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Spatial Heavy Metal Distribution Status in the Coastal Sediments along South East Coast of India

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Abstract:
Heavy metals are natural constituents of the Earth's crust and are present in varying concentrations in all bionetworks. In the aquatic environment their levels are increased due to anthropogenic activities. Rapid growth of the economy and Industrialization has been coupled with increasing environmental pollution. The coastal ecosystems are now facing increasing metal pollution burdens because of the elevated metal discharges from various sources like Industrial and domestic sewage discharges, mining, smelting, e-wastes recycling are important sources contributing to coastal pollution. Prominent levels of metal contamination along the coastal environment can increase the risk of metal exposure to humans by consuming seafood, raising the anxiety for more inflexible control and discharge of metals into the environment. Sampling of coastal sediments was carried out from the period of October 2013 to September 2014 and analyzed. The present study aimed to evaluate heavy metal concentrations of Cd, Pb, Cu, Cr, Ni, Zn and their spatial distribution along the coastal sediments of East Coast of India.

Keywords: *Spatial Distribution , Heavy Metals, Sediments,South East Coast of India*

1. Introduction

Metals are naturally occurring constituents in the environment and vary in concentrations across topographical regions as well as in the aquatic environment, but their levels have increased due to anthropogenic activities. Heavy metal elements in coastal sediment originate from physical and chemical weathering of parent rocks, wastewater discharge and atmospheric deposition [1]. Ocean and coastal waters are the major regions for a variety of human activities like fisheries, agriculture, navigation, oil and mineral exploration and waste disposal .The heavy metal pollution likely results from the pollutants that enter through water system. Untreated urban effluents, mainly industrial and municipal wastes are thus discharged into sea and river [2, 3, 4]. Discharges from extensive urban and industrial development have adversely impacted the quality of coastal water and sediments around the world [5]. In general, heavy metals tend to be adsorbed onto suspended particles and are shifted from the water column into proximal sediment. The wastes of anthropogenic and industrial origin are of composite characters and have considerable amount of heavy metals. The heavy metals in the brackish water phase generally deposit on the sediment bed or remain in dissolved state in the water column, depending on nature of chemical species which are inclined by the physical factors like aquatic salinity, wave action, pH etc. [6]. Industrialization hints to the pollution of bionetworks. Therefore, recognition of pollutants and prevention of their environmental dispersion are one of the necessities in this field. Therefore, we must determine the pollution sources, their marine environmental effects and preventive methods. Heavy metals are a group of the most important pollutants which cause environmental degradation in coastal areas. These heavy metals accumulate in the tissues of aquatic organisms at concentrations many times higher than concentrations in water and may be biomagnified in the food chain to levels that cause physiological impairment at higher trophic levels and in human consumers [7]. Coastal pollution has been increasing significantly over the recent Twenty five years and found expanding environmental problems in the East Coast of India. Urbanization and industrial activities in coastal areas introduce significant amount of heavy metals into the marine environment, causing permanent disturbances in marine ecosystems, leading to environmental and ecological degradation and constitute a potential risk to a number of flora and fauna species, including humans, through food chains [8]. Hence, it is important to determine the concentrations of heavy metals in Water, sediment, and species in order to evaluate the possible risk of human consumption [9]. Accumulation of heavy metals in sediment mainly depends upon concentration of metals in water and particulates. Although some other environmental factors such as salinity, wave action, pH, hardness and temperature play significant roles in metal accumulation. Heavy metals discharged into aquatic system during their transport are distributed between the aqueous phase and sediments. Because of adsorption, Hydrolysis and co-precipitation of metal ions, a large quantity of them are deposited in the sediment while only a small portion of free metal ions stay dissolved in water column [10,11]. The accumulation and mobility of heavy metals in sediments controlled by various factors such as nature of the sediment particles, properties of adsorbed compounds, metal characteristics, redox reactions and biodegradation of sportive substance under specific conditions [12,13]. Sediments in the coastal zone are normally dominated by terrigenous material through Aeolian and

