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Assessing the Physico-Chemical Parameters of Sediment Ecosystem of Vasai Creek at Mumbai, India

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Abstract The present study is concerned with the pollution load monitoring along Vasai Creek of Mumbai with reference to the physico-chemical parameters of sediments. The study was carried for a span of two years from 2009-11 at four sampling stations namely Vasai bundar, Bhayandar west side below Railway Bridge, Bhayandar east side near Retibundar and Ghodbundar site along the flow of Vasai Creek. It was observed that most of the physico-chemical parameters like electrical conductivity, chloride, sulfate, sulfide and phosphate content in the sediment samples were higher during the assessment year 2010-11 as compared to that during the year 2009-10. However the pH values recorded during the year 2009-10 were higher than that recorded during the year 2010-11. The results of present investigation suggest that the present increasing pollution load along the Vasai Creek may affect sediment dwelling organisms and fish resulting in decrease survival, reduced growth, or impaired reproduction and lowered species diversity.

Keywords Sediments, Physico-Chemical Parameters, pH, Electrical Conductivity, Sulfate, Sulfide, Chloride, Phosphate, Vasai Creek, Mumbai, India

1. Introduction

Aquatic ecosystems are affected by several health stressors that significantly deplete biodiversity. In the future, the loss of biodiversity and its effects are predicted to be greater for aquatic ecosystems than for terrestrial ecosystems[1]. Sediments form a natural buffer and filter system in the material cycles of waters. Sediment in our rivers is an important habitat as well as a main nutrient source for aquatic organisms. Sediment strata serve as an important habitat for the benthic macro invertebrates whose metabolic activities contribute to aquatic productivity[2]. Sediment is also the major site for organic matter decomposition which is largely carried out by bacteria. Important macro-nutrients are continuously being interchanged between sediment and overlying water[2]. Furthermore, sediments have an impact on ecological quality because of their quality, or their quantity, or both[3]. It is observed that continuous accumulation of pollutants due to biological and geochemical mechanisms, and cause toxic effect on sediment dwelling organisms and fish, resulting in decrease survival, reduced growth, or impaired reproduction and lowered species diversity[4,5]. Aquatic systems are subjected to strong variations of flow rate, substance input and transport, and sedimentation. Sediment analysis is increasingly important in evaluating qualities of the total ecosystem of a body of water, in addition to the water sample analysis practiced for years[6-14]. In comparison to water testing, sediment testing reflects the long term quality situation independent of current inputs[15,16]. In water testing it is not possible to clearly divide between true suspension substances and temporary suspension substances stirred-up from the sediments. Sediment testing is not, or only minimally, affected by other influences. The suspended and precipitated (non-floating) substances and organic substances in waters are capable of adhering pollutant particles (adsorption). The sediments, both suspended and precipitated substances stored on the water bottom, form a reservoir for many pollutants and trace substances of low solubility and low degree of degradability[17-19]. Pollutants are conserved in sediments over long periods of time according to their chemical persistence and the physical-chemical and biochemical characteristics of the substrata. This can allow conclusions to be drawn regarding sources of contamination. Since sediments act as a sinks and sources of contaminants in aquatic systems, chemical analysis for characterization of sediments also provides environmentally significant information about natural and anthropogenic influence on the water bodies[20-25].

Extensive surveillance, monitoring, and research activities are required to assess the extent and severity of sediment contamination, to evaluate the effects of contaminated sediments on freshwater and marine environment, and to prepare a plan for appropriate remedial action. Therefore we

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carried out a study to understand the physico-chemical properties of sediments samples collected along Vasai Creek of Mumbai which is subjected to heavy pollution load. It is expected that the pollution data generated from such regular scientific study will help to implement compatitable policies and programmes to gauge the extent of pollution. The pollution data of the present study is also expected to help in rational planning of pollution control strategies and their prioritization; assessment of nature and extent of pollution control needed; evaluation of effectiveness of pollution control measures already is existence; evaluation of water quality trend over a period of time; assessment of assimilative capacity of a water body thereby reducing cost on pollution control; understand the environmental fate of different pollutants and also in assessment of creek water fitness for different uses.

