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Assessment of Heavy Metal Enrichment and the Degree of Contamination in Coastal Sediments of East Coast of Tamilnadu, India

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Abstract: The concentration of major and trace elements in coastal sediment samples collected from Pattipulam to Devanampattinam of East coast of Tamilnadu, India was determined using EDXRF technique. The concentration of Al, Ca, K, Fe, Ti, Mg, Mn, V, Cr, Zn, Ni and Co in sediment samples of different locations was reported. The mean concentration found to be: 1665 mg kg^{-1} for Mg; 21719 mg kg^{-1} for Al; 8405 mg kg^{-1} for K; 9284 mg kg^{-1} for Ca; 1520 mg kg^{-1} for Ti; 6554 mg kg^{-1} for Fe; 35.3 mg kg^{-1} for V; 30.1 mg kg^{-1} for Cr; 130.4 mg kg^{-1} for Mn; 2.3 mg kg^{-1} for Co; 20.2 mg kg^{-1} for Ni; 62.2 mg kg^{-1} for Zn, 6.2 mg kg^{-1} for As; 3.4 mg kg^{-1} for Cd; 404.9 mg kg^{-1} for Ba; 15.1 mg kg^{-1} for La; 12.1 mg kg^{-1} for Pb. The mean concentration of the elements is found to be decreased in the following order, Al > Ca > K> Fe >Mg >Ti> Ba >Mn > Zn > V> Cr > Ni > La > Pb > As > Cd > Co in the study area. The heavy metals pollution assessment of sediments are determined using pollution indices like contamination factor (CF) Contamination degree (Cd), Modified contamination degree (mCd) and potential contamination index (Cp). Values of CF indicate that the sediments were not contaminated with these elements. The potential contamination index (Cp) values of all heavy metals showed less than one indicates that sediments are low contamination except cadmium (Cd). This study reflects these pollution indices are efficient tool to assess the pollution status of sediments.

Keywords: Major and Trace elements, sediments, EDXRF, Pollution indices, degree of contamination.

1 Introduction

Pollution of the natural environment by metals is becoming a potential global problem. The pollution agents released into the environment cannot be always immediately observed. Maritime environments, unlike most terrestrial, permanently accumulate pollutants in the sediments and acute or long-term pollution can be easily detected by analyzing sediments with one of the various analytical methods available. In the work presented here, we used EDXRF as a very suitable technique for large area screening because it is fast, nondestructive and requires small quantity of a sample. Some other authors have also used Energy Dispersive X-ray Fluorescence (EDXRF) for sediment analysis [1-3]. The geochemical characteristics of the sediments can be used to infer the weathering trends and the sources of pollution [4-5].

Sediment pollution by heavy metals has been regarded as a critical problem in marine environment because of their toxicity and bioaccumulation [6,7]. Sediment quality has been recognized as an important indicator of water pollution [8]. Since sediments are the main sink for various pollutants, including metals discharged into the environment [9-11]. Sediments also play a significant role in the remobilization of contaminants in aquatic systems under favorable conditions and in interactions between water and sediment. Comprehensive methods for identifying and assessing the severity of sediment contamination have been introduced in order to protect the aquatic life community [12-16].
In this work, sediments have also been employed for the monitoring and assessment of metal pollution from Pattipulam to Devanampattinam of East coast of Tamilnadu, India. This coast is a densely populated area with variety of industrial activities (such as metal smelting, pharmaceuticals etc) and agriculture activities (which

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include maize, cassava, sugarcane and vegetables farming). All these activities release toxic and potentially toxic metals to the environment. This research therefore aims at assessing the influence and sources of these toxic and potentially toxic metals to the environment. This research therefore aims at assessing the influence and sources of these toxic and potentially toxic metals on the sediments from East Coast of Tamil Nadu.

This study is aim at assessing the level of heavy metal enrichment in the sediments as well as the contamination status. The main objectives of the current study are: (1) to determine concentrations of major and trace elements exist in the sediments from Pattipulam to Devanampattinam of East Coast of Tamil Nadu (2) assess the degree of contamination by heavy metals in sediments using pollution indices (3) determine the Contamination degree (Cd), Modified contamination degree (mCd) and potential contamination index (Cp) in coastal sediments. The metals considered of concern in the investigation are Pb, Zn, Cd, Ni, Cr, Ti and Fe.

