

Environmental characterization of marine surface sediments in Adyar river mouth traverses off Bay of Bengal, Chennai

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Abstract

The study of heavy metal distribution in coastal surface sediments is an important component in understanding the exogenous cycling as well as in assessing the cause of anthropogenic influences on the marine ecosystem. The bottom sediments serve as a reservoir for heavy metals and therefore deserve special consideration in the planning and design of aquatic pollution research studies. The study of the geochemistry of sediment requires handling of a large data set that includes the concentrations of various ions; classification, quantification and interpretation of the data are important steps in the assessment of sediment quality. The textural distribution of the surface sediments reveals the predominance of sand in all seasons during the three year study period in the study area. The total heavy metal concentrations from different station studied in the surface sediments of the study area showed significant variations. Metal concentration was higher in the shoreline region when compared with distance away from the shoreline. The enrichment in the concentration of heavy metals in the samples that are close to the shore line indicated that higher concentration was attributable to the anthropogenic activities in coastal area.

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Key words: *Pollution study, marine sediments, physicochemical characteristics, heavy metals, Bay of Bengal.*

1. Introduction

The distribution of metals within the aquatic environment is governed by complex processes of material exchange affected by various natural and anthropogenic activities (Leivouri, 1998; Ip *et al.*, 2007). Although metals are natural constituents of the earth's crust and are present in all ecosystems, their concentrations have been dramatically increased by human activities (Guerzoni *et al.*, 1984). Since heavy metals are toxic, persistent and non-degradable in the environment, the contamination of sediments by these elements represent the greatest ecological risk to coastal marine ecosystem (Garcia *et al.*, 2008). Such pollution has several distinct biological effects, including diseases in plant and animal species (Lamb *et al.*, 1991), local or complete extinction of some species (Vermeij, 1993), and loss or modification of habitat (Nee and May, 1992). The study of the geochemistry of sediment requires handling of a large data set, which includes the concentrations of various ions; classification, quantification and interpretation of the data are important steps in the assessment of sediment quality.

2. Materials and Methods

Surface sediment samples from 5 locations were collected Adyar River Traverses (ART) (Fig. 1) during cruise program by Sagar Purvi, NIOT, MOES, India at >10 meter water depth and in shallow waters by engaging fibre glass boat during pre-monsoon (PRM) (June – August), Monsoon (September - November) and post-monsoon (POM) (December - February) seasons using Van Veen Grab sampler from 5 locations in Bay of Bengal, off Chennai (Plate. 1). Samples were taken from the central part of the grab sampler to avoid any metallic contamination from the metallic sampler and were frozen at -4°C immediately onboard until further analysis. The samples were homogenized following cone and quartering method and were ground, mixed and powdered in an agate mortar (ASTM 230) before analytical procedures were conducted.

Textural studies of sand, silt and clay (Ingram, 1970), Carbonate content (Loring and Rantala, 1992), Organic carbon (OC) (Gaudette *et al.*, 1974) were carried out standard procedure. For

total metal analysis a known quantity of sediment was digested with an acid mixture of HClO₄ and HF and the final residue was leached with HCl and made up to the required quantity (Tessier *et al.*, 1979). Trace metal concentrations (Fe, Mn, Cr, Cu, Ni, Co, Pb and Zn) were measured using flame atomic absorption spectrophotometer (Perkin-Elmer AA700) equipped with a deuterium background corrector. The flame was employed except in the instance of Cd, which required the use of a Graphite furnace because of its much lower concentration. Suitable internal chemical standards (Merck Chemicals, Germany) were used to calibrate the instrument. All the reagents used were of analytical grade and high purity.

3. Results and Discussion

3.1 Surface sediment texture from the ART

The relative abundance of sand and mud (silt + clay) contents of the surface sediment samples, the sand percentage of sediment samples collected during the three consecutive years was characterized by the range between 9.65% to 97.72% with an average of 61.86% to 71% (Fig. 2). POM season samples showed high sand content than MON and PRM season samples. The mud percentage of the surface sediment samples collected during the three consecutive years was characterized by the range 2.28% to 90.35% with an average range of 29.8% to 38.2% (Fig. 3). Samples of PRM seasons showed high mud content than POM season sediment samples. The textural distribution of the surface sediments reveals the predominance of sand in all seasons during the three year study period in the study area. The textural distribution of the surface sediments reveals the predominance of sand in all seasons during the three consecutive years. Although, difference in the textural parameter indicates that they are mainly dependent on the dynamic process that affects the shallow region, rather than the deeper region which acts in an opposite way during all seasons (Jonathan *et al.*, 2007).

3.2 Calcium carbonate (CaCO₃) and Organic carbon (OC) of surface sediment from ART

Analytical results of both CaCO₃ and OC complement each other depending on the textural parameters. The surface sediment samples showed a value of carbonate percentage range of 3.26% to 7.24% with an average range of 4.07% to 6.27% (Fig. 4). While the PRM season samples showed high carbonate content than POM seasons. The OC percentage of surface

sediment samples was characterized by a range of 2.18% to 3.24% with an average range of 2.46% to 2.96% (Fig. 5). Samples of POM seasons showed high OC content than PRM seasons samples. An accurate interpretation of the marine sediment record requires that the processes controlling the preservation of CaCO_3 (Muthuraj and Jayaprakash, 2007). The CaCO_3 content in the surface sediments of the study area was generally low during all seasons of three consecutive years. The various carbonate values observed at different stations were due to changes in the percentage of sand and the flow of water from the coastal industries that bring the non-carbonated materials. Relatively moderate values of carbonates at certain depths may be due to the sturdy currents leading to non-deposition of terrigenous materials (Rao, 1978).

Organic carbon has a significant role in geochemical cycles of major and trace elements that accumulate in sediments; it may be used as an index of depositional environment and sedimentary processes (Seralathan *et al.*, 1993). Distribution of OC also indicated that the concentration was dependent on textural parameters of the sediments. The minor variations in OC values in the near-shore samples indicated that they are moderately influenced by the minor input and deposition of organic debris from local industrial sources where a higher terrestrial and anthropogenic input is always expected due to the relative proximity of rivers that drain into the BoB (Bay of Bengal). The CaCO_3 contents are high where the sand dominance was high, which indicates that carbonates are attached with coarse sediments. However, it has been observed that most of the OC is preserved in fine grained sediments (Salomons and Forstner, 1984). The high inputs of terrigenous material from the adjacent land mass and industrial effluents nearby have increased the OC values close to the shore; others have also reported similar observation (Muthuraj and Jayaprakash, 2007).

3.3 Total heavy metal distribution in the surface sediments from ART

The results of average concentration of total heavy metal in the surface sediments are marginally higher concentrations are recorded in PRM samples than POM samples. The percentage of iron in the surface sediment samples collected during the study period was in the range of 0.49% to 1.21% with an average range of 0.67% – 0.82% (Fig. 6). Manganese ion content of the surface sediment samples collected during the three consecutive years was in the range of 269 to 453 $\mu\text{g/g}$ with an average range of 336.5 – 396 $\mu\text{g/g}$ (Fig. 7). The indicated iron and manganese in

the medium may get converted to complex hydroxyl compounds that may eventually precipitate (Riley and Chester, 1971). It is further possible to infer that higher concentration of Mn^{2+} in the surface sediments might have derived from its mobilization (Karbassi and Amirnejad, 2004). Since Mn^{2+} is lithogenous in origin, its association with Cr^{6+} , Zn^{2+} and Hg^{2+} allow us to infer both lithogenous and anthropogenic source contribute to the Mn^{2+} content in the study area. It is well established that iron and manganese oxides are excellent scavengers for trace metals (Tessier *et al.*, 1979) and thus these metal ions would lead to the co-precipitation of other metals in the water column and increase the concentration of many metals in the sediments.