sedimentary processes [14], resulting in a large majority of land derived contaminants accumulating in them [15]. For heavy metal pollutants, one of the largest problems associated with their threat to the ecosystem is the potential for bioaccumulation and bio-magnification causing heavier exposure for some organisms than is present in the environment alone. Hence, sediments play a key role in transmission and deposition of metals. Accumulated heavy metals in sediment can be chemically altered by organisms and converted into organic complexes, some of which may be more hazardous to animal and human life, via the food chain. More importantly, toxic metals can be taken up by marine organisms, entering the food chain and be potentially transferred to the upper trophic levels, which can eventually lead to adverse effects on humans due to the consumption of contaminated seafood [15,16]. The higher content of mercury (Hg) and cadmium (Cd) poisoning tragedies of the 1950s and 1960s in Japan, there has been considerable concern about metal contamination in aquatic environment. Consequently sediment gives us the source of information in Marine monitoring programs. Moreover, diagenetic reactions are important near the sediment-water interface responding to redox changes and affecting metal concentrations in vertical sediment profiles [17]. In addition, the sediments act as a useful indicator of long and medium term metal flux in industrialized estuaries and rivers, and they help to improve management strategies as well as to assess the success of recent pollution controls [18,19]. The levels of metal in the coastal environment deserve our attention not only because of their potential ecological impacts but also because of the concern for seafood safety. Sediments can be a good pointer of the anthropogenic input of metals because human activities are a primary cause of the variability in metal concentrations. The main objectives of this study are to determine the concentration of six heavy metals (Cd, Cr, Cu, Ni, Pb and Zn) that are usually used as environmental quality benchmarks in surface sediments of East Coast of India.

2. Study Area Description

The study areas are located in the South East Coast of India nearby Gulf of Mannar. Mandapam (latitude 9°16’14”N; longitude 79°7’10”E), Thoothukudi (latitude 8°46’26”N; longitude 78°10’9”E), Arumuganeri (8°59’40”; 78°13’71”) Kanyakumari (latitude 8°4’45”N; longitude 77°32’38”E).Mandapam (nearby by Rameswaram) is situated close to Gulf of Mannar Biosphere. The Biosphere contains 21 islands and also rich in marine biodiversity with estuaries. Thoothukudi and Arumuganeri are the major industrial areas contains major chemical industries like SPIC, Copper smelting plant, Dharangadhara chemicals ,salt pans, Thermal power station, several small scale industrial units are in Thoothukudi SIPCOT complex. Thoothukudi is one of the important major Ports having a number ship movement. The effluents from industries around Thoothukudi and Arumuganeri coastal region are discharged directly or indirectly into the sea and hence there is more possibility for accumulation of large concentration of trace metals into the marine ecosystem. Kanyakumari (formerly known as Cape Comorin), lies at the southernmost tip of East coast of India. It is one of the important Tourist Spot as well as Pilgrim place (Figure 1).

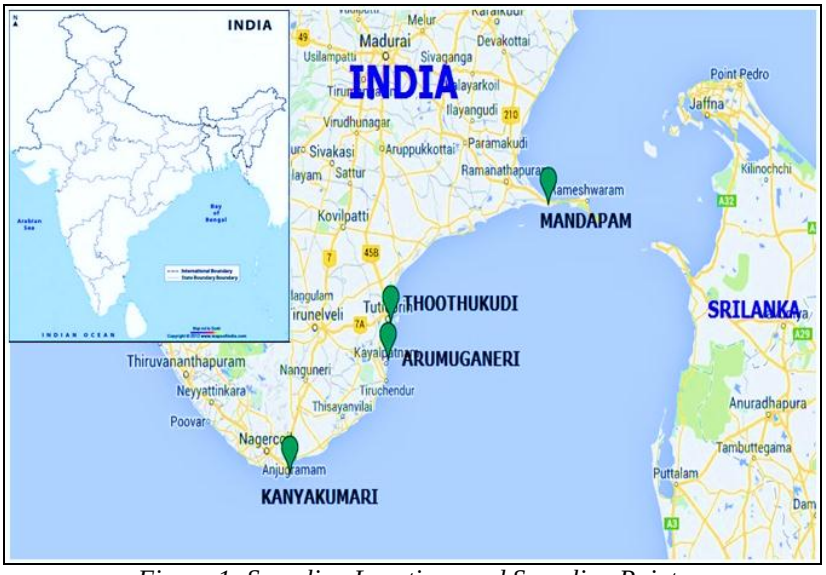

Figure 1: Sampling Locations and Sampling Points

3. Materials and Methods

Monthly variations of Trace metals in sediments are recorded from October 2013 to September 2014. Based on the meteorological events, four seasons are broadly specified as month wise and they are (1) Post -Monsoon (January to March) (2) Summer (April to June) (3) Pre- Monsoon (July to September) ,

