*International Research Journal of Earth Sciences*_____E-ISSN 2321–2527
Vol. **4(4),** 1-8, April **(2016)** *Int. Res. J. Earth Sci.*

Assessment of the Environmental Significance of Heavy Metal Pollution in Surficial Sediments of Uppanar River, Cuddalore District, Tamil Nadu, India

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Available online at: www.isca.in, www.isca.me
Received 17th December 2015, revised 2nd January 2016, accepted 12th February 2016

Abstract

Worldwide, aquatic ecosystems are contaminated with heavy metals from anthropogenic and terrigenous sources. The objective of this study was to explore the heavy metal pollution of Uppanar river of Cuddalore District. This study is to inspect the load of Cr, Ni, Cu, Pb, and Zn in five surface sediments samples were collected and estimated for heavy metals by inductively coupled plasma-mass spectrometry (ICP-MS) in order to establish natural background levels of these metals and to evaluate anthropogenic influences on them. The metal concentrations in sediments ranged as Cr 26.28-90. 24ppm; Ni 23.09 - 53.632ppm; Cu 9.987 - 30.548 ppm; Pb 19.957 - 24. 319ppm; Zn 24.705 -132. 548ppm. It is found that every metal concentration is found to be more in Uppanar River, especially in the upstream area of study area. It is concluded that the sources of pollutants in sediments are from anthropogenic by discharge of various industrial effluents from small and large-scale industries located in and around the SIPCOT area and direct discharge of public sewage.

Keywords: Surface sediments, Heavy metal, Spatial distribution, River, GIS.

Introduction

River's sediments are the major carrier of heavy metals in the aquatic environment. Sediments are a combination of several mechanisms of mineral species as well as organic debris sinks for heavy metals into environment[1,2]. Heavy metal flowing into the aquatic environment is partially associated with fine grained particulates and submerged bottom sediments[3]. In the sediment stores, metal ions have been found in different chemical forms associated with a variety of organic and inorganic phases, depending on chemical and geological conditions[4].

The behavior of pollutants and sediments is an important part of environmental research. These elemental compositions of sediment are governed by the chemistry of soils and parent rocks in the surrounding areas and the physicochemical processes operating in that particular region. The litho contribution of metals is also treated as a background in sediment[5]. So, any significant difference in concentration of particular metal in sediments is attributed to point source such as sea wage discharges, industrial effluent, etc.[6].

In general, heavy metals are among the most common environmental pollutants, and their occurrence in waters and biota indicates the presence of natural or anthropogenetic sources, including urban, industrial and agricultural activities, terrestrial runoff and sewage disposal[7]. These heavy metals when discharged into aquatic systems are immobilized due to the chief processes like adsorption, flocculation and co-precipitation and are easily familiarized into the aquatic system as a result of chemical weathering of soil and anthropogenetic activity or by the metals and substances that contain metals. Hence, heavy metals play an important role in the environmental pollution[8]. As per the estimations made by Milliman and Meade[9], the Indian rivers nearly contribute 30% of sediments transported by World Rivers. So by knowing the facts of metals in the aquatic environment, the aim of this study is to investigate heavy metals like Cr, Ni, Cu, Pb, and Zn distribution in sediments of lower Uppanar River of Cuddalore.

The Study area: The river flows parallel to the south coast of Cuddalore town and many streams of sewages and effluents of industries reach the coast through river. In this district, many small and large-scale industries are established in SIPCOT industrial estate on the western banks of Uppanar River (Figure-1). In the study area next to this coastal zone, industrial activities have started since from 1980's. The industries found in the study area are chemicals, beverage manufacturing, tanneries, soap, oil, paint production, glass pigments, PVC manufacturing, paper and metal processing plants. Other than the industrial development, Cuddalore harbours where mechanized fishing boats are operated in the coastal stretch are found in the estuarine part of Uppanar River. Another source of pollutants is from the nearby Thermal Power Plant, where Ash's water is discharged into the channel of Perumal Lake. The combined affects all this developmental and unplanned discharge of sewage and effluents from the industrial zone for decades deteriorated since the quality of river and coastal water of Uppanar river of Cuddalore district.