2 Materials and Methods

2.1 Sampling and Sample Preparation

Sediment samples were collected along the Bay of Bengal coastline, from Pattipulam to Devanampattinam coast during pre-monsoon condition. These samples were collected pre-monsoon season, when sediment texture and ecological conditions can be clearly observed, when erosional activities are predominant, and sediments were not transported from the river and estuary towards the beach and marine. In order to ensure minimum disturbance of the upper layer, samples were collected by a Peterson grab sampler from 10 m water depths parallel to the shoreline. The grab sampler collects 10 cm thick bottom sediment layer from the seabed along the 22 stations (Fig.1). Sampling locations were selected to collect representative samples from all along the study area.

Table 1 represents the geographical latitude and longitude for the sampling locations at the study area. The sampling locations were selected based on the prevailing stresses and included areas near the urban and domestic effluent discharge point. Uniform quantity of sediment samples were collected from all the sampling stations located between an average interval of 3NM (Nautical mile). Each sample of about 2 kg was kept in a thick plastic bag. Care was taken to ensure that the collected sediments were not in contact with the metallic dredge of the sampler, and the top sediment layer was scooped with an acid washed plastic spatula. Sediment samples were stored in plastic bags and kept in refrigeration at -4ºC until analysis. Then pebbles, leaves and other foreign particles were removed. The samples were sub-sampled using the coning and quartering method.

The sub-samples were air-dried and larger stone fragments (>20mm largest diameter) or shells were removed. The samples were air dried at 105ºC for 24 h to a constant weight and were not separated <63 µm in order to identify the geochemical concentrations in the whole bulk fraction as the study area is dominated by sandy layers in many places. Then samples were ground into a fine powder for 10-15 min, using an agate mortar. All powder samples were stored in desiccators until they were analyzed.

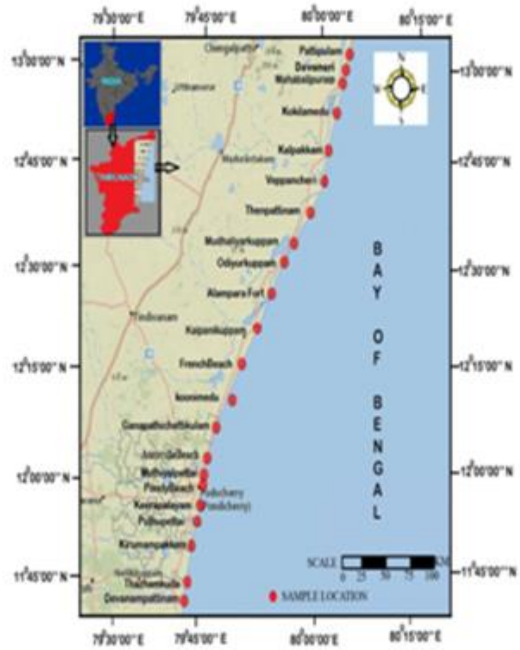

Fig.1. Location Map of collected sediment samples from the east coast of Tamil Nadu.

2.2 EDXRF Technique

The prepared pellets were analysed using the EDXRF (model EX-6600SDD supplied by Xenemetrix, Israel) available at Environmental and Safety Division, Indira Gandhi Centre for Atomic Research (IGCAR), Kalpakkam, Tamil Nadu. The spectrometer is fitted with a side window X-ray tube (370W) that has Rhodium as anode. The power specifications of the tube are 3-60kV; 10-5833µA. Selection of filters, tube voltage, sample position and current are fully customizable.

The detector Silicon Drift Diode 25mm^2 has an energy resolution of 136eV ± 5eV at 5.9keV Mn X-ray and 10-sample turret enables analysing 10 samples at a time. The quantitative analysis is carried out by the In-built software nEXT. A standard soil (NIST SRM 2709a) was used as reference material for standardizing the instrument. The soil standard reference values are given in Table 2. A typical EDXRF spectrum for sediment is shown in Fig. 2.