2. Materials and Methods

2.1. Area of Study

Vasai Creek is an estuarine creek, one of the two main distributaries of the Ulhas Creek in Maharashtra state of western India. The Ulhas Creek splits at the northeast corner of Salsette Island into its two main distributaries, Vasai Creek and Thane Creek. Vasai Creek which lies between latitude 19.315°N longitude 72.875°E, forms the northern boundary of Salsette Island, and empties west into the Arabian Sea. The Creek receives domestic raw sewage as well as industrial waste water effluent from surrounding habitation and nearby industrial belt. The activities like cattle washing, cloth washing, and religious activities like immersion of idols of Lord Ganesha and Deity Durga during Ganesh festival and Navratri festival is also a major source of pollution of creek water.

2.2. Climatic Conditions

Climate is subtropical, with mild winters and warm summers. The weather is typical coastal sultry and humid. The average rainfall of records from 1500 mm to 2000 mm. The place experiences the onset of the monsoon in the month of June and experiences monsoon till the end of September. The average temperature recorded in varies from 25 to 37 degrees.

2.3. Requirements

The chemicals and reagent used for analysis were of analytical reagent grade. The procedure for calculating the different parameters were conducted in the laboratory. The laboratory apparatus were soaked in nitric acid before analysis and then rinsed thoroughly with tap water and de-ionised distilled water to ensure any traces of cleaning reagents were removed. Finally, it is dried and stored in a clean place[26]. The pipettes and burette were rinsed with the same solution before final use.

2.4. Sediment Sampling, Preparation and Analyses

The sediment samples were collected randomly four times in a month in morning, afternoon and evening session from four different sampling stations namely Vasai Bundar *(S-*1*)* , Bhayandar west side of Railway Bridge *(S-*2*)*, Bhayandar east side near Reti Bundar *(S-*3*)*, and Ghodbundar site *(S-*4*)* along the Vasai Creek (Figure 1). The samples were collected and subsequently analysed for a span of two years starting from October 2009 to September 2011. The sampling was done in three shifts i.e. morning shift between 07:00 a.m. to 09:00 a.m., afternoon shift between 02:00 p.m. to 04:00 p.m. and evening shift between 07:00 p.m. to 09:00 p.m. Sediment samples were collected by hand-pushing plastic core tubes (7 cm diameter) as far as possible into the sediment. The sediment cores retrieved in the field were sliced on arrival at the lab at 1-cm depth intervals for the first 15 cm, 2-cm depth intervals from 15–25 cm, and then every 5 cm for the deeper sections of the cores. The sediments were kept cool in icebox during the transportation to the laboratory[27,28]. They were then ground manually to a fine powder in an alumina mortar; it is passed through a 2-mm mesh screen and stored in polyethylene bags based on method used by for further analysis.

Figure 1. Geographical map showing sampling stations along Vasai Creek of Mumbai.

2.5. Physico-Chemical Study

The present study provides a detailed description of the physico-chemical criteria of sediment samples collected from four different sampling stations along Vasai Creek. The samples collected were analysed for pH, electrical conductivity, chloride, sulfate, sulfide and phosphate content. The standard techniques and methods were followed for physical and chemical analysis of sediment samples[29,30].

2.6. Quality Control/Assurance

Sediment samples were collected with plastic-made implements to avoid contamination. Samples were kept in polythene bags that were free from heavy metals and organics and well covered while transporting from field to the laboratory to avoid contamination from the environment. All reagents were standardised against primary standards to determine their actual concentrations. All instruments used were calibrated before use. Tools and work surfaces were carefully cleaned for each sample during grinding to avoid cross contamination. Duplicate samples were analysed to check precision of the analytical method and instrument.

