Marine Pollution Bulletin 119 (2017) 191–203

Contents lists available at ScienceDirect

Marine Pollution Bulletin

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

Baseline

Heavy metal distribution and contamination status in the sedimentary environment of Cochin estuary

P.M. Salas*, C.H. Sujatha, C.S. Ratheesh Kumar, Eldhose Cheriyan

Department of Chemical Oceanography, School of Marine Sciences, Cochin University of Science and Technology, Cochin 682016, Kerala, India

ARTICLE INFO

Keywords:
Heavy metals
Pollution indices
Contamination
Estuarine sediment

ABSTRACT

Heavy metals (Fe, Mn, Cr, Zn, Ni, Pb, Cu, Co and Cd) in the surface sediments of Cochin estuary, Southwest coast of India were analyzed to understand the spatio-temporal variation and contamination status via six sampling campaigns. Pollution indices like enrichment factor, geoaccumulation index and pollution load index inferred that the sediments of the northern arm of the estuary exhibited severe trace metal accumulation. Numerical sediment quality guidelines were applied to assess adverse biological effects of the trace metals, suggesting that occasional biological effect may occur due to Cr, Cu, Ni and Pb. Correlations between metals, organic carbon, silt and clay suggested that both fine grained sediment and organic matter were important carriers for these metals. Multivariate statistics indicated that the sources of Cu and Ni resulted primarily from natural weathering processes, whereas enriched levels of Cd, Cr, Zn and Pb were mainly attributed to anthropogenic activities.

Industrialization and urbanization have created a strong risk of heavy metal contamination in estuaries and coastal ecosystems of tropical and subtropical countries (Bryan et al., 1980; Langston, 1982). Assessment of heavy metal accumulation in aquatic environment arising from anthropogenic activities is of particular concern owing to its toxicity, persistence and biomagnification effects. Enrichment of heavy metals in sediments induces toxic effects on living organisms when they exceed certain concentration limits (Macfarlane and Burchett, 2000). Trace metals once discharged into the estuarine system, undergo several processes such as dissolution, precipitation, sorption, complexation with inorganic or organic ligands and particulate matter and which settles to the bottom sediments, creating a potential source of metal pollution (Lim et al., 2012a, 2012b) which can alter the environmental quality. The fate and transport of trace elements in estuaries are controlled by a variety of factors such as redox potential, ionic strength, abundance of adsorbing surfaces, pH and organic matter (Wen et al., 1999; Mounier et al., 2001). Furthermore, the spatial variation of heavy metal content in surface sediments of urbanized estuaries has often been attributed to mixing of sediments from different origins and point/non-point pollution sources (Forstner, 1981). The concentration of trace metals in sediments usually exceed the overlying water column by three to five orders of magnitude (Zabetoglou et al., 2002) and they may be transferred to higher trophic levels in the food web through biomagnification.

Cochin estuarine system (CES), the largest estuarine system in the Southwest coast of India, forms the part of the Vembanad-Kol wetlands. This tropical ecosystem is under the profound influence of anthropogenic activities like intertidal land reclamation, industrial effluent discharges, harbour development, dredging and urbanization (Gopalan et al., 1983; Menon et al., 2000). In addition to the existing industrial establishments at the upper reaches of the estuary, new projects which have been constructed in the lower reaches of the estuary along the coast include Vallarpadam container terminal, Mareena Park and LNG (Liquefied Natural Gas) terminal and moored buoy terminal may induce alterations in the dynamics and ecology of CES. Lack of proper planning in developmental activities has created an imbalance in the ecosystem, ultimately reducing the carrying capacity of this natural buffering zone. The objectives of the present study were to determine the total concentration and spatio-temporal variation of heavy metals in the surface sediments of Cochin estuary, to evaluate the extent of anthropogenic influences on their distribution pattern. The investigation also aimed to assess the accumulation, contamination status and ecotoxicological effects of heavy metals in the sedimentary environment employing pollution indices and sediment quality guidelines.

Cochin estuarine system, situated at Latitude: 9° 40′ & 10° 12′ N and Longitude: 76° 10′ & 76° 30′ E, has been ranked as one of the most productive estuarine systems (Qasim, 2003). It forms the part of Vembanad Kol wetland constitute a complex, network of shallow brackish water (250 km^2) running parallel to the coast, with two perennial openings to the Arabian Sea with a tidal amplitude less than or equal to 1.0 m. This tropical estuary is a well known 'Ramsar site'

* Corresponding author.
E-mail addresses: salas@cusat.ac.in (P.M. Salas), eldhosecheriyan@cusat.ac.in (E. Cheriyan).

http://dx.doi.org/10.1016/j.marpolbul.2017.04.018
Received 2 December 2016; Received in revised form 6 April 2017; Accepted 10 April 2017
Available online 25 April 2017
0025-326X/