The chromium content of the surface sediment samples collected during the three year study period was in the range of 51 to 97 $\mu\text{g/g}$ with an average range of 77.5 – 90.67 $\mu\text{g/g}$ (Fig. 8). PRM samples showed higher Cr^{6+} content than the POM and MON samples. The observation of high distribution of Cr^{6+} of the study ART indicated that the enrichment of Cr^{6+} is mainly due to the dumping of effluents from the tannery industries located in the nearby study area. The discharge from electroplating industries has been responsible for the enhanced concentration of Cr^{6+} in estuaries and tidal zone sediments (Hema Achyuthan *et al.*, 2002). The higher values of Cr^{6+} could also be due to the corrosion of steel industries and chrome alloys which are used by number of industries (Jonathan *et al.*, 2004).

The copper concentration in the surface sediment samples was relatively high during PRM seasons but low during POM seasons for all the three consecutive years. Copper content of the samples collected during all the three consecutive years was in the range of 27.46 to 90.87 $\mu\text{g/g}$ with an average range of 43.31 – 73.62 $\mu\text{g/g}$ (Fig. 9). Copper is mainly of anthropogenic origin, which may also be probably controlled by sedimentary features such as organic matter and grain size (Harbison, 1984). The copper ions are found to be occurring in higher amounts near the ART regions indicating these metals are used as markers of metal industries (Loska *et al.*, 2004; El Nemr *et al.*, 2006). Copper, Pb^{2+} and Zn^{2+} elements are probably sourced from vehicular emissions. Besides, the existence of mechanical workshops and factories along the draining rivers also may play an important role as an input of the sediments (Wang and Qin, 2006). The agricultural materials, sewage sludge as well as human activities are some of the sources of Cu^{2+} , Pb^{2+} and Zn^{2+} input in soil (Alloway, 1995).

The nickel concentration in the surface sediment samples was relatively high during PRM seasons but low in the samples of POM seasons. Nickel content of the surface sediment samples collected during the three year study period was in the range of 24.37 to 41.35 $\mu\text{g/g}$ with an average range of 25.45 – 38.49 $\mu\text{g/g}$ (Fig. 10). The Ni^{2+} content of sediment is due to probably petroleum-related activity (Vazquez and Sharma, 2004). The anthropogenic input was an important source for these elements, through the extensive use of the antifouling paints by shipping activities (Bothner *et al.*, 1998). Chromium and Ni^{2+} were reported to be enriched mainly by industrial inputs (Rigollet *et al.*, 2004). Further industrial wastes from the Power Plants and other industrial effluents and atmospheric deposition were also reported to be among the sources of these elements (Mucha *et al.*, 2003).

Cadmium content of the surface sediment samples collected during the three consecutive years was in the range of 0.32 to 0.78 $\mu\text{g/g}$ with an average range of 0.51– 0.65 $\mu\text{g/g}$ (Fig. 11). Cadmium enrichment was high in the samples of PRM season compared to POM season. Cadmium enrichment is independent of the accumulation rates of terrigenous detrital input (Muthuraj and Jayaprakash, 2007). With regard to enrichment factor the cadmium contamination is very severe in the study area and mainly implies that the sources are the major industries and shipping activities, atmospheric deposition of finer particles, domestic effluent discharges and the extensive use of paints. Cadmium compounds are used as stabilizers in PVC (Polyvinyl chloride) products, colour pigment, several alloys and, now most commonly, in re-chargeable nickel–cadmium batteries. Metallic cadmium has mostly been used as an anticorrosion agent (Cadmiation). Cadmium is also present as a pollutant in phosphate fertilizers. Natural as well as anthropogenic sources of cadmium, including industrial emissions and the runoff from fertilizer applied lands and sewage sludge dumped in the rivers may lead to contamination of the study area (Lars, 2003). It has been observed that destruction of batteries in bulk quantities by craftsmen to recover Pb^{2+} and Cd^{2+} is also being carried out adjacent to the study area, thereby contributing to the enrichment of heavy metals in the sediments of the study area (Jayaprakash *et al.*, 2010). The cobalt content of the surface sediment samples collected during the three consecutive years was in the range of 12.81 to 25.37 $\mu\text{g/g}$ with an average range of 14.09 – 18.43 $\mu\text{g/g}$ (Fig. 12). The surface sediment samples of PRM seasons showed high Co^{3+} content than POM samples during the period of study. Lead content of the surface sediment samples collected during the three consecutive years was in the range of 16.27 to 25.37 $\mu\text{g/g}$ (Fig. 13). Lead

concentration in the surface sediment samples was relatively high during PRM seasons but low in the samples of POM seasons. Cobalt and lead elements are known as markers of paint industries (Lin *et al.*, 2002) and many are present in the study area. The concentration of lead in the sediments of this region should have originated from the atmospheric deposition of automobile exhaust (Jayaprakash *et al.*, 2010).

Zinc content of the surface sediment samples collected during the three consecutive years was in the range of 43.6 to 78.4 $\mu\text{g/g}$ with an average range of 62.27 to 67.95 $\mu\text{g/g}$ (Fig. 14). Concentration of Zn^{2+} in the surface sediment samples was relatively high during PRM seasons but low in POM seasons. Zinc is used as markers or tracers of motor vehicles. The sources of pollution include industrial effluents such as food and beverage factories, and also domestic effluents. Zinc pollution is also traced from the mixing of runoff from agricultural activities and it is also an indicator of oil pollution (Karbassi, 1996). The mercury concentration in the surface sediment samples showed only marginal changes during the three consecutive years. Mercury content of the surface sediment samples during the three consecutive years was in the range of 0 to 0.006 $\mu\text{g/g}$ with an average of 0 – 0.004 $\mu\text{g/g}$ (Fig. 15). Mercury content was very low in general, at certain seasons it was at very low concentration in the study area and similar observations have already been made (De and Ramaiah, 2007). A major use of mercury is in the chloralkali industry, in the electrochemical process of manufacturing chlorine, where mercury is used as an electrode (Föstner and Wittmann, 1983).

In the absence of very significant correlations with other metal ions this might probably come from limited non-point source pollution. In general, the surface sediment in the shoreline was found to be coarse in nature due to higher concentration of sand than mud which might due to tidal effects (Muthuraj and Jayaprakash, 2007). Further, the increase in fine sediments in the samples of the inner shelf region is an indication of fresh water input with finer particles that settle to the bottom when current and wind speeds reduce (Jonathan *et al.*, 2007). The distribution of heavy metals in marine deposits was influenced by sediment texture, clay content, organic carbon, iron hydrous oxides and carbonates (Föstner and Wittmann, 1983). The higher values during the PRM season could be due to the low flow conditions of the coastal waters which are attributed to the change in current direction (Srinivasalu, *et al.*, 2005). The enrichment in the concentration of heavy metals in the samples which are very close to the shore line

indicated that higher concentration was due to the anthropogenic activities in coastal area (Jonathan *et al.*, 2004). Moreover, it may also be due to the recent development of industries and harbour activities (Jonathan and RamMohan, 2003). In addition, the high values are also attributed to the continental input and runoff from the minor rivers that drain in this region (Muthuraj and Jayaprakash, 2007).