3. Results and Discussion

The experimental data on physico-chemical properties of sediment samples collected from four different sampling stations along the Vasai Creek of Mumbai are presented in Tables 1-4.

Table 1. Physico-Chemical Properties of Sediment Samples Collected at Sampling Station S-1.

Phys-ico-Chemical Properties / Month-Year	pH	Electrical Conductivity µmhos.cm^{-1}	Chloride mg/L	Sulfate mg/L	Sulfide mg/L	Phosphate mg/L
Oct-09	6.5	88	123	154	22	0.14
Nov-09	5.6	72	141	148	25	0.1
Dec-09	7.3	99	168	153	20	0.13
Jan-10	4.9	101	116	164	19	0.18
Feb-10	6.8	121	132	176	24	0.15
Mar-10	7.5	89	149	169	17	0.09
April-10	5.9	95	158	201	19	0.08
May-10	5.5	83	111	234	20	0.11
June.-10	6.2	100	98	256	22	0.09
July-10	6.8	105	126	185	21	0.15
Aug-10	6.4	134	135	189	18	0.16
Sept-10	6.2	128	117	258	24	0.14
Oct-10	5.1	198	201	301	33	0.18
Nov-10	5.9	276	214	345	32	0.1
Dec-10	7.1	187	177	256	30	0.05
Jan-11	7	110	228	170	28	0
Feb-11	3.2	156	254	201	29	0.1
Mar-11	2.9	200	241	276	25	0.19
April-11	2.8	245	225	342	27	0.24
May-11	3.2	228	200	380	25	0.26
June-11	3.5	301	265	352	30	0.2
July-11	2.8	299	289	348	32	0.19
Aug-11	1.1	287	278	333	33	0.22
Sept-11	1.4	265	264	329	35	0.21
Average	**5.1**	**165**	**184**	**247**	**25**	**0.14**

Table 2. Physico-Chemical Properties of Sediment Samples Collected at Sampling Station S-2.

Phys-ico-Chemical Properties / Month-Year	pH	Electrical Conduc-tivity µmhos.cm^{-1}	Chloride mg/L	Sulfate mg/L	Sulfide mg/L	Phosphate mg/L
Oct-09	8.4	87	567	221	5	0.09
Nov-09	8.2	78	672	198	9	0.13
Dec-09	8.9	99	779	234	3	0.18
Jan-10	7.6	90	865	218	6	0.11
Feb-10	7.7	130	832	223	10	0.08
Mar-10	8	199	754	205	11	0.07
April-10	8.5	201	798	198	8	0.07
May-10	6.9	222	801	187	9	0.06
June.-10	7.6	204	763	234	15	0.05
July-10	7.8	209	834	256	12	0
Aug-10	8	215	852	276	11	0.03
Sept-10	7.9	220	887	320	10	0.07
Oct-10	6.1	345	1032	389	18	0.05
Nov-10	5.7	456	541	298	23	0.04
Dec-10	6.4	289	265	163	17	0.01
Jan-11	7.3	120	182	58	15	0
Feb-11	7.1	187	664	286	21	0.01
Mar-11	7.5	245	891	356	24	0.09
April-11	6.2	200	1599	498	20	0.14
May-11	5.9	120	2780	580	20	0.21
June-11	5.9	156	1978	559	18	0.24
July-11	5.5	188	1865	534	17	0.2
Aug-11	5.4	311	1432	576	21	0.19
Sept-11	5.3	378	1297	589	22	0.17
Average	**7.1**	**206**	**997**	**319**	**14**	**0.10**

Table 3. Physico-Chemical Properties of Sediment Samples Collected at Sampling Station S-3.