(4) Monsoon (October to December). Sediment samples from the sites were collected in a Polyethyene bag, dried in oven then crushed powdered and mixed thoroughly followed by screening with a 0.5 mm sieve to remove large particles. For metal analysis in sediments a known quantity (1gm) of the above powdered sediment was digested with an acid mixture of $HClO_4$ and HF and the final residue was leached with HCl and made up to the required quantity [20]. Trace metal concentrations (Cd, Cu, Pb, Cr, Ni, and Zn) was measured using flame atomic absorption spectrophotometer (Perkin-Elmer AAnalyst 700) armed with a deuterium background corrector. Suitable internal chemical standards (Merck Chemicals, Germany) were used to calibrate the instrument. All the reagents used were of analytical grade and high purity. The results of the heavy metal concentrations in sediments were expressed as μg /g (PPM).

4. Results and Discussion

Heavy metals can be introduced to coastal and marine environments anthropogenically, through a variety of sources, including industries, wastewaters and domestic effluents [21].The concentration of Cadmium in the coastal sediment can range from 0.52 to 6.25 (ppm). It was found minimum (0.52 ppm) at Kanyakumari during Pre-Monsoon and maximum (6.25 ppm) at Arumuganeri during Monsoon season as shown in the Figure-2 . Cadmium is a non-essential metal for organisms and also highly toxic to the marine organisms. It is bio-accumulative through the food chain. It has been demonstrated as a highly toxic metal to biota and carcinogenic to humans [22, 23]. Apart from the natural crustal origin the main source of Cd in the coastal environment is mainly of anthropogenic sources. Anthropogenic inputs in coastal sediment include local waste disposal, Industrial effluent discharge, and human developmental activities near coastal areas [24,25]. Comparing to the other metals, the chance of adsorption into particulate material is limited, they usually settled at the bottom and hence an increased concentration in the sediments [26].

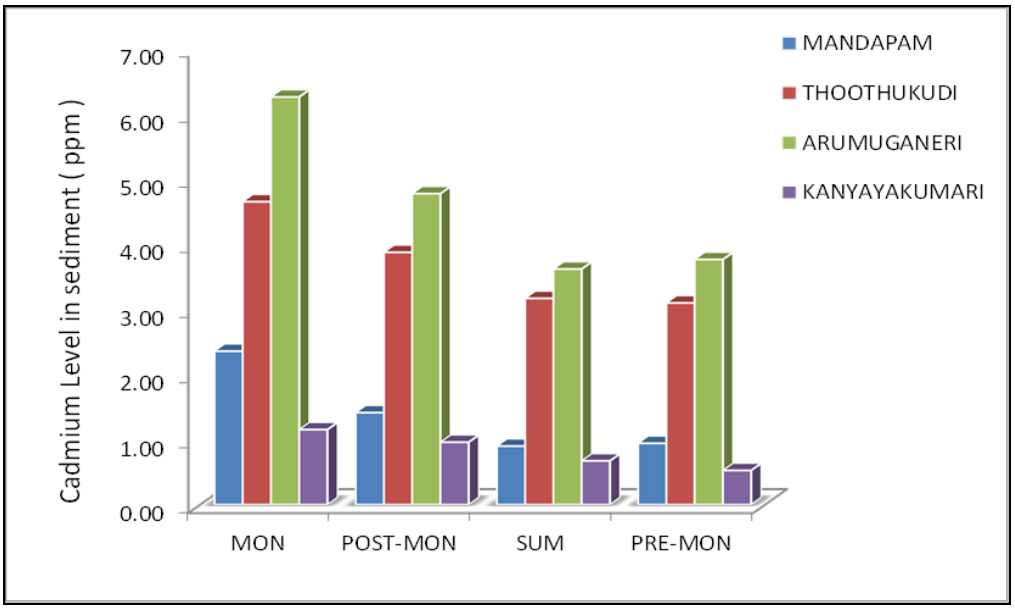

Figure 2: Cadmium Levels in Sediment at different seasons
(Oct 2013 – Sep 2014)