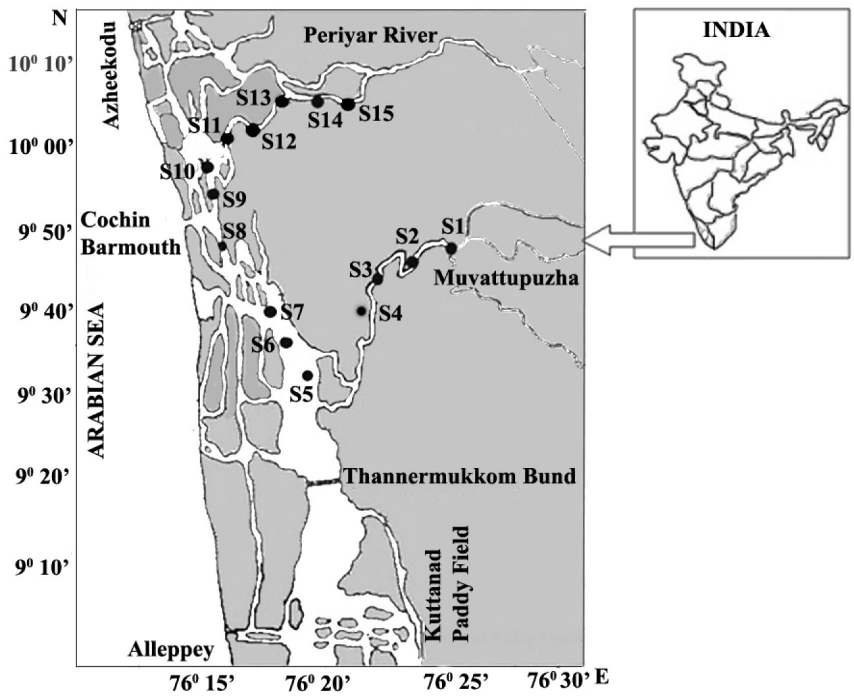

Fig. 1. Location map of the sampling stations.

(No. 1214), which is under the profound influence of monsoon, contributing to about 71% of the annual rainfall (Jayaprakash, 2002). Distinct circulation patterns in the northern and southern arms of the estuary and high flushing during monsoon transforms the estuary into a freshwater habitat and six major rivers discharge about $20{,}000 \times 10^6\ m^3$ of fresh water into the estuary annually (Srinivas, 2000; Balachandran et al., 2008). Variation in the river discharge induces a salinity gradient, which is responsible for the diverse biotopes of plankton communities in the estuary. Existing seasonal conditions in the study area can be categorized as monsoon (June–September), post-monsoon (October–January) and pre-monsoon (February–May). Usually southwest monsoon bring about a rainfall exceeding 300 cm and surplus of fresh water and huge loads of sediment into the estuary, whereas in the non-monsoon season, the river influx reduces and tidal influence gains momentum with an increase in salinity longitudinally leading to the mixed type of estuarine conditions in the Vembanad wetland (Rasheed et al., 1995; Priju and Narayana, 2007). The occurrence of tides with mixed semi-diurnal type and maximum spring tide range of about 1 m have been established (Srinivas et al., 2003). Constant mixing with seawater through tidal exchanges has given it the characteristics of a tropical estuary (Balchand and Nair, 1994; Ajith and Balchand, 1996). Circulation patterns in the northern and southern arms of the estuary are distinctly different, owing to the peculiar topography. The north-western part frequently develops flow-restrictions due to converging tides entering from two adjacent inlets, whereas the southern arm experiences tidal amplification (Balachandran et al., 2008).

The banks of river Periyar and Chithrapuzha encompasses approximately 70% industrial establishments which constitute chemical, engineering, food, drug, paper, rayon, rubber, textiles, and plywood industries. Important chemical industries located at Eloor, like Fertilizers and Chemicals Travancore Limited (FACT), Indian Rare Earths Limited (IRE), Hindustan Insecticides Limited (HIL), Periyar Chemicals, United Catalysts, Merchem and Cominco Binani Zinc are the main point sources of pollution. Similar industrial units located at Ambalamugal, on the banks of Chithrapuzha River include Fertilizer Plant (FACT), Petroleum Refinery (BPCL-KR) and Hindustan Organic Chemicals Limited (HOCL). Heavy metal contamination in Cochin estuary appears to be primarily due to the processing of metal containing materials at the FACT plant, IRE and Merchem. The effluents from these industries contain organics, alcohols, ammonia, nitrates, phosphorous, heavy metals such as Cd, Hg, Cr, Zn and rare earth element products, suspended solids, radiologicals, chlorides of metals etc. The industrial units consume about 189,343 m^3 water per day from the river and in turn discharge routinely about 75% as treated water along with large quantity of effluents and pollutants. It is estimated that nearly 260 million liters of industrial effluents reach the Periyar River daily from the Kochi industrial belt (Green Peace, 2003). According to the report of Green Peace (2003), the lower Periyar has been described as a cesspool of toxins, which have alarming levels of contaminants and pollutants especially toxic metals viz., Pb, Cd, Hg, Cr, Ni, Co and Zn. Previous literature suggest that the industries have effluent treatment plants (ETP) which directly emptying their treated effluents to the lower reaches of River Periyar extending to Cochin estuary (Dsikowitzky et al., 2014). Hence, the lower reaches of the Periyar River are heavily polluted. Pollution of the river and surrounding wetlands may cause a serious threat to aquatic flora and fauna and consumption of polluted river water pose serious health problems (Ciji and Nandan, 2014). The central part of the estuary has been polluted by the release of waste oil, paints, metal and paint scrapings from the Cochin port, Cochin Shipyard and domestic sewage drains. The discharge of industrial effluents along with the restricted flow due to indiscriminate sand mining in the upper reaches of the River Periyar and dredging operations in shallow regions of ship channel in the estuary has resulted in the accumulation of contaminants enriched with heavy metals (Balachandran et al., 2005; George et al., 2012).

Surface sediment samples from fifteen stations (Fig. 1) located along Cochin estuary were collected in six sampling campaigns viz., January 2009 (post monsoon, POM09), April 2009 (pre monsoon, PRM09), August 2009 (monsoon, MON09), January 2010 (post monsoon, POM10), April 2010 (pre monsoon, PRM10) and September 2012 (monsoon, MON12). As the estuary has been continuously subjected to severe deterioration, on account of urbanization and industrialization, a regular monitoring of the physicochemical variables is an essential requirement to assess the variability in the parameters and ecological health. Usually, the monsoon brings heavy rainfall and the