Table 1. Latitude and longitude of Locations

S.NO	Sample ID	ID	Latitude(N)	Longitude(E)	Location
1	PPM	MCS23	12°40'51.27"N	80°15'19.35"E	Pattipulam
2	DVN	MCS24	12°39'19.32"N	80°14'49.68"E	Devaneri
3	MAM	MCS25	12°37'55.53"N	80°14'13.14"E	Mahabalipuram
4	KKM	MCS26	12°34'56.33"N	80°13'22.37"E	Kokilamedu
5	KPM	MCS27	12°30'57.52"N	80°11'50.57"E	Kalpakkam
6	VPC	MCS28	12°27'58.97"N	80°11'16.29"E	Veppancheri
7	TPM	MCS29	12°24'42.28"N	80° 9'48.29"E	Thenpattinam
8	MKM	MCS30	12°21'26.51"N	80° 6'52.67"E	Mudaliyarkuppam
9	OKM	MCS31	12°19'35.89"N	80° 5'44.70"E	Odiyurkuppam
10	APT	MCS32	12°16'19.80"N	80° 3'16.00"E	Alampara fort
11	KPK	MCS33	12°12'42.65"N	80° 1'32.40"E	Kaipanikuppam
12	FBH	MCS34	12° 9'2.75"N	79°59'11.44"E	French beach
13	KMU	MCS35	12° 4'59.37"N	79°55'53.55"E	Koonimedu
14	GCM	MCS36	12° 2'45.84"N	79°56'46.86"E	Ganapathichettikulam
15	ABH	MCS37	11°59'51.98"N	79°55'31.39"E	Auroville beach
16	MPT	MCS38	11°57'43.22"N	79°52'42.65"E	Muthiyalpet
17	PBH	MCS39	11°56'38.16"N	79°52'17.45"E	Pondy beach
18	KEP	MCS40	11°54'23.61"N	79°51'49.37"E	Keerapalayam
19	PPT	MCS41	11°52'45.44"N	79°51'19.75"E	Puthupettai
20	KIP	MCS42	11°50'23.50"N	79°51'54.44"E	Kirumampakkam
21	TKA	MCS43	11°46'28.21"N	79°49'31.03"E	Thazhankuda
22	DPM	MCS44	11°44'41.37"N	79°49'23.01"E	Devanampattinam

Table 2: Results obtained from the analysis of soil standard-2709a reference sample using EDXRF (in mg kg^{-1}).

Element	Certified Values	EDXRF values
Mg	14600.0	14900.0
Al	72100.0	68400.0
K	20500.0	19100.0
Ca	19100.0	16500.0
Ti	3400.0	3100.0
Fe	33600.0	33900.0
V	110.0	98.8
Cr	130.0	112.1
Mn	529.0	568.2
Co	12.8	12.8
Ni	83.0	69.3
Zn	107.0	127.9

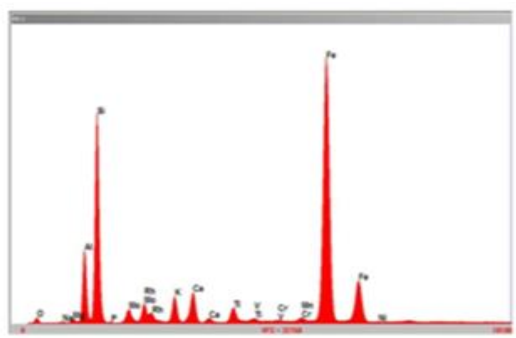

Fig. 2. Typical EDXRF spectrum of sediment sample.

3 Results and Discussions

3.1 Elemental Composition in Coastal Sediments

The concentration of elements in sediments from Pattipulam to Devanampattinam along the East Coast of Tamil Nadu, southeastern India is presented in Table 3. The concentration varies from 20 - 4200 mg kg^{-1} for Mg; 15800 - 27900 mg kg^{-1} for Al; 7200 - 9500 mg kg^{-1} for K; 5800 - 12500mg kg^{-1} for Ca; 376 - 9889 mg kg^{-1} for Ti; 3215 - 21836 mg kg^{-1} for Fe; 22.7 - 162.2 mg kg^{-1} for V; 19.2 - 61.9 mg kg^{-1} for Cr; 61.4 - 386.9 mg kg^{-1} for Mn;

Table 3: Elemental concentration (mg kg^{-1}) in coastal sediment of East coast, Tamil Nadu, India.

