in living

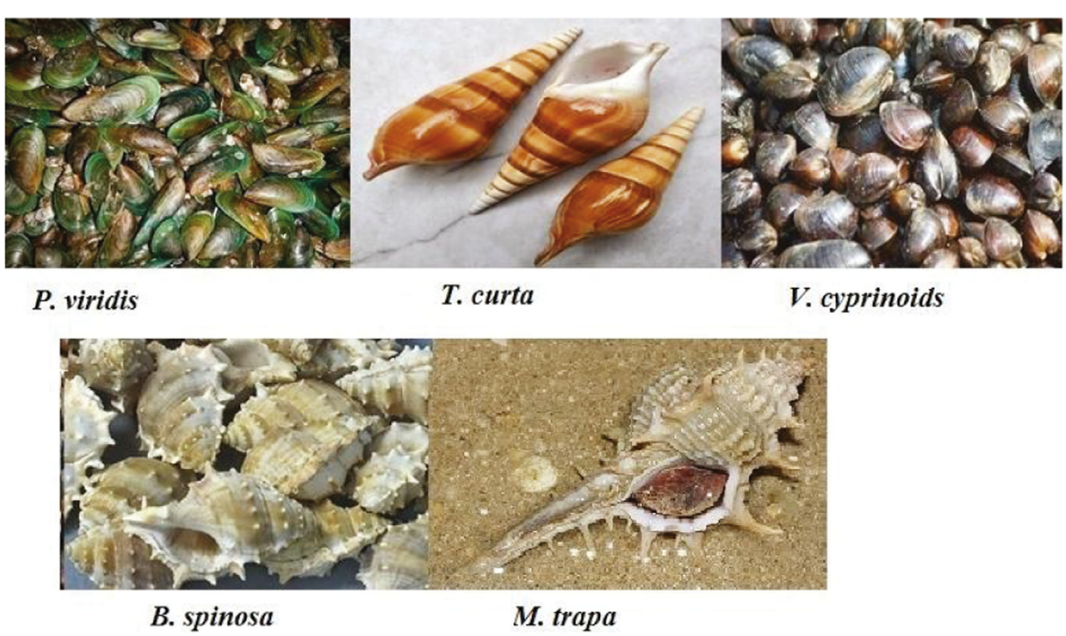

Fig. 1. Species collected for the study.

Please cite this article as: Ragi, A.S., et al., Heavy metal concentrations in some gastropods and bivalves collected from the fishing zone of South India, Marine Pollution Bulletin (2017), http://dx.doi.org/10.1016/j.marpolbul.2017.03.029