The enrichment of Pb^{2+} , Zn^{2+} , Ni^{2+} , Co^{3+} and Cu^{2+} shows similar distribution pattern. The origin of the above metals can be traced to the surface runoff of the fertilizer remains of the adjacent agricultural lands as well as domestic and industrial effluents. Metal concentration was higher in the shoreline region compared distance away from the shoreline. This is due to the clayey nature of the sediments originated from the marine environment. Sediments in the near-shore area move along the coast due to the action of waves, which generate long shore currents and cause sediment transport of chemical constituents. This remobilization contributes environmental disturbance and likely to have a far reaching effect on the life and activities of marine biota in general and pelagic fishery in particular. The association of metals with sand particle suggesting that they are mainly due to the change in the pH condition and the increased input from chemical industries which are anthropogenic in origin (Jayaprakash *et al.*, 2010). The organic matter is important as a controlling factor in the abundance of trace metals (Rubio *et al.*, 2000). It is also understood that OC derived from decaying organic remains has a high capability of accumulating Pb^{2+} , Cu^{2+} and Zn^{2+} by absorption and by the formation of chelating compounds (Wedepohl, 1995). The concentrations of OC affect the trace metal geochemistry of the fine fraction. The strong association of Pb^{2+} , Zn^{2+} , Co^{3+} and Cu^{2+} indicates that these elements are of sewage sludge brought from nearby area (Jonathan *et al.*, 2007). Source of the pollutants are primarily from domestic sewage and small industrial units located on the banks of the River Adyar. The distribution pattern of heavy metals reveals that the anthropogenic contribution of metals, sediment type and organic carbon are the major factors affecting the spatial variation of metals in this region. Thus, it is the anthropogenic input is the major cause of pollutions of heavy metal in the Chennai coastal zone.

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References

Alloway, B. J. (1995). Heavy metals in soils, London, Blackie.

Bothner, M. H., BuchholtzenBrink, M., & Manheim, F.T. (1998). Metal concentrations in surface sediments of Boston harbour changes with time, *Marine Environmental Research*, 45, 17–155.

De J and Ramaiah N. (2007) Characterization of marine bacteria highly resistant to mercury exhibiting multiple resistance to toxic chemicals, *Ecological Indicators*, 7, 511–520.

El Nemr A, Khaled A, and El Sikaily A. (2006). Distribution and statistical analysis of leachable and total heavy metals in the sediments of the Suez Gulf, *Environmental Monitoring and Assessment*, 118(1–3), 89–112.

Föstner U and Wittmann GTW. (1983). Metal pollution in aquatic environment, Springer, Berlin, 486 pp.

Garcia, E.M., Cruz-Motta, J.J., Farina, O., and Bastidas, C. (2008). Anthropogenic influences on heavy metals across marine habitats in the western coast of Venezuela, *Continental Shelf Research*, 28, 2757–2766.

Gaudette, H.E., Flight, W.R., Toner, L., and Folger, D.W. (1974). An inexpensive titration method for the determination of organic carbon in recent sediments, *Journal of sedimentary petrology*, 44, 249–253.

Guerzoni, S., Frignani, M., Giordani, P., and Frasari, F. (1984). Heavy metals in sediments from different environments of a Northern Adriatic Sea area, Italy, *Environmental Geology and Water Sciences*, 6 (2), 111–119.

Harbison, P. (1984). Regional variation in the distribution of trace metals in modern intertidal sediments of Northern Spencer Gulf, South Australia, *Marine Geology*, 61, 221–247.

HemaAchyuthan, Richardmohan D, Srinivasalu S and Selvaraj K. (2002). Trace metals in the sediment cores of estuary and tidal zones from northern part of Southeast coast of India, *Indian Journal of Marine Sciences*, 31, 141–149.

Ingram, R. L. (1970). Procedures in sedimentary petrology, New York: Wiley.

Ip,C.C.M., Li,X.D., Zhang,G., Wai,O.W.H, and Li,Y.S. (2007). Trace metal distribution in sediments of the Pearl River Estuary and the surrounding coastal areas, South China, *Environmental Pollution*, 147, 311–323.

Jayaprakash, M., Urban, B., Velmurugan.P.M., and Srinivasalu, S. (2010). Accumulation of total trace metals due to rapid urbanization in microtidal zone of Pallikaranai marsh, South of Chennai, India, *Environmental Monitoring and Assessment*, 170(1-4), 609-29.

Jonathan, M. P., Stephen-Pichaimani, V., Srinivasalu, S., RajeshwaraRao, N., and Mohan, S. P. (2007). Enrichment of trace metals in surface sediments from the northern part of Point Calimere, SE coast of India, *Environmental Geology*, 55 (8), 1811-1819.

Jonathan, M.P., RamMohan, V., and Srinivasalu, S. (2004). Geochemical variations of major and trace elements in recent sediments, off the Gulf of Mannar, southeast coast of India, *Environmental Geology*, 45,466–480.

Jonathan, M.P., and RamMohan, V. (2003). Heavy metals in sediments of the inner shelf off the Gulf of Mannar, southeast coast of India, *Marine Pollution Bulletin*, 46, 258-268.

Karbassi A R. (1996). Geochemistry of Ni, Zn, Cu, Pb, Co, Cd, V, Mn, Fe, Al and Ca in sediments of North Western part of the Persian Gulf, *International Journal of Environmental Studies*, 54, 205–212.

Karbassi A R and Amirnejad R. (2004). Geochemistry of heavy metals and sedimentation rate in a bay adjacent to the Caspian Sea, *International Journal of Environmental Science and Technology*, 1(3), 191–198.

Lamb, T., Bickham, J.W., and Gibbons, J.W. (1991). Genetic damage in a population of slider turtles (*Trachemys scripta*) inhabiting a radioactive reservoir, *Archives of Environmental Contamination and Toxicology*, 20, 138-142.

Lars, J. (2003). Hazards of heavy metal contamination, *British Medical Bulletin*, 68, 167–182

Leivouri, M. (1998). Heavy metal contamination in surface sediments in the Gulf of Finland and comparison with the Gulf of Bothnia, *Chemosphere*, 36, 43–59.

Lin, Y.P., Teng, T.P., and Chang, T.K. (2002). Multivariate analysis of soil heavy metal pollution and landscape pattern in Changhua County in Taiwan, *Landsc Urban Plan*, 62, 19–35.

Loring, D.H., and Rantala, R.T.T. (1992). Manual for the geochemical analyses of marine sediments and suspended particulate matter, *Earth-Science Reviews*, 32, 235–283.

Loska K, Wiechula D, and Korus I. (2004). Metal contamination of farming soil affected by industry, *Environment International*, 30(2), 159–165

Mucha A, Vasconcelos M, and Bordalo A. (2003). Macrobenthic community in the Douro estuary: relations with trace metals and natural sediment characteristics, *Environmental Pollution*, 121, 169–180.

Muthuraj, S., and Jayaprakash, M. (2007). Distribution and enrichment of trace metals in marine sediments of Bay of Bengal, off Ennore, south-east coast of India. *Environmental Geology*, 56, 207-217

Nee, S., and May, R.M. (1992). Dynamics of meta-populations: habitat destruction and competitive coexistence, *Journal of Animal Ecology*, 61, 37-40.