Copper is a micronutrient for aquatic life, but the toxic nature increases with concentration. The concentration of copper in the coastal sediments varied from 6.92 to 41.94 ppm) as shown in the diagram [3]. It was found minimum (6.92 ppm) at Mandapam during Post- Monsoon and maximum (41.94 ppm) at Thoothukudi during Post Monsoon season. The observed high concentrations in the coastal sediments is due to the industrial effluents, Industrial water coolant discharge, Combustion of coal in Power Plants, Municipal domestic sewage and copper ore handling at harbor . Also Copper is used as an ingredient in antibiofouling paints which are applied in marine equipments [27,28]. Another possibility for higher concentration of Cu is due to the usage of copper-based herbicides used in the nearby agricultural land [29]. The high concentration is due to surface runoff in these coastal areas during inter-monsoon fall.

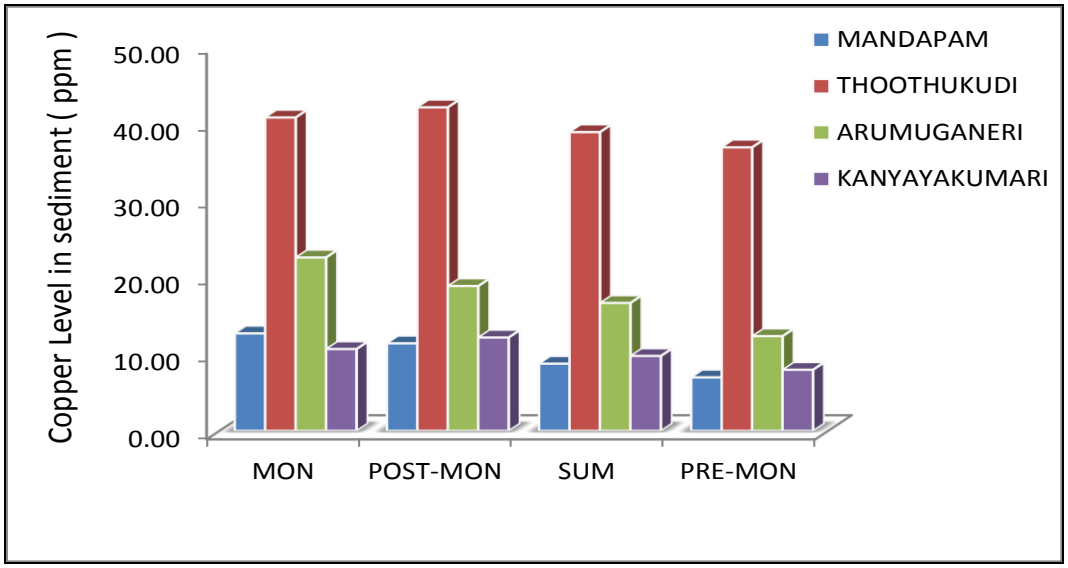

Figure 3: Copper Levels in Sediment at different seasons
(Oct 2013 – Sep 2014)

The concentration of Lead in the coastal sediments can range from 15.43 to 51.40 (ppm) . It was found minimum (15.43 ppm) at Kanyakumari during summer and maximum (51.40 ppm) at Thoothukudi during Monsoon season as shown in the diagram [4]. Lead concentration in coastal environment can be attributed by the sources like automotive exhausts, domestic sewage, agricultural runoff ,power-plant operation , loading and unloading of cargo as well as dredging activities in harbor zones, and leaching from antifouling paints used in marine vessels and burnt exhaust from automobile [30,31]. Generally Lead transported through the atmosphere and later settled in the seawater, subsequently wet and dry fallout in sediments. In the absence any industry close to the study areas, the reason for the higher Lead content is due to the extensive increase of automobiles and motor fishing boats usage [32, 33].

