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Baseline

Spatial risk assessment and trace element concentration in reef associated sediments of Van Island, southern part of the Gulf of Mannar, India

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ABSTRACT

Forty eight surface sediment samples were collected from the vicinity of Van Island in order to assess the sediment pollution level and potential ecological risk on coral reef ecosystem. The analytical and correlation results indicate a distribution of elements is chiefly controlled by the $CaCO_3$ and OM. The enrichment factor and geoaccumulation index show the elevated level of Pb in the surface sediments is due to application of lead petrol and coal incinerating power plants. The sediment pollution index reveals that majority of the sediments falling under highly polluted sediment category (35.4%) followed by moderately polluted (25%) and dangerous sediment category (14.58%). The potential ecological risk suggests that nearly 66.6% of the samples falling under the low risk category, moderate risk category (20.8%) followed by considerable risk category (8.33%) and very high risk category (4.1%). The accumulation level of trace elements clearly suggests that the coral reef ecosystem is under low risk.

Trace elements are transported from the source to the marine environment as dissolved species in water or in association with suspended (particulate organic matter) sediments (Saouter et al., 1993). The association and distribution of these metals are controlled by several processes such as the direct absorption by fine-grained inorganic particles, adsorption process by ferric and manganese oxy-hydroxides due to complexation with natural organic and inorganic particles and direct precipitation as new solid phases (Calmano et al., 1993, Leivouri, 1998, Jonathan et al., 2010). In addition, the distribution of the trace elements is controlled by their input sources (e.g. upwelling, river, or atmospheric input) and incorporated on the particle surfaces, such as clay minerals, organic matter, bacteria etc. and finally transported throughout the marine ecosystem. The accumulated trace elements are of considerable environmental concern due to their toxicity, wide sources, non-biodegradable properties and accumulative behaviours. Some elements become toxic when they are not metabolized by the body and accumulate in the soft tissues, which cause ecological damage (Jain et al., 2008). The essential trace elements play an important role in biological systems, but they become toxic at higher concentrations. The non-essential trace elements are potentially toxic even at relatively low concentrations and their bioaccumulation in tissues leads to intoxication, cellular and tissue damage, decreased fertility, dysfunction of a variety of organs and cell death (Damek-Proprawa and Sawicka-Kapusta, 2003, Krishna Kumar et al., 2015). The sediment accumulated metal may be re-suspended and cause secondary contamination to the water environment, because sediments act both as a sink and a source for metals in the aquatic environment. The accumulation and distribution of the metals depend on hydrodynamics, biochemical processes and environmental conditions of marine environments. Sediment pollution index (SPI) is applied to evaluate the trace metal concentrations along with metal toxicity in the sediments. Similarly, the potential ecological risk index is calculated to measure the risk assessment of heavy metals in the sediments in terms of risk assessment code.

The Gulf of Mannar biosphere reserve extends from Rameswaram Island to Tuticorin and lies between 8° 45′ N to 9° 25′ N and 78° 5′ E to 79° 30′ E, extending about 140 km. There are 21 islands running almost parallel to the coastline of Mannar. These islands lie between 8° 47′ N to 9° 15′ N and 78° 12′ E to 79° 14′ E and they are situated at an average distance of about 8 km from the coastline of the Gulf of Mannar. The coral islands are invariably affected by natural and anthropogenic factors, including instability of island substratum by exploitation of corals and

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destructive fishing practices up to 2005. Later, such irregular practices were totally banned due to the implementation of strict enforcement and awareness among the fishermen. Van Island is the first of the 21 islands and belongs to a Tuticorin group (Fig. 1). The total area of the island is 16 ha and major part of the island was eroded by the action of sea waves, especially along the northern part (present area – 5.7 ha, Diraviya Raj et al., 2015). The average elevation of the Van Island is 0.5 to 1.5 m above the mean sea level. The study area is endowed with three distinct ecosystems such as corals, sea grass and mangroves. Many workers have carried out their research on various aspects including the natural impact on the reef system, radio nuclides on marine biota, trace element studies in marine sediments and coral species in the Gulf of Mannar (Inigovalan et al., 2015; Madhu et al., 2014; Jayaprakash et al., 2014; Kasilingam et al., 2016; Krishna Kumar et al., 2015). The aim of the present work is to provide the concentration and distribution of metals and to evaluate the sediment pollution and potential ecological risk levels of metals by applying the sediment pollution index and potential risk index method.