Physi-co-Chemical Properties / Month-Year	pH	Electrical Conduc-tivity µmhos.cm^{-1}	Chloride mg/L	Sulfate mg/L	Sulfide mg/L	Phosphate mg/L
Oct-09	7.7	201	55	86	15	0.11
Nov-09	7.1	234	48	67	19	0.23
Dec-09	7.5	243	67	56	13	0.19
Jan-10	7.6	276	89	45	12	0.31
Feb-10	8	287	101	49	16	0.18
Mar-10	8.1	299	123	51	14	0.15
April-10	7.8	347	99	45	17	0.1
May-10	7.5	251	95	63	18	0.09
June.-10	7.6	256	78	99	11	0.07
July-10	8	267	70	105	13	0.1
Aug-10	8.2	288	68	116	15	0.34
Sept-10	8.5	300	87	78	19	0.59
Oct-10	7.1	393	123	101	17	1.03
Nov-10	5.8	456	147	115	20	0.71
Dec-10	6.7	301	195	65	25	0.12
Jan-11	7.5	110	180	26	20	0
Feb-11	7	177	205	59	29	0.07
Mar-11	6.9	245	265	187	34	0.09
April-11	6.5	266	274	299	40	0.25
May-11	6.2	220	200	390	36	0.82
June-11	5.9	286	225	250	43	0.56
July-11	5.8	300	232	366	41	0.65
Aug-11	6	315	243	401	45	0.78
Sept-11	5.9	387	256	373	39	0.89
Average	**7.1**	**279**	**147**	**146**	**24**	**0.35**

Table 4. Physico-Chemical Properties of Sediment Samples Collected at Sampling Station S-4.

Physico-Chemical Properties / Month-Year	pH	Electrical Conductivity µmhos.cm^{-1}	Chloride mg/L	Sulfate mg/L	Sulfide mg/L	Phosphate mg/L
Oct-09	6.5	114	154	108	23	0.05
Nov-09	6.1	143	138	134	21	0.03
Dec-09	6.2	128	187	126	20	0.04
Jan-10	6.3	134	199	121	18	0.02
Feb-10	6.9	150	123	99	16	ND
Mar-10	7	142	145	87	19	ND
April-10	5.9	129	141	111	21	0.01
May-10	6.3	135	152	119	22	0.03
June.-10	6.6	141	151	114	20	0.04
July-10	6.5	150	138	134	19	0.05
Aug-10	6	118	139	140	18	0.07
Sept-10	6.7	135	152	154	15	0.06
Oct-10	5.9	178	189	203	33	0.11
Nov-10	6.1	199	254	234	19	0.12
Dec-10	6.6	145	167	171	23	0.09
Jan-11	7.5	110	120	118	15	0
Feb-11	5.5	176	156	231	24	0.1
Mar-11	5.1	256	201	376	29	0.09
April-11	4.2	250	234	499	37	0.07
May-11	4.7	200	275	550	35	0.08
June-11	3.9	276	287	529	43	0.09
July-11	3.5	300	299	503	46	0.11
Aug-11	3	315	301	567	51	0.12
Sept-11	3.2	322	256	497	55	0.1
Average	**5.7**	**181**	**190**	**247**	**27**	**0.07**

pH is a measure of the acidity or alkalinity of water and is one of the stable measurements. pH is a simple parameter but is extremely important, since most of the chemical reactions in aquatic environment are controlled by any change in its value. Anything either highly acidic or alkaline would kill marine life. Aquatic organisms are sensitive to pH changes and biological treatment requires pH control or monitoring. Surface waters having a pH values below six can be hazardous to aquatic life. Thus, pH is having primary importance in deciding the quality of waste water effluent. Waters with pH value of about 10 are exceptional and may reflect contamination by strong base such as NaOH and $Ca(OH)_2$[31].In the present investigation, the biyearly average pH values of effluent samples collected from different sampling stations vary between minimum of 5.1 in the samples collected at S-1 sampling station to maximum of 7.1 at S-2 and S-3 sampling stations (Tables 1,2 and 3). It was observed that at all the four sampling stations; the pH of sediment samples in 2009-10 was higher than that collected in 2010-11 (Figure 2).