Rao, C.H.M. (1978). Distribution of CaCO_3 , Cu^{2+} and Mg^{2+} in sediments of the northern half of western continental shelf of India, *Indian Journal of Marine Sciences*, 7,151–154.

Rigollet V, Sfriso A, Marcomini A, and De Casabianca ML. (2004). Seasonal evolution of heavy metal concentrations in the surface sediments of two Mediterranean *Zostera marina* L. beds at Thau lagoon (France) and Venice lagoon (Italy), *Bio-resource Technology*, 95, 159–167.

Riley J P and Chester R. (1971). Introduction to marine chemistry, Academic Press, London.

Rubio, B., Nombela, M.A., and Vilas, F. (2000). Geochemistry of major trace elements in sediments of the Ria de vigo (NW Spain) an assessment of metal pollution, *Marine Pollution Bulletin*, 40, 968–980.

Salomons, W., and Forstner, U. (1984). Metals in hydrocycle. Springer, Berlin, pp 63–98.

Seralathan, P., Meenakshikutty, N.R., Asaref, K.V., and Padmalal, D. (1993). Sediment and organic carbon distribution in the Cochin harbour area, *Indian Journal of Marine Sciences*, 22, 252–255.

Srinivasalu, S., Nagendra, R., Rajalakshmi, P.R., Thangadurai, N., ArunKumar, K., and Achyuthan, H. (2005). Geological signatures of M9 tsunami event on the sediments of Tamil

Nadu Coast. In: Ramasamy SM, Kumanan CJ (eds) Tsunami: in the Indian content, Allied Publishers, pp 171–181.

Tessier, A., Campbell, P.G.C., and Bisson, M. (1979). Sequential extraction procedure for the speciation of particulate trace metals. *Analytical Chemistry*, 51, 844–851.

Vazquez, F.G., and Sharma, V.K. (2004). Major and trace elements in sediments of the Campeche Sound, southeast Gulf of Mexico, *Marine Pollution Bulletin*, 48, 87–90.

Vermeij, G.J. (1993). Biogeography of recently existing marine species: implications for conservation. *Conservation Biology*, 7, 391-397.

Wang X S and Qin Y. (2006). Comparison of magnetic parameters with vehicular Br levels in urban roadside soils, *Environmental Geology*, 50, 787–791

Wedepohl, K.H. (1995). The composition of the continental crust. *Geochimica et Cosmochimica Acta*, 59, 1217–1232.

Diagrams and Plates used in the Study

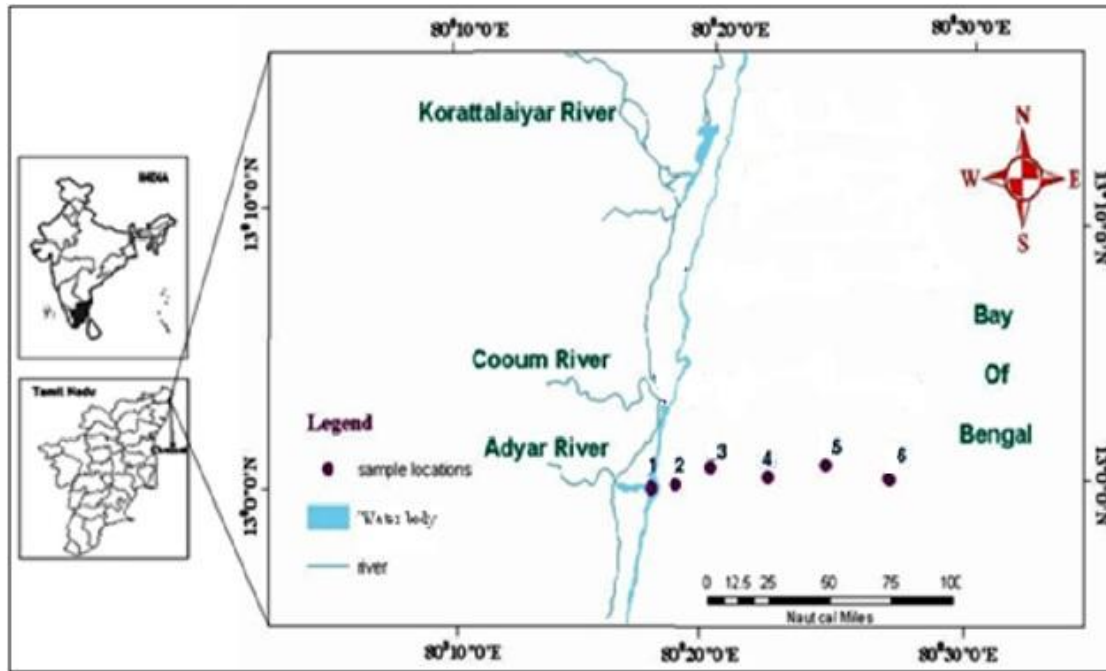


Fig 1: Study area showing sample locations in the inner shelf of Adyar River Mouth Traverses of Bay of Bengal off Chennai, Tamil Nadu, India



Plate 1: Collection of surface sediment samples by using Van Veen Grab sampler in the inner shelf of Adyar River Mouth Traverses of Bay of Bengal

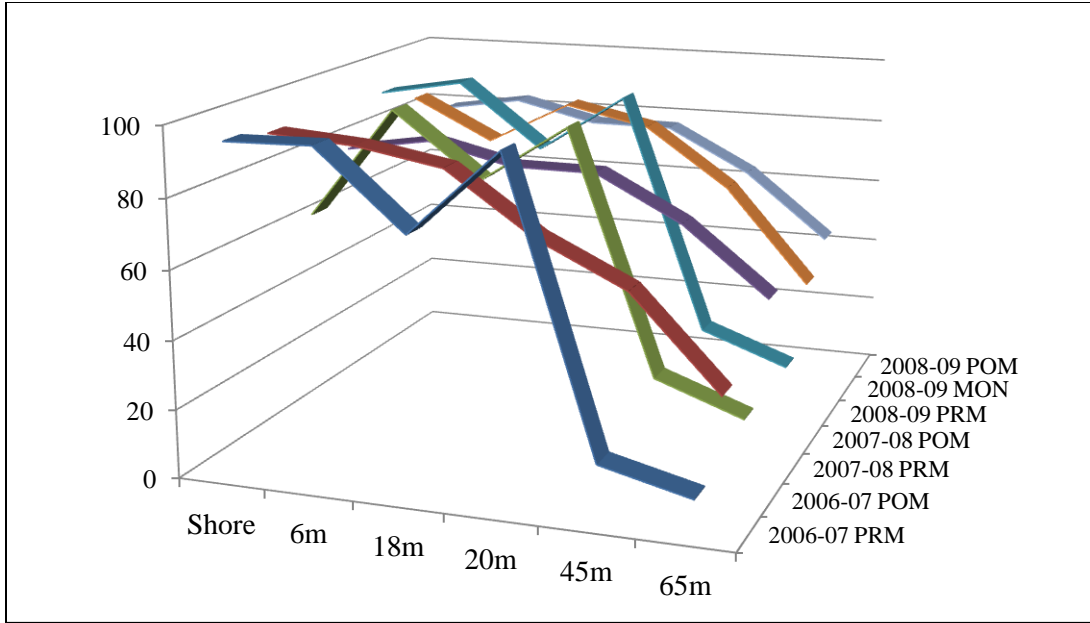


Fig 2: Surface sediments texture of Sand in three consecutive years in the study area

