Assessment of Heavy Metal Contamination in the Sediments of Ithikkara River, Southern Kerala

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Abstract

The study was conducted to investigate the heavy metal pollution in the sediments of Ithikkara River, Southern Kerala. Results showed that the concentration of Iron, Cadmium, Copper, Zinc and Lead varies from below detectable level (BDL) to 0.429 µg g^{-1}. It was observed that iron concentration shows much highest compared to other heavy metals. The results of the degree of contamination indicating that all the stations are having low contamination factor. Considering the mean I_{geo} values, the sediments are enriched for metals in the following order, Zn>Cu>Pb>Fe>Cd and results showing unpolluted situations in all the stations with respect to different seasons. Pollution load index values of all the stations are less than one. The results of the statistical analyses revealed that the total concentrations of the trace metals analyzed are lower than that of average shale values. The results of CF, I_{geo} and PLI indicated that the river is under the class of zero contamination.

Key words

Contamination factor, Heavy metals, I_{geo} values, Pollution, Pollution load index, Sediments, Zero contamination.

1. Introduction

Sediments are both potential sources and carriers of natural geochemical constituents and are derived principally from weathering of rocks. The rivers are excellent carriers of geochemical signals from land to the ocean. Human activities in a river basin are often responsible for accelerated erosion of sediments that can be transported to a river during rainy periods or floods. The sediments had a specific role in the cycling and transportation of nutrients and contaminants and preservation of water quality makes the ecosystem lively. Heavy metal pollution in aquatic ecosystems is a worldwide environmental problem that has received increasing attention over the last few decades because of their environmental persistence, toxicity and ability to be incorporated into food chains[6].

Heavy metals are significantly hazardous pollutants in aquatic environments even at very low concentrations[18]. As trace elements, some heavy metals such as copper, selenium and zinc are essential to maintain the metabolism of organisms. However, at higher concentrations they can lead to poisoning because they cannot be degraded or destroyed and shows persistent toxic effects[9]. The metal load of a riverine system is regulated by factors such as basin physiography, geology, lithology, hydrology, land use pattern, pollution and biological productivity[7]. Through natural and anthropogenic sources these metals are the most common environmental pollutants occurrence in water. Land runoff, mining activities and anthropogenic inputs usually causes metal accumulation in river environments. The contamination of heavy metals, especially in sediments, has become one of the most challenging pollution issues owing to the toxicity, abundance, persistence, and subsequent bio-accumulation of these materials[3].

Considering the importance of sediments in elemental cycling, the present study has been aims to evaluate the status of various heavy metal contamination in the sediments of Ithikkara River. The heavy metals like Iron (Fe), Cadmium (Cd), Copper (Cu), Zinc (Zn) and Lead (Pb), were analyzed to find out their impact on the river system.

2. Materials and Methods

2.1 Study Area

Ithikkara River is one of the important river of Kerala State falls mainly in Kollam district and a small portion of the basin area falls in Thiruvananthapuram district. The river lies between North latitudes 8°47′ – 9°0′ 56″ and East longitudes 76°34′27″ – 77°2′25″ with catchment area of ~642 km^2. The river is bounded by Kallada river basin in the north and Ayirror and Vamanapuram river basin in the south. The river originating from the Madatharaikunnu of Western Ghats mountain ranges and flows for a length of 56 km before debouching in to the Paravur lake which merges finally with Arabian Sea near Pozhikkara, Paravur. The river generally exhibits a dendritic drainage pattern. The slope of the basin area is generally leveled surface to moderately steeply sloping[8]. Geologically the basin area consists metamorphic rocks of khondalitic group which include garnetiferous biotite gneiss, garnet biotite gneiss of magmatic complex leptynites or garnetiferous quartzo feldspathic gneiss, charnockite gneiss, pyroxene granulite and calc-granulite[8]. The soil in Ithikkara River basin varies with respect to drainage, texture, depth and degree of erosion etc.

2.2 Sample collection

Six stations were selected for the present study. Station 1 (S1) Mannur (highland portion of Ithikkara River) having an elevation of 78 m, Station 2 (S2) Vellaramkulam lies at an elevation of 70 m; Station 3 (S3) Ayur at an elevation of 50 m; Station 4 (S4) Velinelloor at an elevation of 38 m; Station 5 (S5) Ithikkara at an elevation of 20 m and Station 6 (S6) Perumpuzha is the downstream region of the river. The samples were collected from February 2010 to January 2011 from the Ithikkara River using a Van Veen grab of size 45 cm^2 for the analysis of different parameters. The samples were stored in polythene covers until further processing. The sediment was extracted using acid mixture of nitric acid and perchloric acid. After digestion the solutions were diluted by deionized water. The samples were analysed using a double beam atomic absorption spectrophotometer (GBC, model- 932).