Materials and Methods

Sediment sampling and analysis: Five surface sediment samples (0-10cm) had been collected in Uppanar River in each sampling location was identified and recorded utilizing a hand-held GPS (Magellan). The collected samples were represented as S1, S2, S3, S4, and S5 respectively and stored in clean poly bags for further analytical work. The samples were air dried at 50^{o}C for 48h and analyzed for Cr, Ni, Cu, Pb, and Zn. The samples were analyzed in a range of 0.15 – 0.20 g added with 2ml supra- pure HNO_3 acids and 0.5 ml of H_2O_2 to the sample into Teflon bombs for digestion with a microwave system (Milesstone High performance Microwave Digestion Unit MLS 1200 mega). After digestion, the samples were diluted to de-ionized water (Elgastat Maxima). The determination of concentration of the analytic 50ml with elements was done with inductively Coupled Plasma mass spectrometer (ICP-MS) Perkin Elan DRC II)

Results and Discussion

The entire heavy metal absorptions in sediment of the sampling locations of Uppanar River are shown in Table-1. The metal content ranges as Cr:26.28-90.24ppm; Ni: 23.09-53.632ppm; Cu: 9.987-30.548ppm; Pb: 19.957-24.319ppm; Zn: 24.705-132.548ppm. The mean concentrations of these metals are 43.77, 36.09, 18.16, 21.73 and 67.27(ppm) for Cr, Ni, Cu, Pb, and Zn. The increasing order of average domination of each metal is as follows Cu < Pb < Ni < Cr < Zn. The transformation of metals in the suspended sediment's environment is based on the physicochemical changes in water during sediment-water interface. The settling of lead, copper, chromium, zinc and nickel in sediments is insoluble hydroxides as alkaline pH, oxides and carbonates. However, the metals like chromium, copper and nickel in sediments show a higher concentration due to the interaction of organic matter in the aqueous phase[10,11].

Copper (Cu): Concentration in sediments are found higher in S4 and S5 (30.548 ppm and 30.048 ppm) of stagnant water of the upstream area than S1, S2, and S3 (9.987, 10.11 and 10.15 ppm). The Cu in this area displays a lower level of concentration than the Indian Standards for industrial effluence as (3mg/l)[12,13]. According to Usha Damodhar and Vikram Reddy[14] the mean Cu concentration in the study area is due to the lowest river discharge. During monsoon season, when rainwater is mixed with freshwater, the level of suspended copper concentration will be more in both surface and bottom waters[15]. In general, elevated concentration of copper is noted in marine and river zones[16]. This is revealed that the higher amount of Cu in sediment is due to the anthropogenic activities, agriculture, sludge, municipal and industrial solids dumped into the river water (Figure-2). However, there is no considerable relation between salinity and copper concentration for inshore and estuarine waters[16]. In the study area the samples S4 and S5 in the upstream side is recognized by higher absorption of copper that is deserved by natural weathering of soil, which is transported by river, effluents from industries and from sewage treatment plants in the study area[17-19].

Lead (Pb): Content in the sediments in S4 and S5 is (24.084 ppm and 24.319 ppm) and the minimum amount of concentration in S1, S2, and S3 in the downstream side with 20.051, 20.25, and 19.957 ppm in (Figure-3). Lead occurs in nature at an average crust abundance of 16 µg-l. In aquatic environment the terrestrial systems direct the primary sinks for Pb. The mean Pb level in sediments of Indian River is about 14 µg-1, which is lower than the world average[20,21]. It is understood that the low and constant Pb concentrations indicates the importance of anthropogenic input and considered to be the major source of elevated Pb concentrations in marine sediments[22,23]. Lead values in bay, estuarine and other coastal sediments (marsh environments) have also been much altered by man's activities.