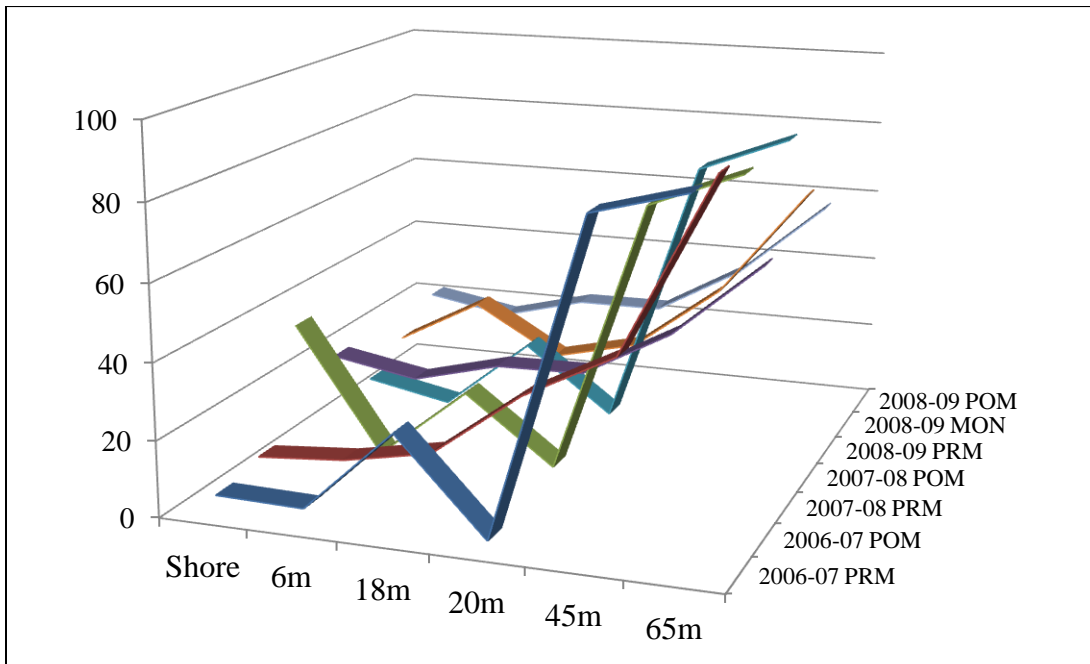


Fig 3: Surface sediments texture of Mud in three consecutive years in the study area