2.3 Statistical Evaluation

Statistical tools like Contamination Factor (CF), Pollution Load Index (PLI) and Geo-accumulation Index (Igeo) are used to document and or compare the levels of contamination or pollution caused by heavy metals in the aquatic environment[17].

3. Results

Heavy metals are elements having relative density 5 gm/cm^3 and have the ability to accumulate within compartments[1]. Sediment acts as a sink for heavy metals and they play a vital role in changing the environmental matrix of the system. Table 1 shows the monthly and annual distributions of heavy metal concentrations in the Ithikkara River during the study period.

Iron (Fe)

The distribution of Fe in the sediments of Ithikkara River varied between 0.023 and 0.429 µg g^{-1} with an annual average concentration of 0.199 µg g^{-1}. Among the stations, the highest and lowest concentration of Fe was reported for station 6 (0.429 µg g^{-1}) during November 2010 and station 1 (0.023 µg g^{-1}) in July 2010. During premonsoon, monsoon and postmonsoon seasons the respective ranges are 0.058 to 0.397 µg g^{-1} (Av. 0.218 µg g^{-1}), 0.023 to 0.380 µg g^{-1} (Av. 0.165 µg g^{-1}) and 0.050 to 0.429 µg g^{-1} (Av. 0.215 µg g^{-1}). The pattern of distribution of iron in the river sediment was maximum in premonsoon season followed by postmonsoon and monsoon seasons.

Cadmium (Cd)

In the sediment of Ithikkara River the cadmium concentration varies between below detectable level (BDL) to 0.102 µg g^{-1} with average annual concentration of 0.017 µg g^{-1}. Considering the stations, the highest value was observed at station 6 during May 2010 and below detectable level was reported at stations such as 1, 2 and 3. During premonsoon, monsoon and postmonsoon seasons the ranges of cadmium in the river sediments are BDL to 0.102 µg g^{-1} (Av. 0.021 µg g^{-1}), BDL to 0.032 µg g^{-1} (Av. 0.007 µg g^{-1}) and BDL to 0.070 µg g^{-1} (0.021 µg g^{-1}), respectively. Considering the seasonal averages, the highest value was reported for both premonsoon and postmonsoon seasons with 0.021 µg g^{-1} followed by monsoon season.

Copper (Cu)

The levels of copper in the sediments ranged from 0.001 to 0.096μg g^{-1} with an annual average distribution of 0.041 μg g^{-1}. The highest value was observed at station 6 during December 2010 and the lowest value was reported at station 2 during June 2010. The ranges of Cu during premonsoon, monsoon and postmonsoon seasons are 0.006 to 0.091 μg g^{-1} (Av. 0.048 μg g^{-1}), 0.001 to 0.077 μg g^{-1} (Av. 0.033 μg g^{-1}) and 0.007 to 0.096 μg g^{-1} (Av. 0.048 μg g^{-1}), respectively. Among the seasons high seasonal average was reported in premonsoon and postmonsoon seasons followed by monsoon season.

Zinc (Zn)

The concentration of Zn was ranged from 0.009 μg g^{-1} and 0.108 μg g^{-1} with an annual average concentration of 0.05 μg g^{-1}. The highest concentration of zinc was observed at station 5 during October 2010 and lowest value was reported at station 1 during December 2010. The ranges of zinc during premonsoon, monsoon and postmonsoon seasons are 0.018 to 0.099 μg g^{-1} (Av. 0.055 μg g^{-1}), 0.011 to 0.079 μg g^{-1} (Av. 0.040 μg g^{-1}) and 0.009 to 0.108 μg g^{-1} (Av. 0.053 μg g^{-1}), respectively. The seasonal averages show its maximum during premonsoon season followed by postmonsoon and monsoon seasons.