The Pb concentration in sediments of study area exceeds the maximum tolerance level of (0.1mg/l) of Indian standards. Lead value in bay, estuarine and other coastal sediments have been made altered by man's activities. The medium concentrations of Pb in Indian rivers are lower than the world average[24,25]. Nevertheless, the mean concentration of Pb in the present study is higher than the permissible limit as shown (Table-2). It is also said that the higher concentration of lead is from lithogenic sources, industrial wastages and occasionally through anthropogenic activities. Natural sources of lead into the surface environment arise from the weathering of geological materials and emissions from the volcanoes in atmosphere, windblown dust, sea spray, biogenic material and forest fires. Naturally, Lead occurs in minute concentrations in all rocks, soils and also as lead metal used in ammunition, as oxides in glass and ceramics and in metal casting[14,22]. It is evidenced that in the study area, small and large industries use lead materials for production and various effluents from SIPCOT industries, and public sewages take part in the major role in enriching Pb concentration in surface sediments of upstream of the study area.

Nickel (Ni): In the present study has higher concentrations in S4 and S5 (53.632 ppm and 52.956 ppm), whereas least concentration of nickel is reported in S1, S2, and S3 with (23.09, 25.54, and 25.293 ppm in (Figure-4). Nickel value in bay, estuarine and other coastal sediments always show minimum concentration[26] as shown in the Table-2. In this area, the higher amount of nickel is from lithogenic sources, industrial wastages and by anthropogenic activities (Figure-4). The nickel in the marine environment arises as sulphide and oxide minerals but Ni is a fairly toxic element, the volatile compound like nickel tetra carbonyl Ni (CO) 4, used for the extraction of the element by the Mond process is poisonous.

Chromium (Cr): Exhibit a significant concentration in S4 in the upstream side with 90.24 ppm, and the lowest amount in

S1, S2, S3, and S5 (32.37, 26.28, 29.43 and 40.53ppm (Figure-5). The average value of chromium is 43.77ppm, when evaluated with the estuary sediments from different area of India Table 2. Chromium absorption in the sediment will be more from lithogenic supply, industrial wastages and anthropogenic behaviors. Naturally, chromium is found in rocks, soil, plants, and animals. It also occurs as blended with other elements as chromium salts, a few of which are soluble in water. Naturally unpolluted metallic form rarely occurs, so chromium does not evaporate, and they can be present in air as particles. Chromium is an element, and it does not degrade nor destroyed. It is a significant component in metallurgy used as a constituent of stainless and in "Chrome plates" and as pigments[22].

Zinc (Zn): Accumulation is more in S4 and S5 (132.548 – 129.168ppm, with an average of 67.279ppm. Zinc primarily occurs as structure of silicates and oxides and further goes into solution during chemical weathering of these minerals[27]. The amount of zinc in the sediments is accredited by various sources of contribution to the river, such as leaches from fertilizers, insecticides and sludge practice in farm lands close to source. The least amount of Zn is attributed by the reliability of nearby sources like hazardous waste sites, highly-developed areas such as lead smelters and the emission of industrial effluents through the transmission of iron pipes (Figure-6). Mine drainage, urban runoff and sewage municipal sewages are the major sources of zinc[14,29].

Table-1
Heavy metal concentration in sediments of Uppanar River (ppm)

Location Name	Cr	Ni	Cu	Pb	Zn
S1	32.37	23.09	9.987	20.051	24.705
S2	26.28	25.54	10.11	20.27	25.19
S3	29.43	25.293	10.15	19.957	24.784
S4	90.24	53.632	30.548	24.084	132.548
S5	40.53	52.936	30.048	24.319	129.168
Mean	43.77	36.0982	18.1686	21.7362	67.279
Minimum	26.28	23.09	9.987	19.957	24.705
Maximum	90.24	30.548	30.548	24.319	132.548

Table-2
Heavy metal Concentration level in Estuary sediments from Different area of India (ppm)

Rivers & Estuary	Cr	Ni	Cu	Pb	Zn	Reference
Present Study	43.77	36.09	18.16	21.73	67.27	-
Cauvery Estuary	NA	NA	12	10	NA	30
Vellar Estuary	NA	NA	36.5	NA	NA	31
Coromandal Coast Pondicherry	NA	33.51	34.59	NA	NA	26
Pitchavaram mangrove eco system	141.2	62	32	11.2	NA	32
East coast Estuarine	318	582	NA	11	NA	33
Tamirabirani river and Estuary	97.162	11.858	7.758	7.30	NA	34