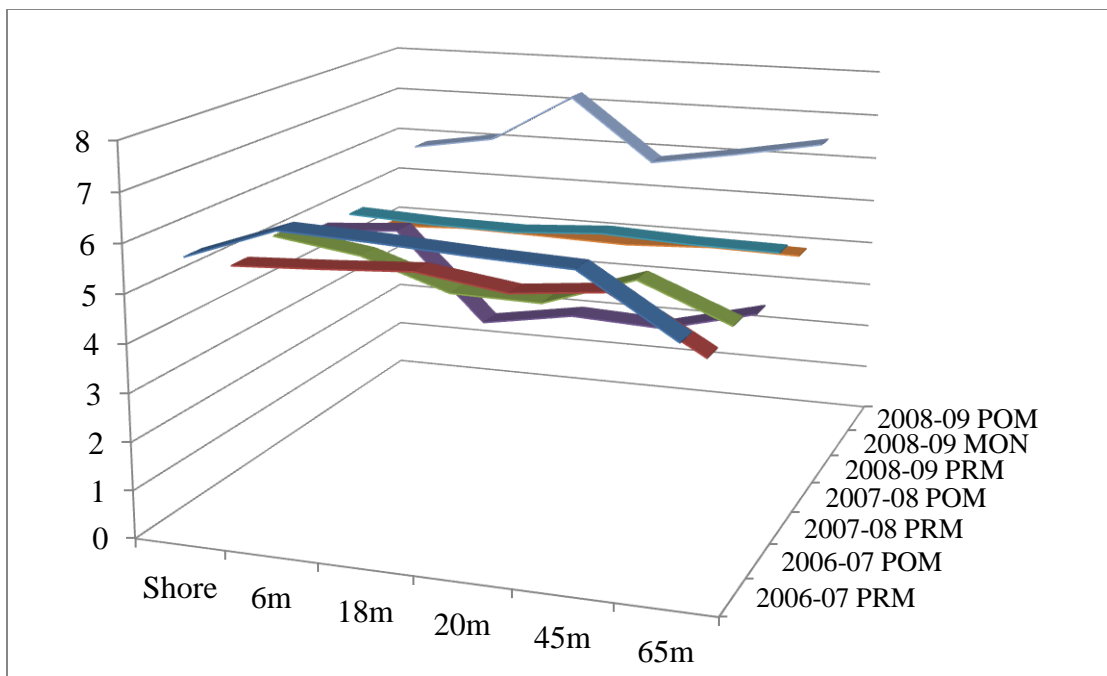


Fig 4: Calcium carbonate content of surface sediments in the study area

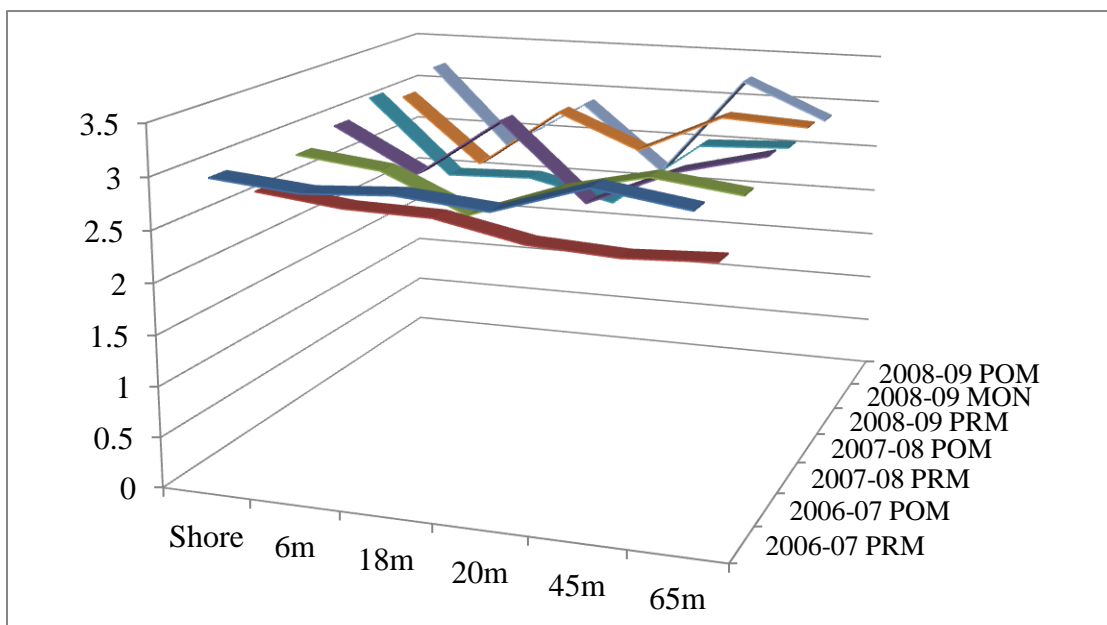


Fig 5: Total organic carbon content of surface sediments in the study area

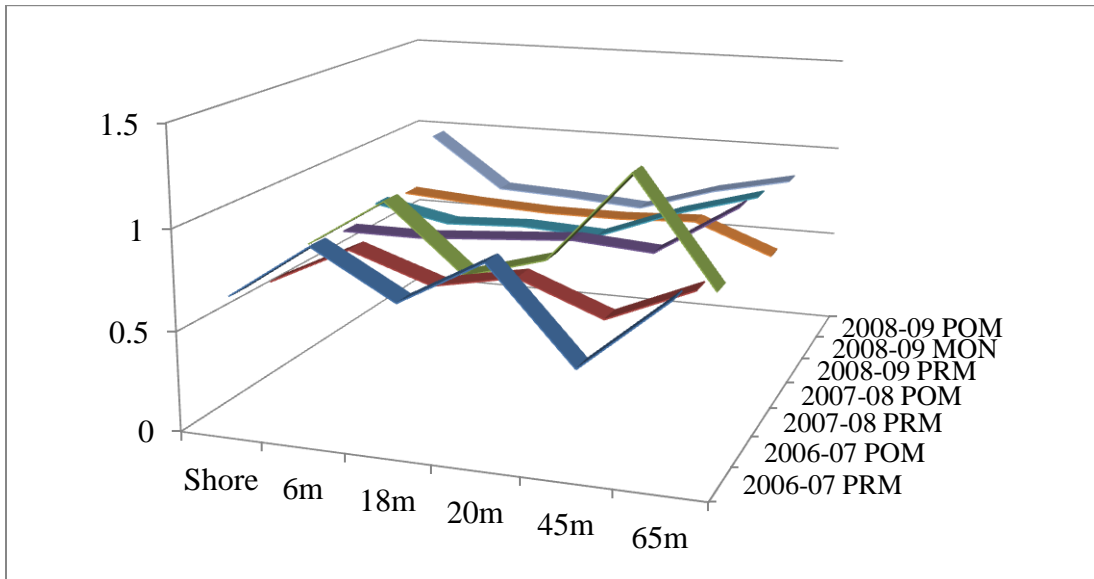


Fig 6: Iron concentration in sediment samples of the study area

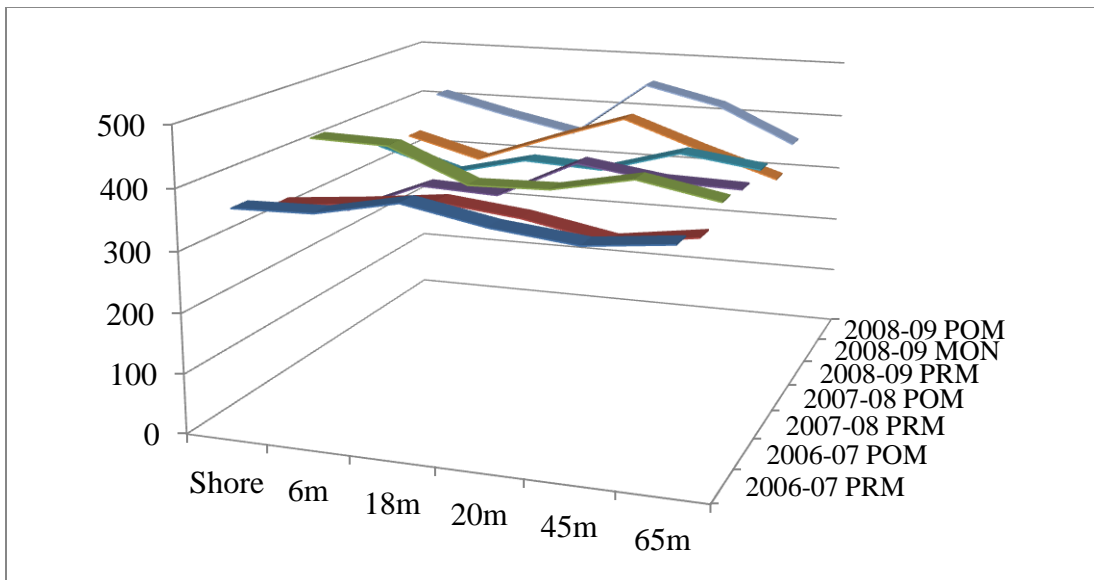


Fig 7: Manganese concentration in sediment samples of the study area

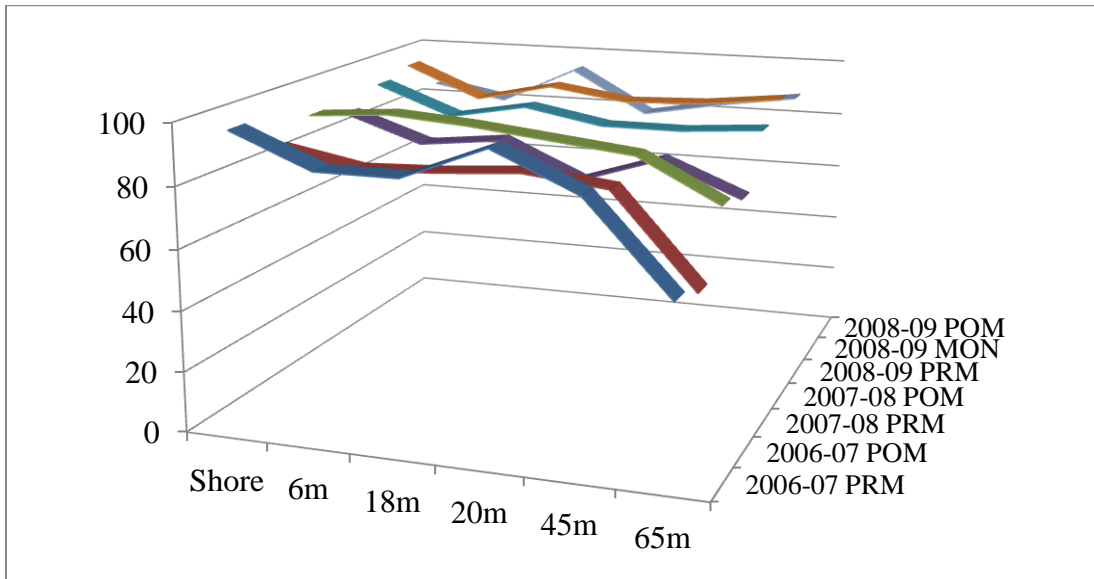


Fig 8: Chromium concentration in sediment samples of the study area

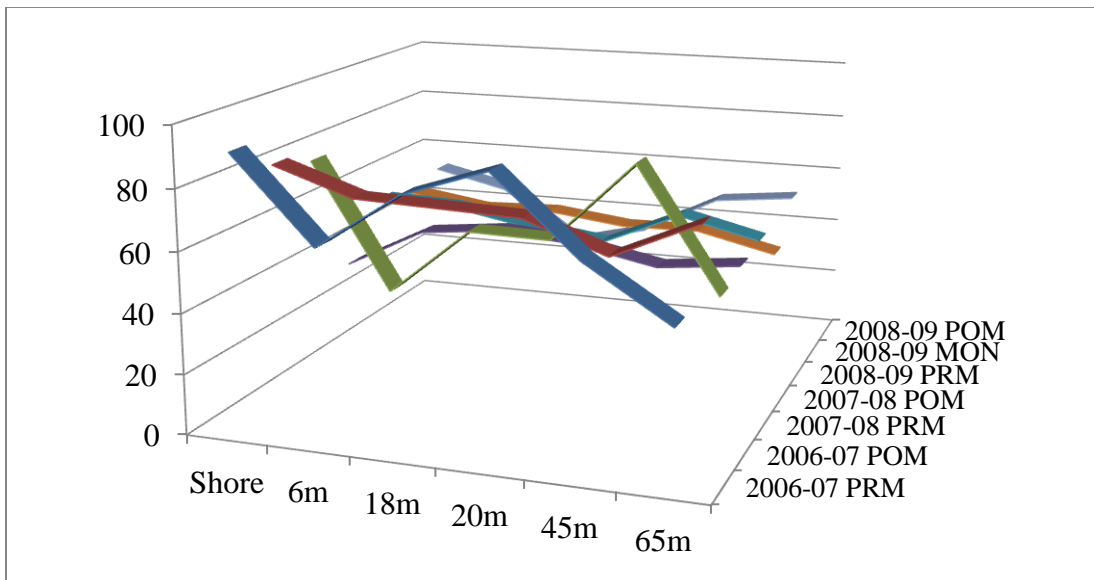


Fig 9: Copper concentration in sediment samples of the study area

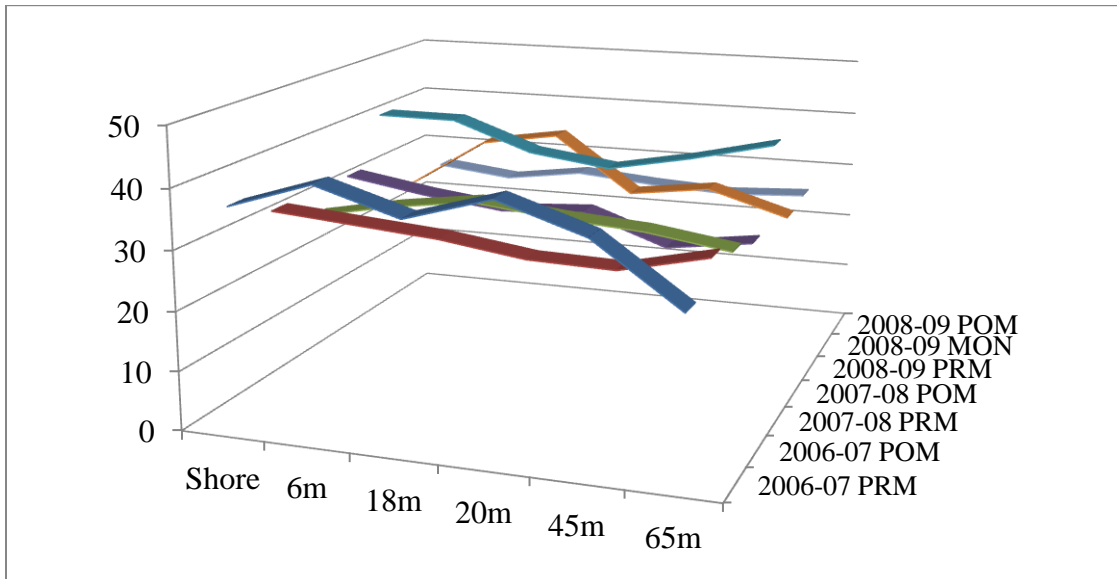