S. No	Location ID	Location	Mg	Al	K	Ca	Ti	Fe	V	Cr	Mn	Co	Ni	Zn	As	Cd	Ba	La	Pb
1	PPM	Pattipulam	500	21722	9200	8550	1043	5486	26.9	29.9	108.8	2.1	18	66	6.2	4.9	422.9	9.9	12.9
2	DVN	Devaneri	2600	27900	8900	11000	9889	21836	162.2	61.9	386.9	7.1	20.3	58.7	7	3.2	362.8	123	14
3	MAM	Mahabalipuram	900	21800	8300	9800	2122	9138	45.8	31.6	178.3	3.3	18.7	34.1	5.8	0	435.8	10.2	6.1
4	KKM	Kokilamedu	1500	24000	9300	10500	1911	7557	35.6	26.3	156.5	2.7	18.1	27.9	5.6	4.7	485.2	21.8	6.1
5	KPM	Kalpakkam	900	22600	9300	9500	1352	6396	30.5	28	120.5	2.1	18.6	36.2	5.7	3.9	434.4	20.4	10
6	VPC	Veppancheri	2500	24900	9000	9800	1614	7355	34.2	29.4	138.5	2.7	20	36.5	5.3	7.5	453.8	18.1	8.9
7	TPM	Thenpattinam	4200	23700	8700	10800	1543	7423	35.6	38.6	153.5	2.8	24	120.3	8.4	2.6	434.6	18.7	25.8
8	MKM	Mudaliyarkuppam	20	17700	7200	7000	779	3945	23.8	21.7	88.9	1.4	19.7	50.1	5.5	0	302.9	7.5	7
9	OKM	Odiyurkuppam	200	18300	8100	8100	661	4036	24	21.4	81.6	1.4	16.6	22.7	4.9	2.7	421.5	0	3.8
10	APT	Alampara fort	2400	23200	8600	10400	859	5513	28	23.6	113.2	2.1	20.6	44.2	5.5	4.6	436	2.4	7.3
11	KPK	Kaipanikuppam	600	17800	7400	6400	614	3532	23.2	19.2	77.2	1.2	16.3	34.9	4.7	5.2	348.9	6	2.3
12	FBH	French beach	2600	20200	7300	8500	1242	6283	29.5	27.8	136.5	2.3	19.3	34.9	4.7	7.1	335.4	4.8	4.5
13	KMU	Koonimedu	2500	21800	7900	9400	1089	5694	28.2	32.3	123.9	2.1	21.8	121.9	8.3	0.2	337.1	1.1	24.7
14	GCM	Ganapathichettikulam	1600	19900	7800	8100	845	4509	24.7	29.3	95.9	1.6	21.5	116.8	7.2	0	373.2	15.5	22.5
15	ABH	Auroville beach	1500	21700	9100	10400	1027	5431	26.1	26.7	109.2	2	18.3	44.2	5.6	4.8	426.8	12.7	7.5
16	MPT	Muthiyalpet	1600	21500	8900	9300	942	4866	25.3	24.6	103.1	1.7	24.3	66.3	6.7	0	402.5	6.9	14
17	PBH	Pondy beach	1300	22600	9300	9600	772	4649	24.9	25.9	95.1	1.8	25.8	83.8	6.7	2.5	442.4	10.8	18.6
18	KEP	Keerapalayam	1800	26100	9500	12500	753	5303	26.6	26.3	115.8	2	22.8	87.6	7	13.7	433.4	2.6	16.4
19	PPT	Puthupettai	1800	20000	8000	8400	945	5433	27.3	30.7	102	2.1	19.1	65.9	6.3	0	450.4	13.2	14.2
20	KIP	Kirumampakkam	2500	23100	7700	10700	1632	8982	36.9	40.7	184	3.3	21.4	53.8	5.5	3.7	373.9	2.4	9.6
21	TKA	Thazhankuda	1900	15800	7600	5800	376	3215	22.7	19.8	61.4	1.1	17.9	91.1	6.7	2.5	393.2	3	18.7
22	DPM	Dhevanampattinam	1200	21500	7800	9700	1422	7604	35	45.6	138.3	2.9	22.1	70.3	6.3	1.5	401.6	20.2	11.7
Average			1665	21719	8405	9284	1520	6554	35.3	30.1	130.4	2.4	20.2	62.2	6.2	3.4	404.9	15.1	12.1
Minimum			**20**	**15800**	**7200**	**5800**	**376**	**3215**	**22.7**	**19.2**	**61.4**	**1.1**	**16.3**	**22.7**	**4.7**	**0.2**	**302.9**	**1.1**	**2.3**
Maximum			**4200**	**27900**	**9500**	**12500**	**9889**	**21836**	**162.2**	**61.9**	**386.9**	**7.1**	**25.8**	**121.9**	**8.4**	**13.7**	**485.2**	**123**	**25.8**
Crustal Average (Turekian and Wedepohl, 1961)			**15000**	**80000**	**26600**	**22100**	**4600**	**47200**	**130**	**90**	**850**	**19**	**68**	**95**	**13**	**0.3**	**580**	**92**	**20**

