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Geochemical assessment of heavy metals pollution in surface sediments of Vellar and Coleroon estuaries, southeast coast of India

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ABSTRACT

Surface sediments were collected from Vellar and Coleroon estuaries for determine sediment texture, calcium carbonate, organic matter and heavy metals. Pollution indices such as pollution load index (PLI), contamination factor (CF), enrichment factor (EF) and geo-accumulation index (I_{geo}) were done for this study to know the level of heavy metals pollution in the estuarine ecosystem. Pearson correlation matrix and factor were used to assess the relationship and source of heavy metals in the estuarine sediments. The results of PLI values reveal that the study area was polluted by all the heavy metals. The calculated values of CF and I_{geo} followed the decreasing order Cu > Ni > Pb > Co > Cr > Zn > Mn > Fe and illustrate that Cu, Ni and Pb are contaminated due to anthropogenic sources in both estuaries. Correlation and factor analysis suggest that Fe—Mn oxyhydroxides, organic matter and fine particles are responsible for high concentration of heavy metals.

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Estuarine and coastal environments receive huge amounts of harmful heavy metals, and are engaged in numerous ways into the environment predominantly as it drains into the aquatic environments, especially by industrial effluents. The toxicity of those heavy metals achieves greater importance as they accumulate in sediments (Jayaprakash et al., 2014). Generally heavy metals, enter the aquatic environment through atmospheric deposition, erosion of geological matrix or owing to anthropogenic activities caused by industrial discharges, domestic sewage and mining wastes (Solai et al., 2013). The estuaries allow the fine materials to deposits of generally enriched with metals and organic matter (Cook et al., 2007; Anithamary et al., 2013). The estuarine sediments undergo various physio-chemical changes due to the contribution of rivers and seawater, along with an increasing population, fishing activity and other anthropogenic activities (Ramanathan et al., 1999) which can provide valuable data regarding to modern human effects on the geological cycle (Chandrasekaran et al., 2013). Discharging of industrial and urban wastes into water bodies directly disturbs the equilibrium among the metals in sediments (Yu et al., 2001; Filgueiras et al., 2004). The estuarine environments could severely disturb by heavy metals due to industrial wastes and anthropogenic activities, as they tend to act as sinks for fine, pollutants reactive sediments (Magesh et al., 2013). The hydrodynamic setting of the estuarine region, which helps to heavy metals to be deposited in the bottom of estuarine region (Krom et al., 2009; Fernandes et al., 2011). The accumulation of heavy metals in estuaries, which may leads to severe environmental problems. Subsequently heavy metal concentration in sediment can be used to expose the past and intensity of pollution of the region (Sekabira et al., 2010).

Most of the heavy metals trapped by sediments and forming stable complexes with sediment texture, organic matter and Fe—Mn oxyhydroxides (Rajendran et al., 1992; Jonathan et al., 2004; Dhanakumar et al., 2013). The heavy metals accumulation in coastal environment has significantly enriched in recent times due to anthropogenic activities (Buggy and Tobin, 2008; Dessai and Nayak, 2009; Botte et al., 2010; Yang et al., 2012). Several indices have been established to evaluate the contamination level of heavy metal in sediments (Spencer and Macleod, 2002; Caeiro et al., 2005), such as pollution load index, enrichment factor and geo-accumulation index (Igeo). These indices will focus on sediment contamination in terms of heavy metals and its potential sources. Many researchers have much attention with concern to geochemistry of Vellar and Coleroon estuarine sediments (Seralathan and Seetharamasamy, 1987; Subramanian et al., 1989; Purvaja and Ramesh, 2000; Alagarsamy and Zhang, 2010; Anithamary et al., 2013; Dhanakumar et al., 2013; Santhi and Prabhahar, 2014; Venkatramanan et al., 2015). This ecosystem is perfect location to study a number of processes such as evaporation, mixing, dissolution and chemical exchange between water and sediments which are significant in understanding hydrogeochemical processes (Ramanathan et al., 1999). Sediment characteristics such as sediment texture, organic matter content, calcium carbonate and heavy metal determination, which are helps to find out bioavailability and potential toxicity (Du Laing et al., 2002) of the ecosystem. Most of the previous studies carried out either in Vellar or Coleroon Estuary. Hence, the

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present research is focused on both Vellar and Coleroon estuaries by comprehensive studies on geochemistry of sediment characteristics and potential anthropogenic impact of heavy metals.