Fig 10: Nickel concentration in sediment samples of the study area

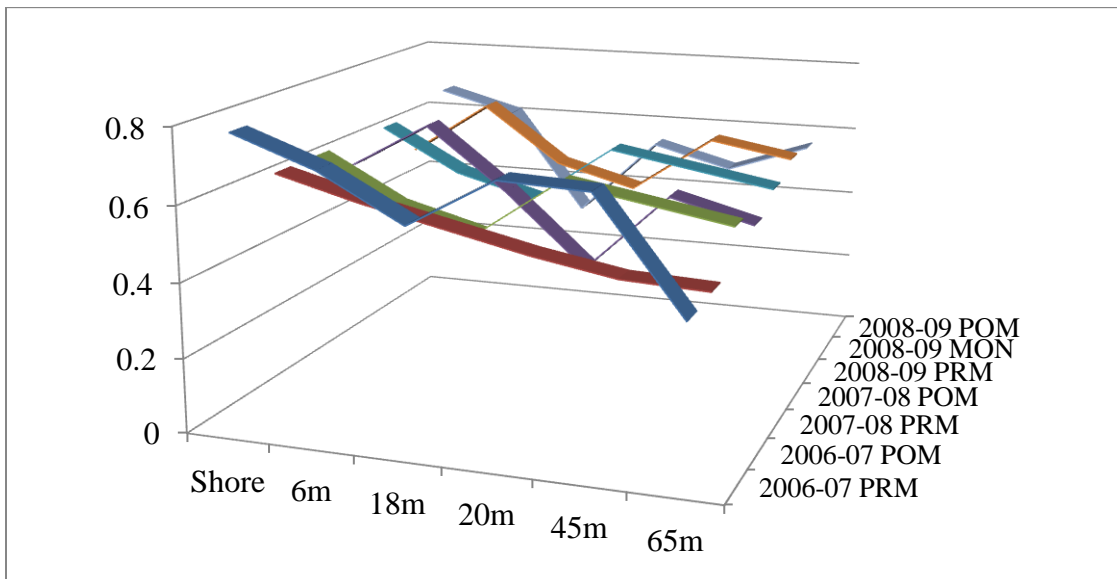


Fig 11: Cadmium concentration in sediment samples of the study area

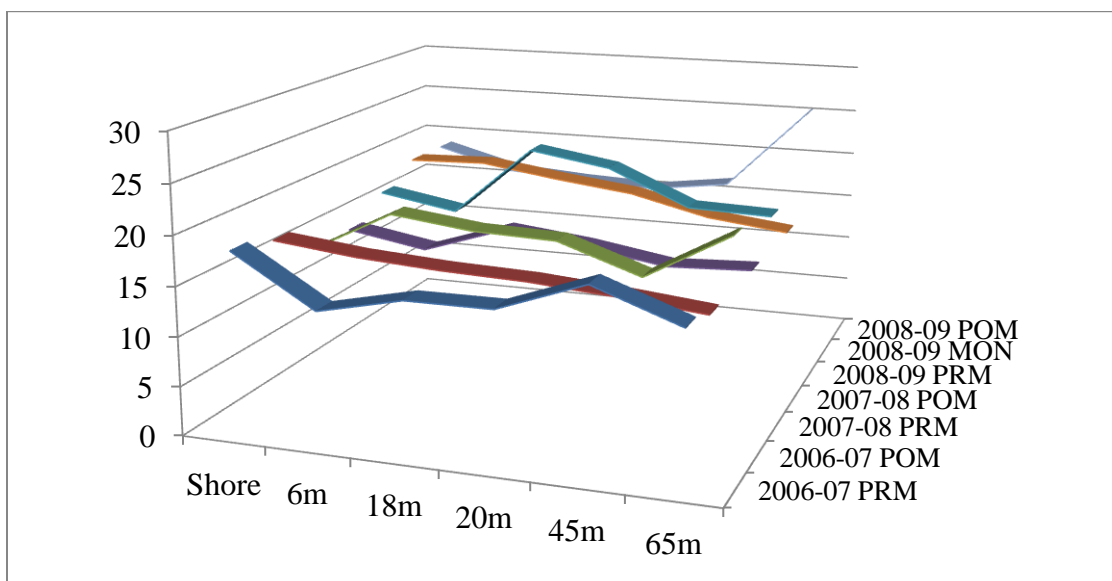


Fig 12: Cobalt concentration in sediment samples of the study area

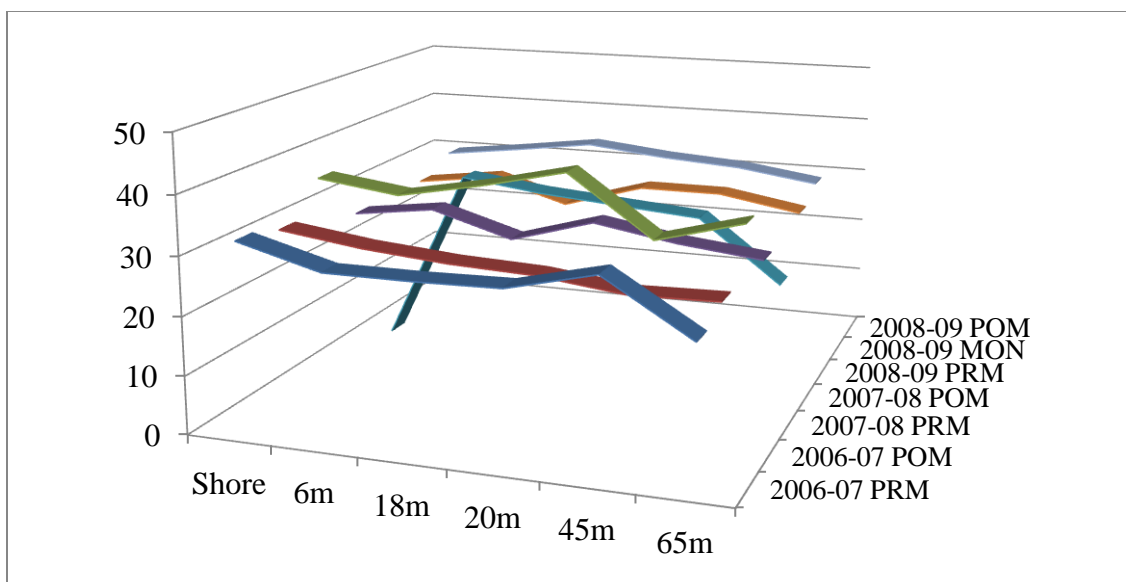


Fig 13: Lead concentration in sediment samples of the study area

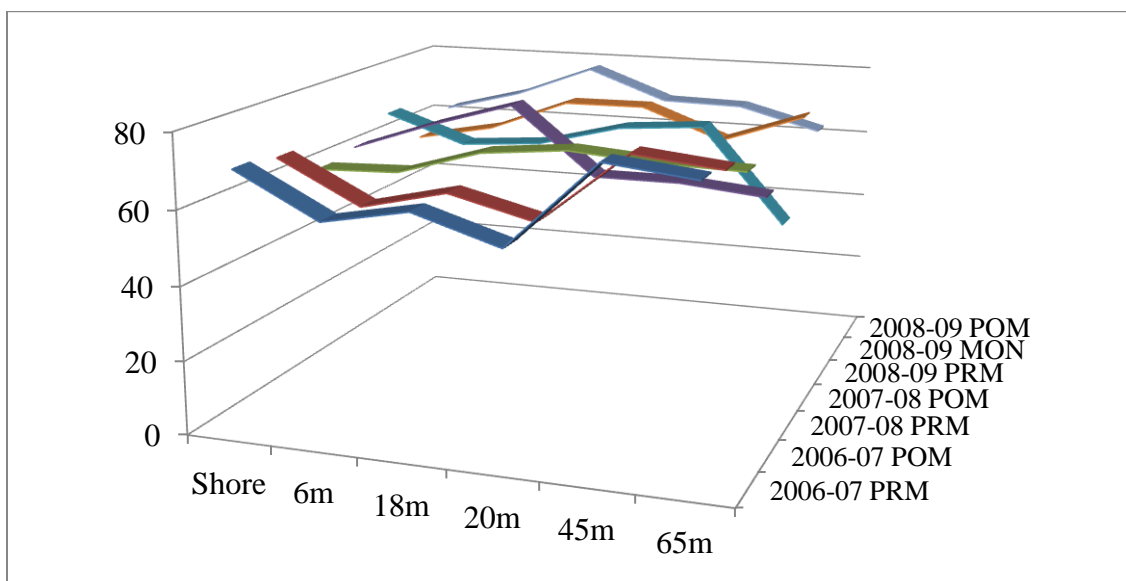


Fig 14: Zinc concentration in sediment samples of the study area

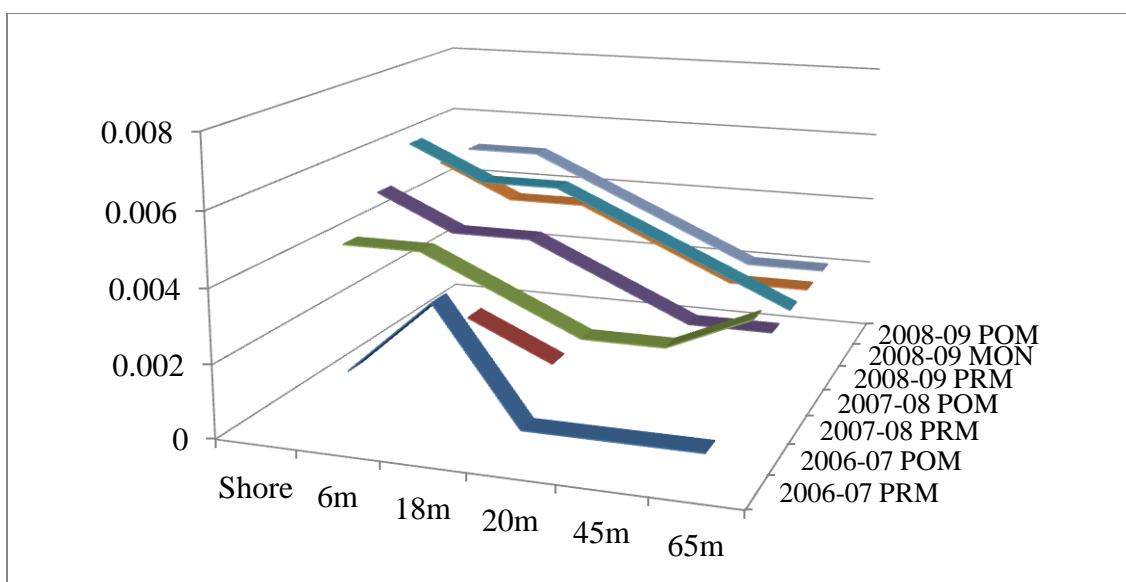


Fig 15: Mercury concentration in sediment samples of the study area

About the Authors:



Dr. R. Kannan is a researcher in the field of Environmental Sciences, started his research career in Centre for Environmental Sciences, Anna University as a Junior Project. Later he joined as a Junior Research Fellow in Centre for Advanced Studies in Botany, University of Madras and also completed his doctoral degree in the field of Environmental Sciences under the supervision of Dr. V. Kannan. His articles were published in international journals with impact factors and also published in national journals. He has participated and presented his research findings in various national and international conferences. He is an active member of Marine Biology Association of India. At present he is working as Assistant Professor in Department of Chemistry and Environmental Sciences, AMET University, Chennai.

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