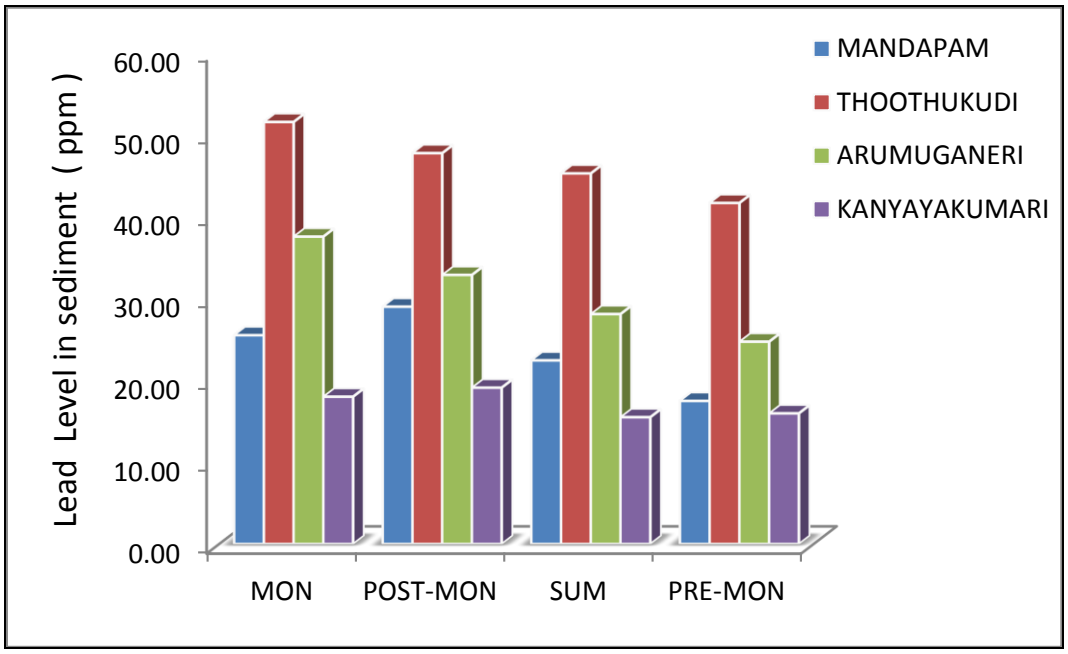

Figure 4: Lead Levels in Sediment at different seasons (Oct 2013 – Sep 2014)

The concentration of Chromium in the coastal seawater can range from 7.39 to 29.56 (ppm). It was found maximum (29.56 ppm) at Thoothukudi during Post-monsoon season, and minimum (7.39 ppm) at Kanyakumari during Summer season as shown in the Figure -5.The effluent of metal industry, corrosion of building materials, domestic and Municipal sewage play an important role in increasing the chromium concentration in the marine environment [34]. Land run off during monsoon season also increasing Chromium concentration [35].