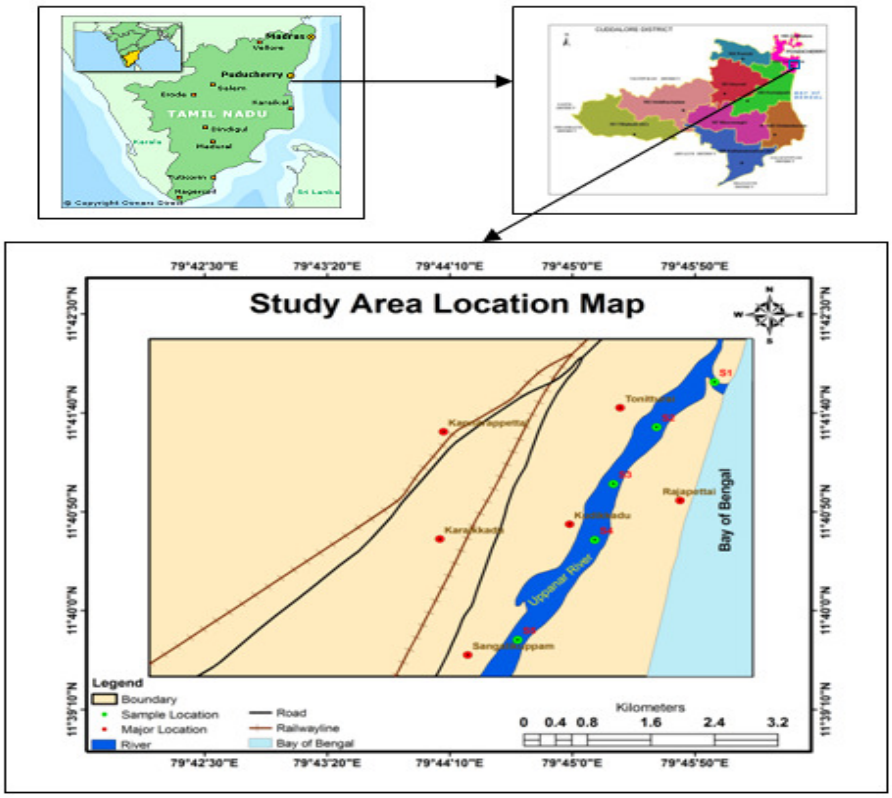

Figure-1
Study area Location Map

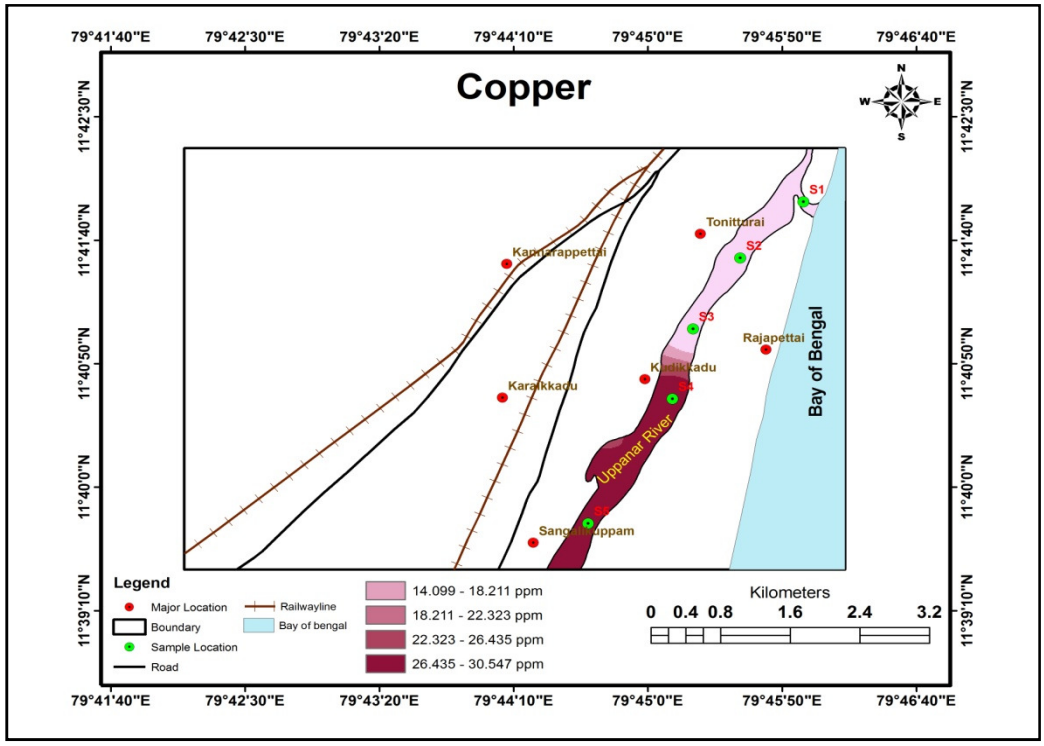

Figure-2
Concentration of Copper at different location

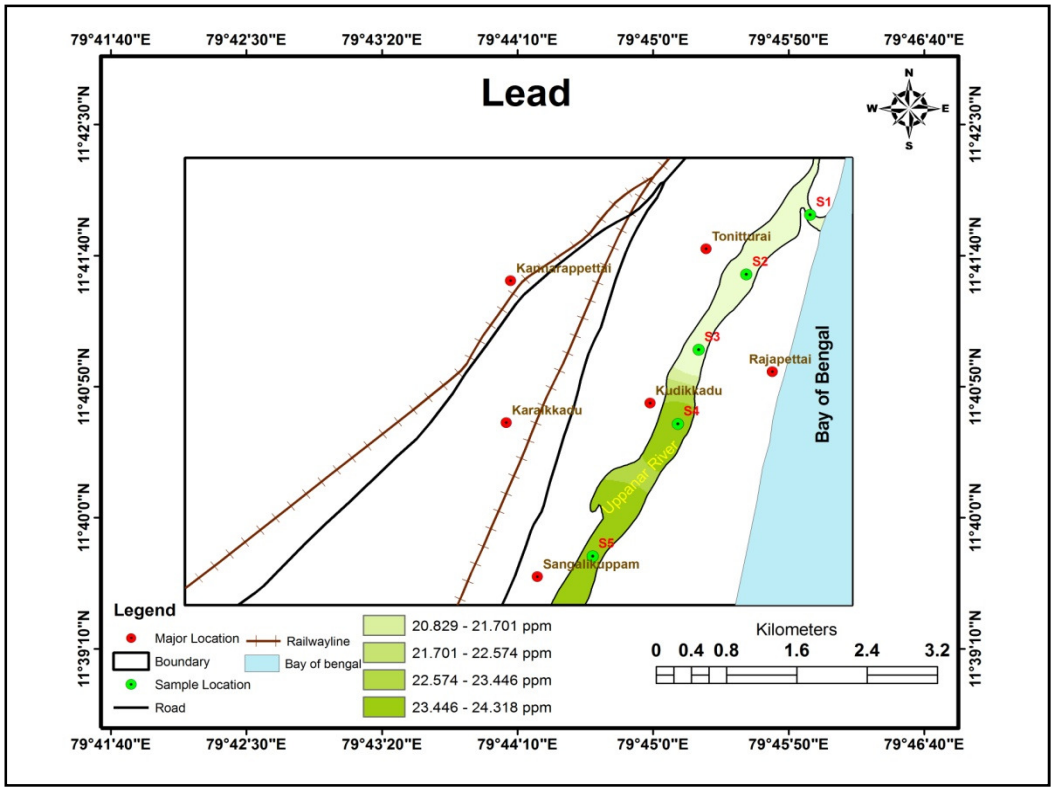

Figure-3
Concentration of Lead at different location

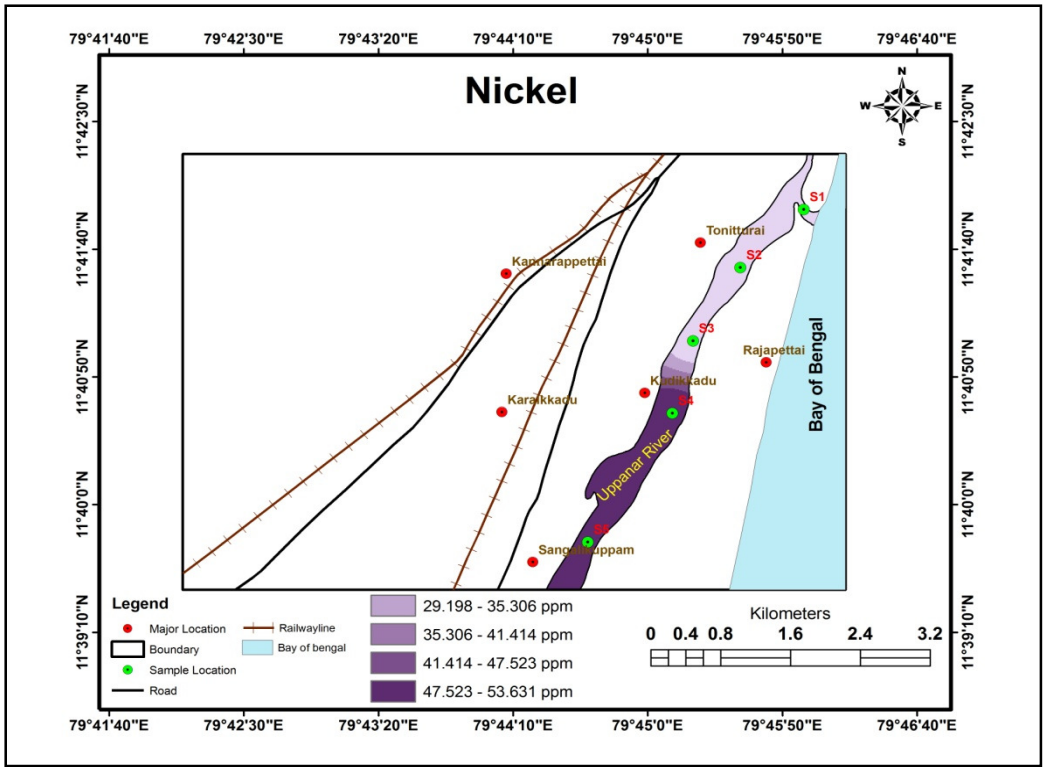

Figure-4
Concentration of Nickel at different location

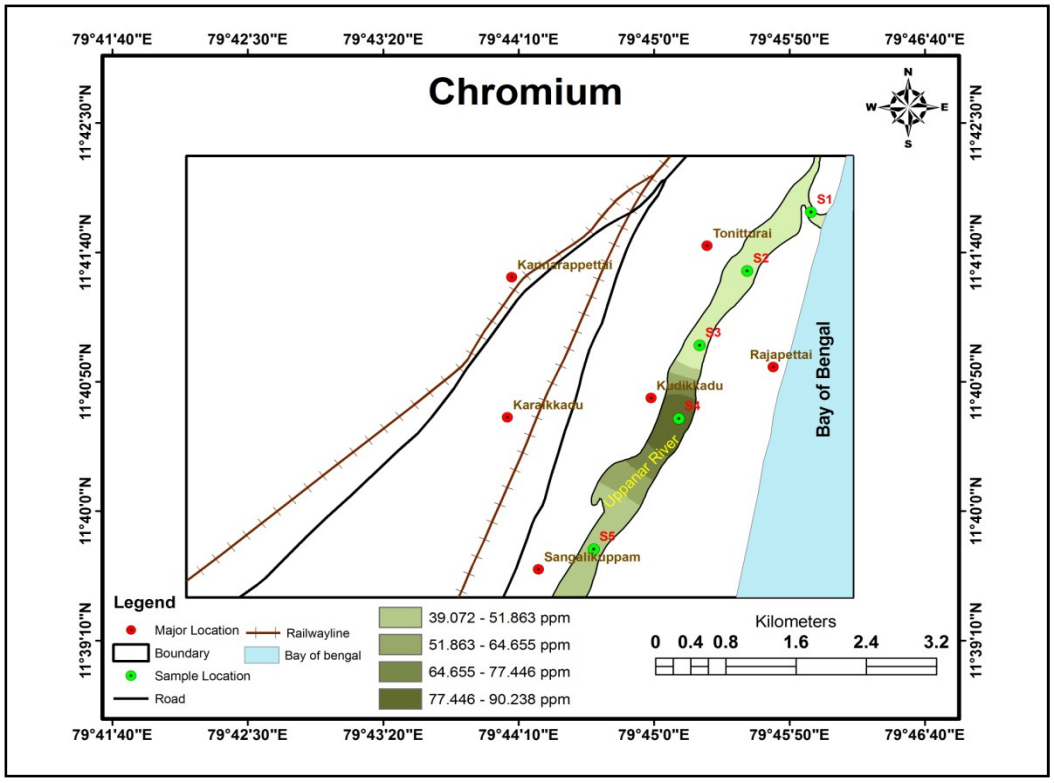

Figure-5