1.1 - 7.1 mg kg^{-1} for Co; 16.3 - 25.8 mg kg^{-1} for Ni; 22.7 - 121.9 mg kg^{-1} for Zn; 4.7 - 8.4 mg kg^{-1} for As; 0.2 - 13.7 mg kg^{-1} for Cd; 302.9 - 485.2 mg kg^{-1} for Ba; 1.1 - 123 mg kg^{-1} for La and from 2.3 -25.8 mg kg^{-1} for Pb. Among the heavy metals detected, Aluminum (Al) is the most abundant metal in the sediments. The mean of metal concentration decreased in the following order, Al> Ca > K> Fe >Mg >Ti> Ba >Mn > Zn > V> Cr > Ni > La > Pb > As > Cd > Co in the study area [17, 18]. The location of Devaneri (DVN) is characterized by higher concentrations of Al, Ti, Fe, V, Cr, Mn, Co and La when compared with other locations. This may be due to the high tourists' boat activities and other anthropogenic activities like shipping and harbour activities, industrial and urban wastage discharges, dredging, etc.,

3.2 Contaminant Factor (CF)

Contaminant factor (Cf) is the ratio obtained by dividing the concentration of each metal in the sediment by the background value [19]. CF is considered to be an effective tool in monitoring the pollution over a period of time and is given by the formula,

$$CF = \frac{C_{heavymetal}}{C_{background}} --------- (1)$$

Contamination; and Cf > 6 is very high contamination. The Contaminant Factor in sediments from Pattipulam to Devanampattinam along the East Coast of Tamil Nadu, southeastern India is presented in Table 4.

The results of CFs are 0.001 to 0.280 (average 0.111) for Mg, 0.198 to 0.349 (average 0.271) for Al, 0.271 to 0.357 (average 0.316) for K, 0.262 to 0.566 (average 0.420) for Ca, 0.082 to 2.150 (average 0.330) for Ti, 0.068 to 0.463 (average 0.138) for Fe, 0.175 to 1.248 (average 0.272) for V, 0.213 to 0.688 (average 0.334) for Cr, 0.072 to 0.455 (average 0.153) for Mn, 0.058 to 0.374 (average 0.123) for Co, 0.240 to 0.379 (average 0.297) for Ni, 0.239 to 1.283 (average 0.654) for Zn, 0.362 to 0.646 (average 0.474) for As , 0.667 to 45.667 (average 11.409) for Cd , 0.522 to 0.837 (average 0.698) for Ba, 0.012 to 1.337 (average 0.164) for La and 0.115 to 1.290 (average 0.606) for Pb respectively. Values of CF for all samples are less than 1 except Cadmium. The results indicating that sediments were low contaminated with these elements. Figure 3 shows variation contamination factor with locations.

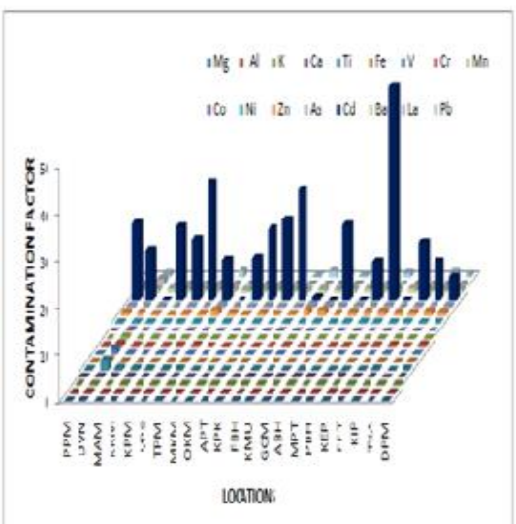

Fig.3. Contamination factor values in sediment sample of the east coast of Tamil Nadu. , India.