This study has been conducted in Vellar (11°28′ to 11°31′ N; 79°45′ to 79°47′ E) and Coleroon estuaries (11°21′ to 11°23′ N; 79°46′ to 79°50′ E). The Vellar River originates in Chitteri Hills (Eastern Ghats) at an elevation of 900 m, and it has a total length of 210 km through Salem and Cuddalore districts in Tamil Nadu. Coleroon is one of the major branches of Cauveri River, which splits from Cauvery near Srirangam. It flows about 150 km and empties into the Bay of Bengal. Both estuaries are geographically located in Cuddalore District along the southeast coast of Tamil Nadu, India and it is a portion of Cauvery River basin. The Vellar and Coleroon estuaries open into Bay of Bengal. The study area experiences tropical climatic condition with a temperature ranges from 18 to 36 °C. The northeast monsoon provides greater portion of the annual precipitation (1200 mm). Vellar and Coleroon rivers flow in sub parallel pattern to each other and these rivers are ephemeral and carry flood during monsoon. The geology of the study area is predominantly made up of Precambrian rocks, peninsular granitic gneiss, charnockites, quartzite, limestone, Closepet granite and alluvium (Ramanathan et al., 1993; Madras Science Foundation, 2000). On its course, both rivers receive numerous tributaries, urban drainages, and industrial effluents that are eventually dumped into the estuarine regions (Dhanakumar et al., 2013). Some of these tributaries are extensive outflow to the agricultural grounds. These estuaries fringed with variety of mangrove patches, mud flat shrubs which is breeding ground for number of marine and brackish water organisms.

Surface sediment samples were collected from 24 selected stations in Vellar and Coleroon estuaries during August 2015, in each estuary 12 stations have been selected according to various locations in which sea water mixing with fresh water near Parangipettai (Porto Novo) and Pazhaiyar as shown in Fig. 1. The geographical locations of the sampling stations were marked using a hand-held GPS. Sediment samples were collected by Van Veen grab sampler. From the grab sampler, sediment was collected by using plastic spatula and transferred into precleaned polyethylene bags. The sediment samples were air dried, homogenized to analyses the sediment texture and heavy metals concentration. After coning and quartering of sediment samples, sand and mud (silt + clay) were estimated following the method of Ingram (1970), by using 230 (63 μm) ASTM mesh. Carbonate content ($CaCO_3$) was measured by following the procedure of Loring and Rantala (1992), using hydrochloric acid, and organic matter (OM) in the sediments was determined following the technique of Gaudette et al. (1974), with the help of potassium dichromate, silver sulphate and concentrated sulphuric acid.

The heavy metals (Fe, Mn, Cr, Cu, Pb, Zn, Ni and Co) were determined after preliminary treatment and total decomposition of sediments subsequent procedure of Tessier et al. (1979). The finely ground (with help of an agate mortar and pestle) sediment sample was digested with acid mixture of 4:1 HF and $HClO_4$ on a hot plate up to 100 °C in Teflon bomb. The residual sediment was then dissolved in concentrated HNO_3 and heated again. After ensuring complete digestion of the sediment sample, the solution from the Teflon bomb were transferred into acid washed polypropylene volumetric flaks. Finally the solution was made up of 100 ml with ultrapure water. The final solution was analyzed for heavy metals using Atomic Absorption Spectroscopy (AAS - Perkin Elmer AAnalyst 700) equipped with a deuterium background corrector in the Department of Applied Geology, University of Madras. For quality assurance, appropriate internal chemical standards (Merck Chemicals, Germany) were used to calibrate the instrument. Likewise, the reagents