Concentration of Chromium at different location

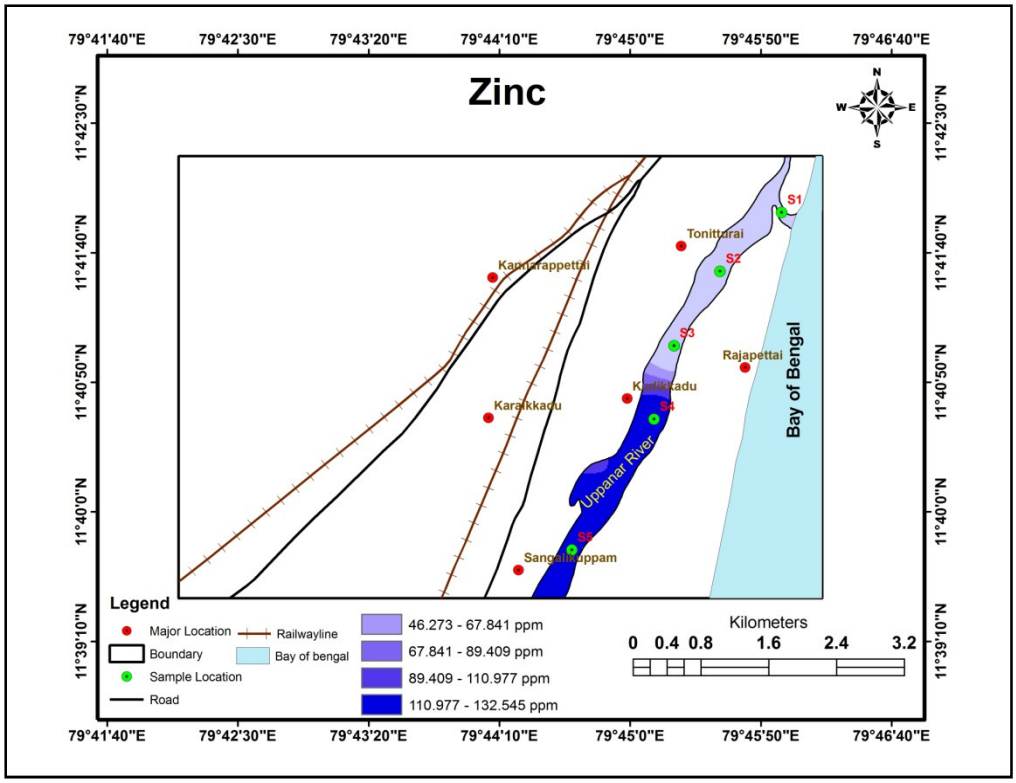

Figure-6
Concentration of Zinc at different location

Conclusion

The study has established that Cr, Ni, Cu, Pb, and Zn are present in the sediments of Uppanar River by the change degrees of concentration. It is assumed that the level of absorption that the contamination of above metals will continue to increase in River Uppanar. In the present study, all the metals are found in higher concentration in the upstream side of the river, where more industries are aligned along the river bank areas in SIPCOT. In this industrial area majority of the industrial wastage, agricultural waste and sewage waste, which are treated or untreated is discharged into the river, the water flow in this area is stagnant or flow of water will be fewer, which lead to contamination and spoil the ecosystem. Contamination of water by chemical elements has seriously affected the people's health because most of these heavy metals directly cause serious ailments.

Acknowledgment

The authors wish to thanks the authorities of Annamalai University for permitting us to work on this topic and also acknowledge the help for the analysis work done NGRI Hyderabad.

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