3.3 Contamination Degree (Cd)

To facilitate pollution control, Hakanson (1980) [20] proposed a sedimentlogical approach using a diagnostic tool named the 'degree of contamination'. Cd was determined as the sum of the Cf for each sample:

$$Cd = \sum_{i=1}^{i=n} Cf ---------------- (2)$$

For contamination degree, Hakanson (1980) [20] proposed this classification: Cd<6 indicate a low degree of contamination; 6<Cd<12 is a moderate degree of contamination; 12<Cd<24 is a considerable degree of contamination; and Cd > 24 is a high degree of contamination, indicating serious anthropogenic pollution. The contamination degree values are reported in Table 4.

The calculated Contamination degree value of 2.441 for Mg; 5.973 for Al; 6.951 for K; 9.242 for Ca; 7.268 for Ti; 3.055 for Fe; 5.977 for V; 7.348 for Cr; 3.375 for Mn; 2.726 for Co; 6.547for Ni, 14.402 for Zn, 10.431 for As, 251 for Cd, 15.36 for Ba, 3.60 for La and 13.33 for Pb. The obtained Contamination degree value for the elements Mg, Al, Fe, V, Mn, Co and La shows the low degree of contamination. K, Ca, Ti, Cr, Ni and As shows the moderate degree of contamination whereas Cd, Zn exhibited high degree of contamination from its value of 251. This may be due to recent increase in major industrial (in the coastal areas) and a minor harbor activity that involves movement of naval vessels throughout the year may increase the contamination levels in coastal areas. Figure 4 shows variation contamination degree with locations.

3.4 Modified Degree of Contamination

The modified degree of contamination was introduced to estimate the overall degree of contamination at a given site according to the formula [21-23]

$$mCd = \frac{\sum_{i=1}^{i=n}}{n} Cf ----------- (3)$$

Table 4 shows the modified degree of contamination (mCd) of sediment samples of east coast of Tamil Nadu, India. The calculated modified degree of contamination value 0.144 for Mg; 0.351 for Al; 0.409 for K; 0.544 for Ca; 0.428 for Ti; 0.180 for Fe; 0.352 for V; 0.432 for Cr; 0.199 for Mn; 0.160 for Co; 0.385 for Ni, 0.847 for Zn, 0.614 for As, 14.765 for Cd, 0.904 for Ba, 0.212 for La and 0.784 for Pb. From obtained values of modified degree of contamination of Mg, Fe, Mn, Co, La registered very low degree of contamination. Mg noticed low degree of contamination from its value of 0.144 whereas Cd Table 4 shows the modified degree of contamination (mCd) of sediment samples of east coast of Tamil Nadu, India. The calculated modified degree of contamination value 0.144 for Mg; 0.351 for Al; 0.409 for K; 0.544 for Ca; 0.428 for Ti; 0.180 for Fe; 0.352 for V; 0.432 for Cr; 0.199 for Mn; 0.160 for Co; 0.385 for Ni, 0.847 for Zn, 0.614 for As, 14.765 for Cd, 0.904 for Ba, 0.212 for La and 0.784 for Pb. From obtained values of modified degree of contamination of Mg, Fe, Mn, Co, La registered very low degree of contamination. Mg noticed low degree of contamination from its value of 0.144 whereas Cd showed high degree of contamination of its value 14.765.

Table 4: Contamination factor (Cf), Contamination Degree (Cd) and Modified Degree of Contamination (mCd) and Potential contamination index (Cp) of sediment samples of east coast of Tamil Nadu, India.