Lead (Pb)

The lead concentration in the sediment of Ithikkara River ranged between below detectable level to 0.097 μg g^{-1} with an annual average concentration of 0.028 μg g^{-1}. A highest concentration of 0.097 μg g^{-1} was reported at station 5 during April 2010 and below detectable level was reported at stations 1 and 2. The range of lead during premonsoon, monsoon and postmonsoon seasons are 0.001 to 0.097 μg g^{-1} (Av. 0.041 μg g^{-1}), BDL to 0.042 μg g^{-1} (Av. 0.014 μg g^{-1}) and BDL to 0.072 μg g^{-1} (Av. 0.029 μg g^{-1}), respectively. Among the three different seasons, the highest seasonal average was reported for premonsoon season followed by postmonsoon and monsoon seasons.

Contamination Factor (CF) and Degree of Contamination (Cd)

CF values indicate the enrichment of metals in the sediment. The results of the contamination factor and degree of contamination values for the selected elements in the sediments of Ithikkara River are given in Table 2.

The CF factor of the elements Fe, Cd, Cu, Zn and Pb are ranged from 0.020 to 0.071 (Av. 0.040), BDL to 0.267 (Av. 0.084), 0.0002 to 0.0020 (Av. 0.0009), 0.0001 to 0.0010 (Av. 0.0004) and 0.0006 to 0.0046 (Av, 0.0019), respectively. Among the seasons premonsoon shows highest CF values for all the elements followed by postmonsoon and monsoon seasons. Considering the degree of contamination, the highest degree of contamination was reported at station 3 (0.33) and lowest at station 1 (0.022).

Geo-accumulation Index (I_{geo})

Geo-accumulation index (I_{geo}) is a most commonly used criterion for the quantification of heavy metal pollution in aquatic sediments. The range of I_{geo} values for Fe, Cd, Cu, Zn and Pb are

-0.227 to -0.161 (Av. -0.190), -0.401 to -0.166 (Av. -0.246), -0.105 to -0.078 (Av. -0.092), -0.096 to -0.077 (Av. -0.086) and -0.120 to -0.089 (Av. -0.101), respectively. Table 3 gives the obtained Geoaccumulation index (I_{geo}) values of Ithikkara River.

Pollution Load Index (PLI)

Pollution load index (PLI) is used to assess the extent of pollution by trace metals. The pollution load index calculated for the sediments of Ithikkara River is given in Table 4. The PLI values of sediment ranged from 0.0008 to 0.0065 (Av. 0.0031). Considering the seasonal load it were ranged from 0.0017 to 0.0065 (Av. 0.0035), 0.0017 to 0.0032 (Av. 0.0025) and 0.0008 to 0.0046 (Av. 0.0033), respectively for premonsoon, monsoon and postmonsoon seasons.

4. Discussion

The concentration of Fe in the sediment of Ithikkara River shows fluctuating results with respect to stations and seasons. Human induced disturbances like agricultural practices, land clearing, soil quarrying, clay and sand mining activities contribute considerable amount of iron rich particulate sediments to the fluvial system. Similar reports were also made by Osakwe et al., (2014) in Imo River System, Southeastern Nigeria and Shanbehzadeh et al., (2014) in Tembi River. According to Montalvo et al., (2014) cadmium is not an essential metal and its occurrence in sediments is mainly by human activities. As a hazardous heavy metal like mercury, cadmium is not essential for plants and animals and its presence in the environment only causes harm and no gain (Sobha et al., 2009). The analytical result of cadmium in the sediment of Ithikkara River showed low concentrations throughout the study period. Similarly low level of Cd was reported by Osakwe et al., (2014) in Imo River System. In the present study, high values of copper were reported in the regions where sewage and other domestic waste discharge are severe. Generally the distribution of Cu shows an increasing trend towards the downstream. This may be due to the pollutants which were transported by river flow and finally accumulate near the river mouth. Similar result was observed by Chen et al., (2012). The concentration of copper in various aquatic environments was also reported by Mane et al., (2013) in Sudha Dam of Bhokar and Nimisha and Sheeba (2013) in Periyar River.

Zinc can enter the aquatic environment from a number of sources including industrial discharges, sewage effluent and runoff (Boxall et al., 2000). In Ithikkara River the concentration of zinc varies with respect to various anthropogenic activities which were the key sources contributing the enrichment of Zn in the sediment. The station have high Zn content is may be due to the accumulation of terrigenous materials coming through the drainage and also due to washing and bathing using detergents. Similar findings were reported by Marathe et al., (2011) in Tapti River. In Ithikkara River, the concentration of Pb shows some significant seasonal variations. It shows an increasing trend from upstream stations to downstream. The concentration of Pb varies where the urban waste discharges is severe. In non-monsoon seasons the concentration of lead is comparatively high in all the stations. Similar observations were reported by Aji (2005) in Pamba River.