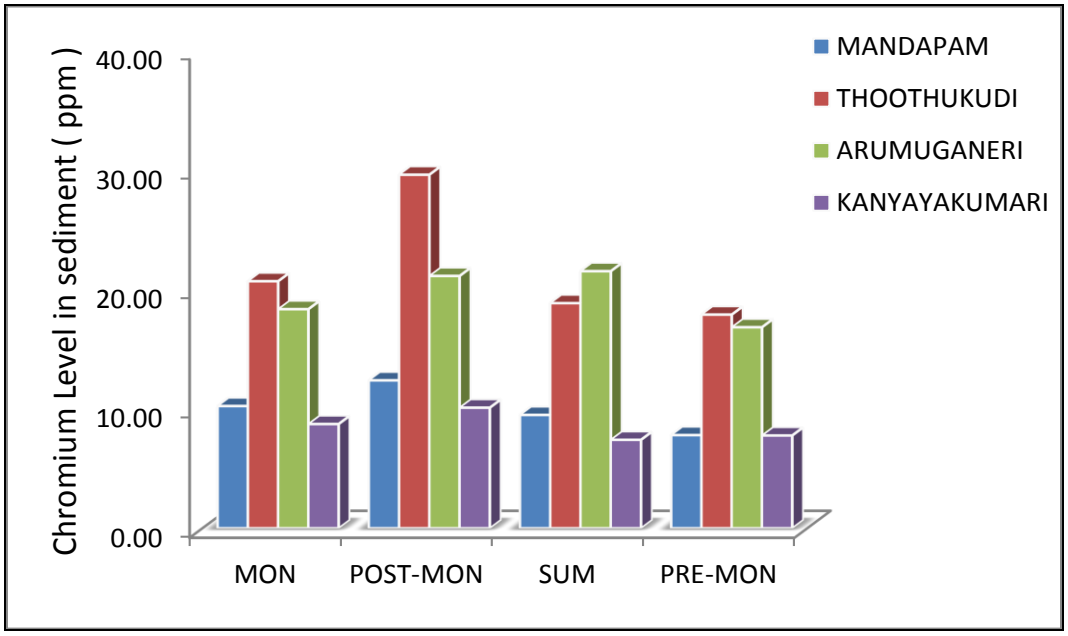

Figure 5: Chromium Levels in Sediment at different seasons (Oct 2013 – Sep 2014)

Nickel is biologically essential trace element that is widely distributed in the environment. Nickel is known to be a nutritional requirement for many marine organisms, which is necessary for plants to metabolize urea [36]. The concentration of Nickel in sediments can range from 6.07 to 25.98 (ppm).It was found maximum at Thoothukudi during monsoon season, and minimum at Mandapam during Pre-Monsoon season as shown in the Figure - 6. Higher concentration Nickel along the coastal region due to the discharge of industrial effluents and domestic sewage, land run off from nearby coastal region[37]. The petroleum related activities also bring Nickel and contaminate the coastal environment [38].

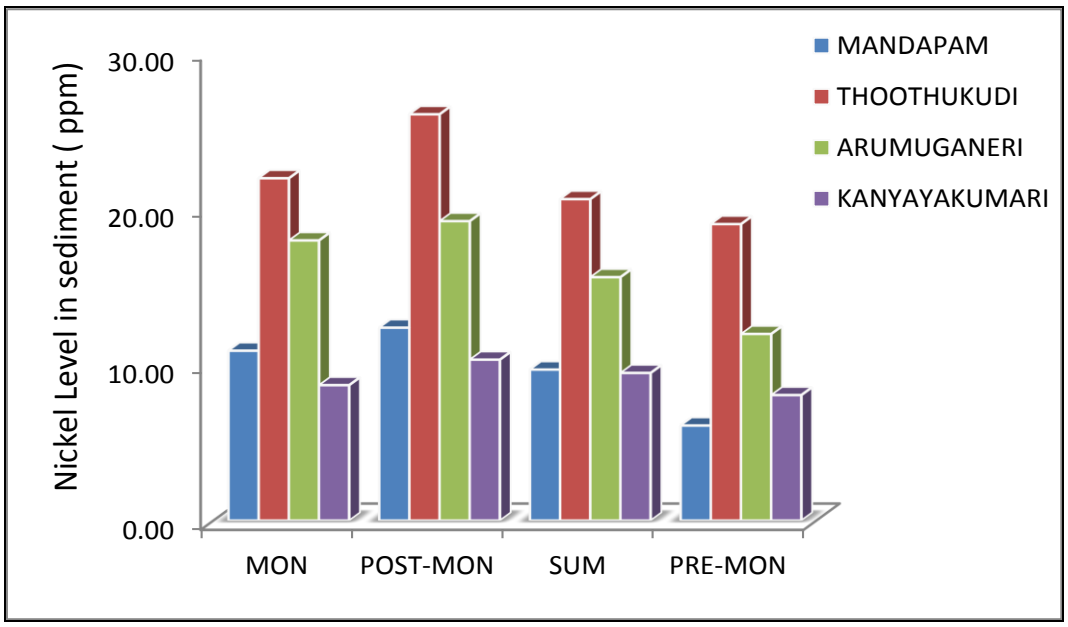

Figure 6: Nickel Levels in Sediment at different seasons (Oct 2013 – Sep 2014)

Zinc is present in all organisms and also essential trace element for metabolic processes.The concentration of Zn in sediments ranges from 10.59 to 30.68 (ppm), It was found maximum (30.68 ppm) at Thoothukudi during monsoon season, and minimum (10.59 ppm)at Mandapam during Pre-monsoon season as shown in the diagram [7].