. No	Location ID	Location	Mg	Al	K	Ca	Ti	Fe	V	Cr	Mn	Co	Ni	Zn	As	Cd	Ba	La	Pb
1	PPM	Pattipulam	0.033	0.272	0.346	0.387	0.227	0.116	0.207	0.332	0.128	0.111	0.265	0.695	0.477	16.333	0.729	0.108	0.645
2	DVN	Devaneri	0.173	0.349	0.335	0.498	2.15	0.463	1.248	0.688	0.455	0.374	0.299	0.618	0.538	10.667	0.626	1.337	0.7
3	MAM	Mahabalipuram	0.06	0.273	0.312	0.443	0.461	0.194	0.352	0.351	0.21	0.174	0.275	0.359	0.446	0	0.751	0.111	0.305
4	KKM	Kokilamedu	0.1	0.3	0.35	0.475	0.415	0.16	0.274	0.292	0.184	0.142	0.266	0.294	0.431	15.667	0.837	0.237	0.305
5	KPM	Kalpakkam	0.06	0.283	0.35	0.43	0.294	0.136	0.235	0.311	0.142	0.111	0.274	0.381	0.438	13	0.749	0.222	0.5
6	VPC	Veppancheri	0.167	0.311	0.338	0.443	0.351	0.156	0.263	0.327	0.163	0.142	0.294	0.384	0.408	25	0.782	0.197	0.445
7	TPM	Thenpattinam	0.28	0.296	0.327	0.489	0.335	0.157	0.274	0.429	0.181	0.147	0.353	1.266	0.646	8.667	0.749	0.203	1.29
8	MKM	Mudaliyarkuppam	0.001	0.221	0.271	0.317	0.169	0.084	0.183	0.241	0.105	0.074	0.29	0.527	0.423	0	0.522	0.082	0.35
9	OKM	Odiyurkuppam	0.013	0.229	0.305	0.367	0.144	0.086	0.185	0.238	0.096	0.074	0.244	0.239	0.377	9	0.727	0	0.19
10	APT	Alampara fort	0.16	0.29	0.323	0.471	0.187	0.117	0.215	0.262	0.133	0.111	0.303	0.465	0.423	15.333	0.752	0.026	0.365
11	KPK	Kaipanikuppam	0.04	0.223	0.278	0.29	0.133	0.075	0.178	0.213	0.091	0.063	0.24	0.367	0.362	17.333	0.602	0.065	0.115
12	FBH	French beach	0.173	0.253	0.274	0.385	0.27	0.133	0.227	0.309	0.161	0.121	0.284	0.367	0.362	23.667	0.578	0.052	0.225
13	KMU	Koonimedu	0.167	0.273	0.297	0.425	0.237	0.121	0.217	0.359	0.146	0.111	0.321	1.283	0.638	0.667	0.581	0.012	1.235
14	GCM	Ganapathichettikulam	0.107	0.249	0.293	0.367	0.184	0.096	0.19	0.326	0.113	0.084	0.316	1.229	0.554	0	0.643	0.168	1.125
15	ABH	Auroville beach	0.1	0.271	0.342	0.471	0.223	0.115	0.201	0.297	0.128	0.105	0.269	0.465	0.431	16	0.736	0.138	0.375
16	MPT	Muthiyalpet	0.107	0.269	0.335	0.421	0.205	0.103	0.195	0.273	0.121	0.089	0.357	0.698	0.515	0	0.694	0.075	0.7
17	PBH	Pondy beach	0.087	0.283	0.35	0.434	0.168	0.098	0.192	0.288	0.112	0.095	0.379	0.882	0.515	8.333	0.763	0.117	0.93
18	KEP	Keerapalayam	0.12	0.326	0.357	0.566	0.164	0.112	0.205	0.292	0.136	0.105	0.335	0.922	0.538	45.667	0.747	0.028	0.82
19	PPT	Puthupettai	0.12	0.25	0.301	0.38	0.205	0.115	0.21	0.341	0.12	0.111	0.281	0.694	0.485	-	0.777	0.143	0.71
20	KIP	Kirumampakkam	0.167	0.289	0.289	0.484	0.355	0.19	0.284	0.452	0.216	0.174	0.315	0.566	0.423	12.333	0.645	0.026	0.48
21	TKA	Thazhankuda	0.127	0.198	0.286	0.262	0.082	0.068	0.175	0.22	0.072	0.058	0.263	0.959	0.515	8.333	0.678	0.033	0.935
22	DPM	Dhevanampattinam	0.08	0.269	0.293	0.439	0.309	0.161	0.269	0.507	0.163	0.153	0.325	0.74	0.485	5	0.692	0.22	0.585
Average			**0.111**	**0.271**	**0.316**	**0.42**	**0.3304**	**0.1389**	**0.272**	**0.334**	**0.1534**	**0.1239**	**0.2976**	**0.6546**	**0.474**	**11.409**	**0.698**	**0.164**	**0.606**
Minimum			**0.001**	**0.198**	**0.271**	**0.262**	**0.082**	**0.068**	**0.175**	**0.213**	**0.072**	**0.058**	**0.24**	**0.239**	**0.362**	**0.667**	**0.522**	**0.012**	**0.115**
Maximum			**0.28**	**0.349**	**0.357**	**0.566**	**2.15**	**0.463**	**1.248**	**0.688**	**0.455**	**0.374**	**0.379**	**1.283**	**0.646**	**45.667**	**0.837**	**1.337**	**1.29**
Contamination Degree			2.441	5.973	6.951	9.242	7.268	3.055	5.977	7.348	3.375	2.726	6.547	14.402	10.431	251	15.36	3.6	13.33
Modified Degree of Contamination			0.144	0.351	0.409	0.544	0.428	0.18	0.352	0.432	0.199	0.16	0.385	0.847	0.614	14.765	0.904	0.212	0.784
Potential Contamination Index			0.281	0.349	0.357	0.566	2.15	0.463	1.248	0.688	0.455	0.374	0.379	1.283	0.646	45.667	0.837	1.337	1.29