The results of contamination factor indicating that all the stations are having low contamination factor. The station (S3) having highest degree of contamination is an indication of serious anthropogenic pollution activities and in near future it can cause potential pollution risk.

Similar results have also been reported in Hindon River by Suthar et al., (2009). The result of the I_{geo} values for Ithikkara River sediments indicate that all the metals at all the stations during different seasons falls well below the geoaccumulation grade value zero. Considering the mean I_{geo} values, the sediments are enriched for metals in the following order: Zn>Cu>Pb>Fe>Cd and these are showing unpolluted nature of all the stations with respect to different seasons. So on the basis of geoaccumulation indices, the Ithikkara River sediments may be considered as unpolluted. Similar findings were reported by Manoj et al., (2012) in Subarnarekha River. Pollution load index (PLI) is used to assess the extent of pollution by trace metals (Mohiuddin et al., 2010). Among the seasons the comparatively highest PLI was reported during premonsoon followed by postmonsoon and monsoon seasons. Similar result was observed by Manoj et al., (2012) in Subarnarekha River. From the results, it is clear that in all the stations, the values are less than one ie. in uncontaminated stage. At present the river is in uncontaminated stage but is showing the sign of to be contaminated in near future if not properly managed these resources.

5. Conclusion

The results showed that the concentration of Iron, Cadmium, Copper, Zinc and Lead varies from below detectable level (BDL) to 0.429 µg g^{-1}. It was observed that iron concentration shows much highest concentration compared to other heavy metals. The statistical analysis revealed that the total concentrations of the trace metals analyzed are lower than that of average shale values. The result of CF, I_{geo} and PLI indicate that the river is under the class of zero contamination. The comparatively high values reported in the river environment are mainly attributed through the deposition of organic rich wastes from municipal sewage in to the river. During the study period the Ithikkara River is not in a stage of heavy metal contamination but it has the symptoms to be polluted in nearby future. So, there should be strict regulations and continuous monitoring are necessary to control various anthropogenic activities that takes part with in the river or in its catchment area. On the light of the observed results it is recommended that continuous monitoring and further studies are to be carried out in the river system to ascertain long-term effects of anthropogenic impacts and to effectively control and minimize the human activity towards this pristine natural ecosystem.

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Table 1. Monthly and annual variations of heavy metal concentrations in the sediments of Ithikkara River