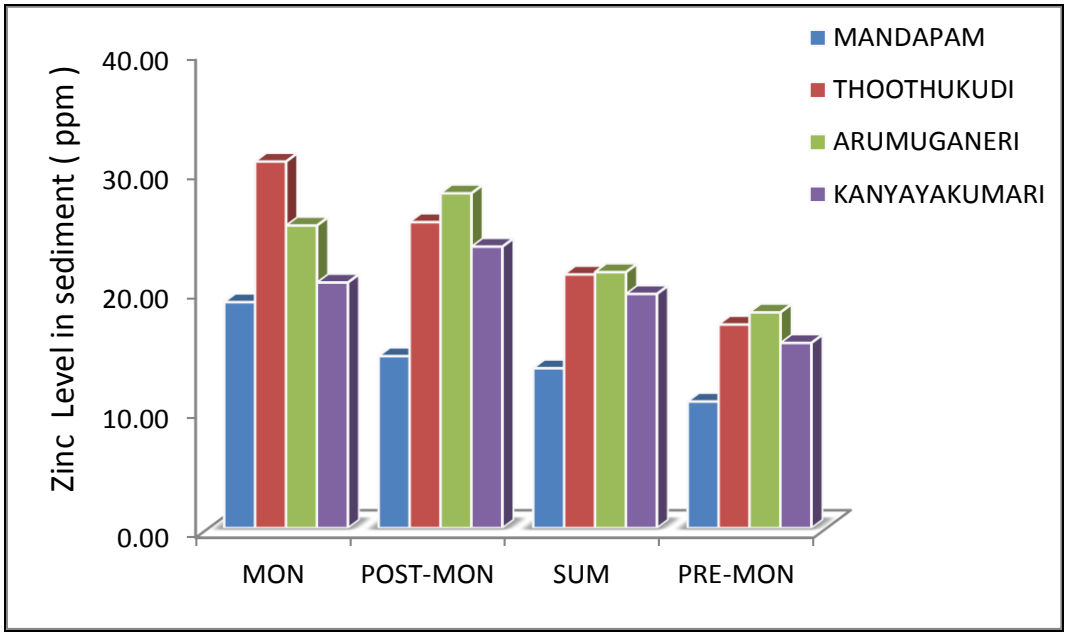

Figure 7: Zinc Levels in Sediment at different seasons (Oct 2013 – Sep 2014)

The high concentration of Zinc observed in the coastal sediments may be due to the drainage of domestic sewage, surface and riverine runoff waters, and industrial effluents .Due to the coal powered thermal power plant, atmospheric deposition of fly ash , anthropogenic sources and dredging and dumping of sediments also increase the Zinc content [39]. Increase in Zinc content particularly during monsoon period coincided with relatively high organic content observed. This identifies that land runoff, agricultural waste and drainage are also the sources of Zinc like Copper [40].

5. Conclusion

In general due to the land based activities increase the heavy metal accumulation in the coastal sediments. Analyzing the trend of results obtained during the present study, apparently that the monsoon plays a prominent role in the distribution of heavy metals. However the increased Industrial activities like Thermal power station, Copper smelter Industry, Petrochemicals, Alkali Industry and other allied small industries around Thoothukudi and Arumuganeri will be the key source for the anthropogenic contribution. Because of the Heavy metals results of Thoothukudi and Arumuganeri transacts gradually increases in all metal levels especially Cadmium and Copper levels. The wide expansion of Tuticorin Port Trust and greater mobilization of shipment also polluted the coastal environment. The coastal region should be given great attention to control the anthropogenic input into the marine environment. Continuous monitoring of the near shore area is highly recommended for assessing the pollution levels in the coastal area.

6. References

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