Forty-eight sediment samples were collected from the fringing reef complex of Van Island, Gulf of Mannar to study the trace element concentration in the reef sediments. The sampling station was fixed using a handheld global positioning system (Garmin eTrex GPS). The collected samples were packed in a thick polyethylene bag and properly labeled before laboratory analysis. Calcium carbonate ($CaCO_3$) and trace element analyses were performed as suggested by Loring and Rantala (1992). Organic carbon (OC) was determined by exothermic heating and oxidation with potassium dichromate and concentrated H_2SO_4. The excess amount of dichromate is titrated with 0.5 N ferrous ammonium sulfate solution (Gaudette et al., 1974). 100 g of the bottom sediment (from each sampling location) were dried at 60 °C (for 24 h) and their associated algae and large size/broken shell materials were removed. 0.5 g of the pulverized fine grained particles (<63 μm) were completely digested in a Teflon beaker using a mixture of concentrated nitric (HNO_3), perchloric ($HClO_4$) and hydrofluoric acids (HF) with the ratio of 3:2:1, respectively. The concentrations of the selected elements (Fe, Mn, Pb, Zn, Cu, Cr and Ni) were analyzed by an atomic absorption spectrophotometer (ELICO SL-194) at Centre for Geo-technology, Manonmaniam Sundaranar University, Tirunelveli. MESS - 2 certified reference material was used for accuracy assessment and the recovery efficiency ranges from 92 to 97.5% of the studied trace elements (Table 1). The limits of detection (LODs) of trace elements are 0.01 $\mu g\ g^{-1}$ for Fe, Zn, Cr, Co, Ni, Cd, 0.02 $\mu g\ g^{-1}$ for Mn and 0.05 $\mu g\ g^{-1}$ for Pb.

The spatial distribution of $CaCO_3$, OM, Fe, Mn and other trace elements is shown in Figs. 2 and 3. The surface sediments are mainly composed of sand with considerable amount of shell fragments. The high percentage of $CaCO_3$ is observed on the reef-dominated area, which is due to the availability of coral sand and the presence of calcium secreting micro faunas. Similarly, the maximum percentage of OM is noticed at sea grass meadows. The highest concentration of Fe and Mn is noticed along the northwestern part and southern part of the island. The low concentration of the Fe is recorded at coral covered northeastern part of the study area. The well-flourished coral cover along the northeastern part is probably due to minimal enrichment of trace elements in the sediment. The concentration of Zn is below the detection limit in the majority of the samples. However, the elevated concentration of Pb is noticed in the majority of the samples. The highest concentration of lead is probably due to urban development in Tuticorin and vicinity of coal incineration power plants and port activities. The elevated level of Cr and Cu in few samples may be due to availability of enrichment of $CaCO_3$ and OM in the sediments.

The enrichment factor for each metal is calculated by dividing its ratio to the normalizing element by the same ratio found in the chosen

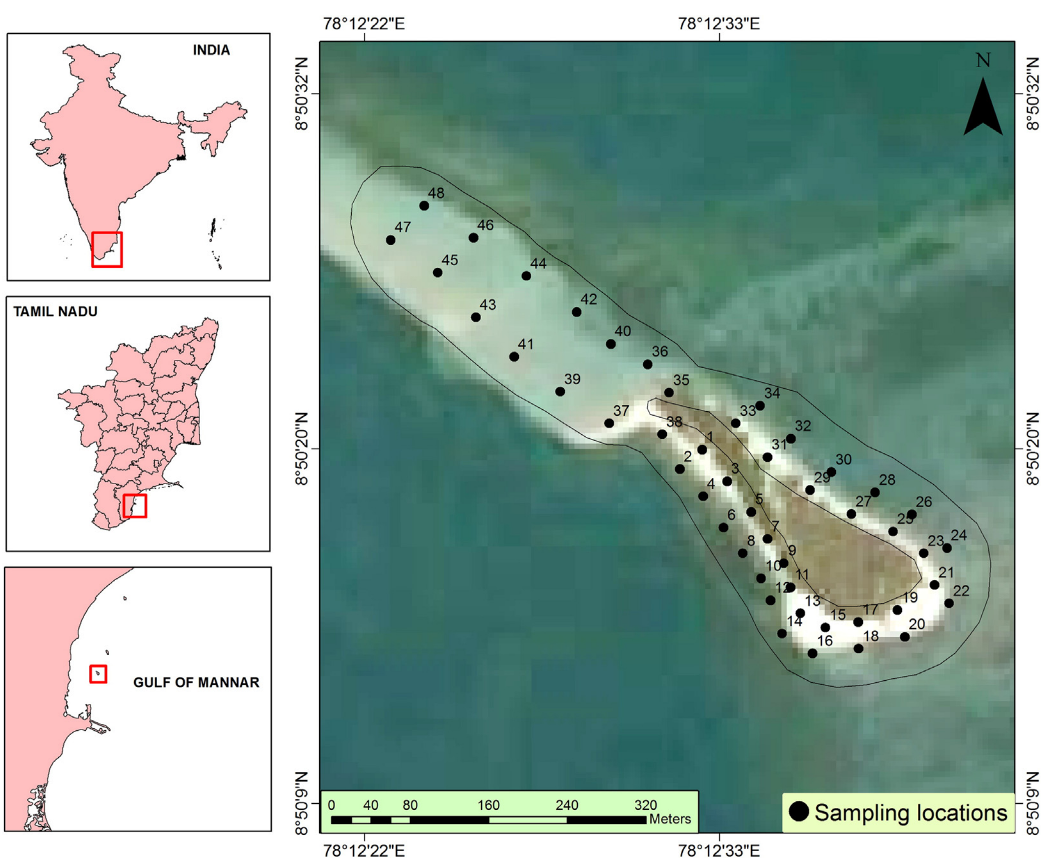

Fig. 1. Sample location map of the study area.