STATION 1													
METAL	**FEB**	**MAR**	**APR**	**MAY**	**JUN**	**JUL**	**AUG**	**SEP**	**OCT**	**NOV**	**DEC**	**JAN**	**ANNUAL**
IRON	0.07	0.058	0.099	0.139	0.05	0.023	0.037	0.043	0.086	0.096	0.073	0.096	0.073
CADMIUM	BDL	BDL	BDL	0.005	BDL	BDL	BDL	BDL	BDL	0.002	0.002	0.002	0
COPPER	0.012	0.019	0.006	0.018	0.016	0.002	0.002	0.004	0.009	0.02	0.011	0.007	0.01
ZINC	0.035	0.018	0.022	0.026	0.022	0.019	0.011	0.028	0.017	0.012	0.009	0.013	0.02
LEAD	0.001	0.002	0.002	0.003	BDL	BDL	BDL	0.002	0.001	0.003	BDL	0.002	0.001
STATION 2													
METAL	**FEB**	**MAR**	**APR**	**MAY**	**JUN**	**JUL**	**AUG**	**SEP**	**OCT**	**NOV**	**DEC**	**JAN**	**ANNUAL**
IRON	0.13	0.152	0.166	0.197	0.08	0.061	0.039	0.085	0.05	0.079	0.099	0.12	0.1
CADMIUM	0.015	0.009	0.002	BDL	BDL	0.002	0.003	BDL	BDL	0.01	0.013	0.007	0.01
COPPER	0.008	0.006	0.041	0.032	0.001	0.002	0.002	0.004	0.012	0.016	0.018	0.016	0.01
ZINC	0.023	0.036	0.028	0.036	0.018	0.033	0.019	0.023	0.029	0.018	0.031	0.027	0.03
LEAD	0.007	0.007	0.005	0.006	BDL	0.003	0.003	0.002	0.005	0.002	0.003	0.003	0.004
STATION 3													
METAL	**FEB**	**MAR**	**APR**	**MAY**	**JUN**	**JUL**	**AUG**	**SEP**	**OCT**	**NOV**	**DEC**	**JAN**	**ANNUAL**
IRON	0.169	0.156	0.117	0.106	0.11	0.096	0.127	0.118	0.08	0.137	0.155	0.146	0.13
CADMIUM	0.008	0.004	0.004	0.005	BDL	BDL	0.001	0.004	0.027	0.018	0.011	0.021	0.01
COPPER	0.031	0.033	0.047	0.062	0.027	0.017	0.033	0.032	0.044	0.059	0.033	0.068	0.04
ZINC	0.047	0.044	0.034	0.049	0.024	0.021	0.037	0.028	0.036	0.056	0.037	0.044	0.04
LEAD	0.038	0.052	0.04	0.058	0.002	0.01	0.017	0.013	0.026	0.033	0.021	0.03	0.028
STATION 4													
METAL	**FEB**	**MAR**	**APR**	**MAY**	**JUN**	**JUL**	**AUG**	**SEP**	**OCT**	**NOV**	**DEC**	**JAN**	**ANNUAL**
IRON	0.252	0.278	0.224	0.173	0.2	0.186	0.209	0.242	0.2	0.242	0.283	0.305	0.23
CADMIUM	0.002	0.031	0.004	0.011	0.006	0.01	0.017	0.022	0.016	0.035	0.033	0.028	0.02
COPPER	0.052	0.067	0.065	0.087	0.042	0.038	0.041	0.033	0.047	0.059	0.052	0.064	0.05
ZINC	0.085	0.028	0.048	0.079	0.046	0.055	0.079	0.065	0.019	0.051	0.072	0.076	0.06
LEAD	0.091	0.084	0.062	0.075	0.042	0.036	0.021	0.011	0.062	0.051	0.042	0.036	0.051

STATION 5													
METAL	**FEB**	**MAR**	**APR**	**MAY**	**JUN**	**JUL**	**AUG**	**SEP**	**OCT**	**NOV**	**DEC**	**JAN**	**ANNUAL**
IRON	0.28	0.336	0.318	0.356	0.22	0.162	0.257	0.294	0.374	0.307	0.331	0.321	0.3
CADMIUM	0.016	0.034	0.033	0.051	0.009	0.004	0.006	0.016	0.011	0.035	0.026	0.022	0.02
COPPER	0.088	0.081	0.06	0.076	0.059	0.042	0.049	0.077	0.067	0.069	0.077	0.074	0.07
ZINC	0.083	0.065	0.091	0.088	0.059	0.036	0.051	0.049	0.108	0.073	0.095	0.084	0.07
LEAD	0.083	0.077	0.097	0.087	0.035	0.021	0.034	0.033	0.064	0.072	0.061	0.063	0.061
STATION 6													
METAL	**FEB**	**MAR**	**APR**	**MAY**	**JUN**	**JUL**	**AUG**	**SEP**	**OCT**	**NOV**	**DEC**	**JAN**	**ANNUAL**
IRON	0.34	0.387	0.368	0.397	0.34	0.261	0.333	0.38	0.33	0.429	0.386	0.411	0.36
CADMIUM	0.032	0.068	0.066	0.102	0.018	0.008	0.012	0.032	0.022	0.07	0.052	0.044	0.04
COPPER	0.091	0.086	0.055	0.046	0.066	0.036	0.069	0.072	0.075	0.088	0.096	0.075	0.07
ZINC	0.087	0.069	0.099	0.094	0.056	0.062	0.052	0.075	0.096	0.099	0.081	0.084	0.08
LEAD	0.033	0.009	0.027	0.031	0.041	0.002	0.007	0.011	0.033	0.045	0.032	0.022	0.024

Table 2. Contamination factor and degree of contamination of sediments in Ithikkara River