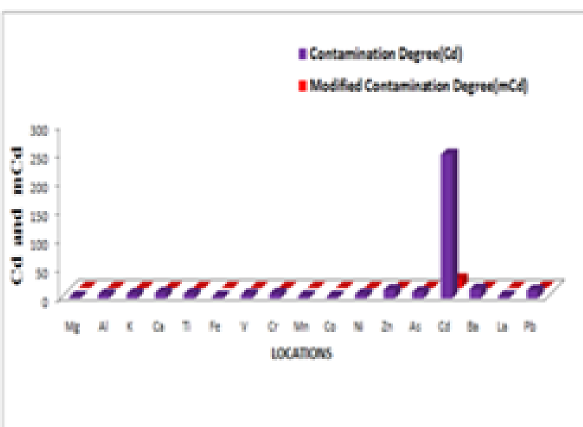

Fig . 4. Shows variation Modified degree of Contamination with locations.

3.5 Potential Contamination Index (Cp)

The potential contamination index can be calculated by the following method [20]

$$C_p = \frac{(\mathrm{Metal})_{\mathrm{sample\ maxmium}}}{(\mathrm{Metal})_{\mathrm{Background}}} \text{ ------- } (4)$$

Where $(\mathrm{Metal})_{\mathrm{Sample\ maximum}}$ is the maximum concentration of a metal in sediment, and $(\mathrm{Metal})_{\mathrm{Background}}$ is the average value of the same metal in a background level. The calculated potential contamination index values of heavy metals given in Table 4.

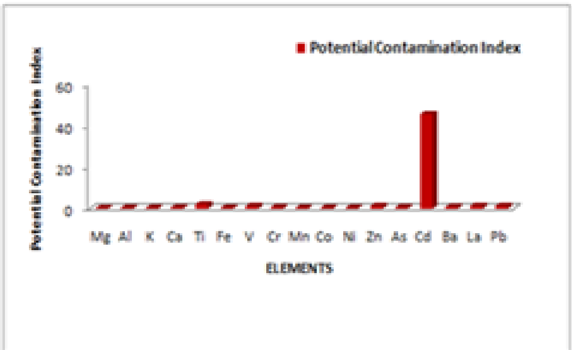

Fig. 5. Potential Contamination index of heavy metals in locations.

The Cp values of heavy metals shows, value of Mg, Al, K, Ca, Fe, Cr, Co, Mn, As, Ba and Ni shows the <1 indicates that low contamination whereas Ti, V, Zn, La and Pb lies between 1 and 3 indicates moderate contamination of sediments. The Cp values of Cadmium(Cd) shows the sediments are severely contaminated due to anthropogenic activities in the coastal area. Figure 5 shows variation potential contamination index with locations.

4 Conclusions

The concentration of major and trace elements has been determined in coastal sediments using EDXRF technique. The low heavy metal content in sediments indicates that sediments are not polluted. The CF values of the studied heavy metals indicating low contamination in sediments whereas some locations of Thenpattinam (TPM), Koonimedu (KMU), Ganapathichettikulam (GCM) showed moderate contamination due to anthropogenic inputs. The potential contamination index (Cp) noticed that sediments are low contamination except Cd. From obtained values of modified degree of contamination (mCd) of Mg, Fe, Mn, Co, La registered very low degree of contamination. The results indicating that the study area is not much polluted by heavy metals. This work represents the current status of sediment quality from Pattipulam to Dhevanampattinam along the East Coast of Tamil Nadu, India that will be very useful tool to authorities in charge of sustainable estuarine and coastal zone management.

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