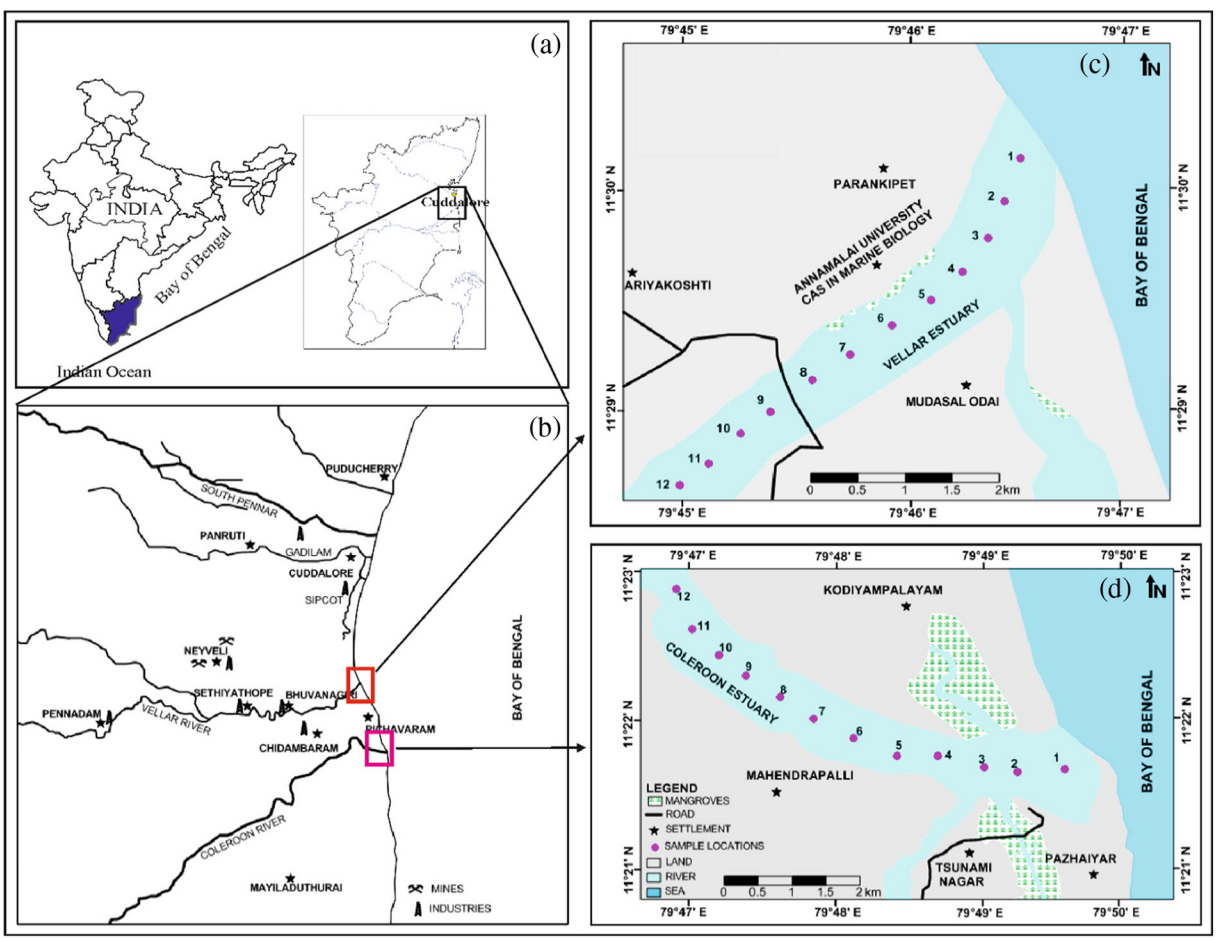

Fig. 1. Location map of the study area with sample locations in Vellar and Coleroon estuary, SE Coast of India.

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