Stations	Contamination Factor					Degree of Contamination
	Fe	Cd	Cu	Zn	Pb	
Premonsoon						
S1	0.034	0.063	0.0003	0.0003	0.0013	0.099
S2	0.064	0.050	0.0006	0.0001	0.0007	0.115
S3	0.061	0.267	0.0007	0.0002	0.0009	0.330
S4	0.035	0.230	0.0012	0.0010	0.0046	0.271
S5	0.041	0.050	0.0014	0.0009	0.0042	0.098
S6	0.039	0.033	0.0020	0.0005	0.0026	0.077
Monsoon						
S1	0.021	BDL	0.0004	0.0001	0.0006	0.022
S2	0.033	BDL	0.0002	0.0001	0.0007	0.034
S3	0.040	0.037	0.0006	0.0002	0.0010	0.078
S4	0.043	0.080	0.0009	0.0004	0.0021	0.127
S5	0.021	0.053	0.0013	0.0004	0.0018	0.078
S6	0.020	0.050	0.0015	0.0004	0.0021	0.074
Postmonsoon						
S1	0.025	0.023	0.0002	0.0001	0.0007	0.049
S2	0.060	0.043	0.0003	0.0002	0.0008	0.105
S3	0.071	0.237	0.0010	0.0003	0.0013	0.310
S4	0.034	0.143	0.0010	0.0007	0.0031	0.182
S5	0.046	0.070	0.0015	0.0007	0.0032	0.121
S6	0.036	0.100	0.0017	0.0005	0.0024	0.140
Min.	**0.020**	**BDL**	**0.0002**	**0.0001**	**0.0006**	**0.0217**
Max.	**0.071**	**0.267**	**0.0020**	**0.0010**	**0.0046**	**0.3299**
Avg.	**0.040**	**0.084**	**0.0009**	**0.0004**	**0.0019**	**0.1284**

Table 3. Geoaccumulation Index (Igeo) values in the sediments of Ithikkara River

Stations	Fe	Cd	Cu	Zn	Pb
Premonsoon					
S1	-0.182	-0.219	-0.080	-0.083	-0.098
S2	-0.220	-0.204	-0.088	-0.079	-0.090
S3	-0.217	-0.401	-0.090	-0.086	-0.093
S4	-0.184	-0.370	-0.097	-0.093	-0.120
S5	-0.193	-0.204	-0.099	-0.093	-0.118
S6	-0.190	-0.182	-0.105	-0.094	-0.109
Min.	-0.220	-0.401	-0.105	-0.094	-0.120
Max.	-0.182	-0.182	-0.080	-0.079	-0.090
Avg.	-0.198	-0.263	-0.093	-0.088	-0.105
Monsoon					
S1	-0.162	Nil	-0.083	-0.079	-0.089
S2	-0.182	Nil	-0.079	-0.077	-0.090
S3	-0.191	-0.187	-0.089	-0.080	-0.095
S4	-0.196	-0.236	-0.094	-0.086	-0.105
S5	-0.163	-0.208	-0.098	-0.089	-0.103
S6	-0.161	-0.204	-0.100	-0.088	-0.105
Min.	-0.196	-0.236	-0.100	-0.089	-0.105
Max.	-0.161	-0.187	-0.079	-0.077	-0.089
Avg.	-0.176	-0.209	-0.091	-0.083	-0.098
Postmonsoon					
S1	-0.169	-0.166	-0.078	-0.077	-0.090
S2	-0.215	-0.196	-0.080	-0.082	-0.091
S3	-0.227	-0.375	-0.094	-0.084	-0.098
S4	-0.182	-0.295	-0.095	-0.078	-0.112
S5	-0.199	-0.226	-0.100	-0.096	-0.113
S6	-0.185	-0.256	-0.102	-0.095	-0.108
Min.	-0.196	-0.236	-0.100	-0.089	-0.105
Max.	-0.161	-0.187	-0.079	-0.077	-0.089
Avg.	-0.196	-0.252	-0.091	-0.085	-0.102
Annual Average					
Min.	-0.227	-0.401	-0.105	-0.096	-0.120
Max.	-0.161	-0.166	-0.078	-0.077	-0.089
Avg.	-0.190	-0.241	-0.092	-0.085	-0.101

Table 4. Pollution Load Index (PLI) values in the sediments of Ithikkara River

Stations	Premonsoon	Monsoon	Postmonsoon
S1	0.0019	-	0.0008
S2	0.0017	-	0.0017
S3	0.0037	0.0017	0.0046
S4	0.0065	0.0032	0.0045
S5	0.0040	0.0024	0.0042
S6	0.0030	0.0025	0.0040
Min.	**0.0017**	**0.0017**	**0.0008**
Max.	**0.0065**	**0.0032**	**0.0046**
Av.	**0.0035**	**0.0025**	**0.0033**