It is well known that electrical conductance is a good measure of dissolved solids. Conductivity is a measurement used to determine mineralization of water. Certain physiological effects on plants and animals are often affected by the number of available ions in the water. In the present investigation, the biyearly average conductivity values of the water samples varies from minimum of 165 µmhos/cm to maximum of 279 µmhos/cm at S-1 and S-3 sampling stations respectively (Tables 1 and 3). From the results of present investigation it was observed that electrical conductivity values for the assessment year 2009-10 were lower than that obtained for the assessment year 2010-11 which is represented graphically in the Figure 3.

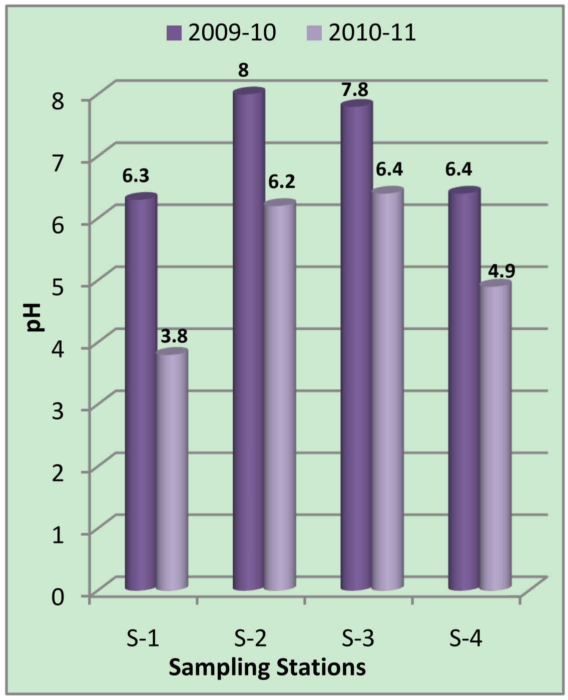

Figure 2. Variation in pH values of sediment samples collected along Vasai Creek.

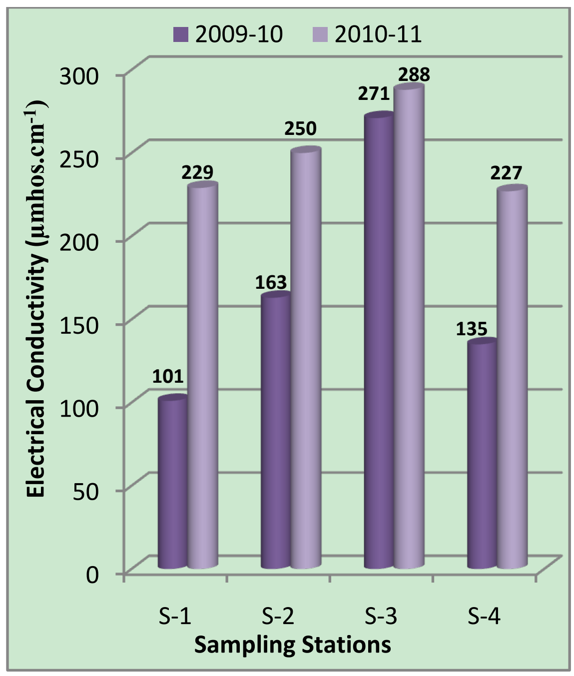

Figure 3. Variation in electrical conductivity values of sediment samples collected along Vasai Creek.

Chloride occurs in all natural waters in widely varying concentrations. Plants do not thrive as well on chlorinated as on unchlorinated water; wild animals develop atherosclerosis by consumption of chlorinated water[32]. The biyearly average chloride content in the sediment samples collected at S-1, S-2, S-3 and S-4 sampling stations were found to be 184 mg/L, 997 mg/L, 147 mg/L and 190 mg/L respectively (Tables 1-4). It was observed that the average chloride content for the assessment year 2010-11 was more than that obtained for the year 2009-10 (Figure 4).

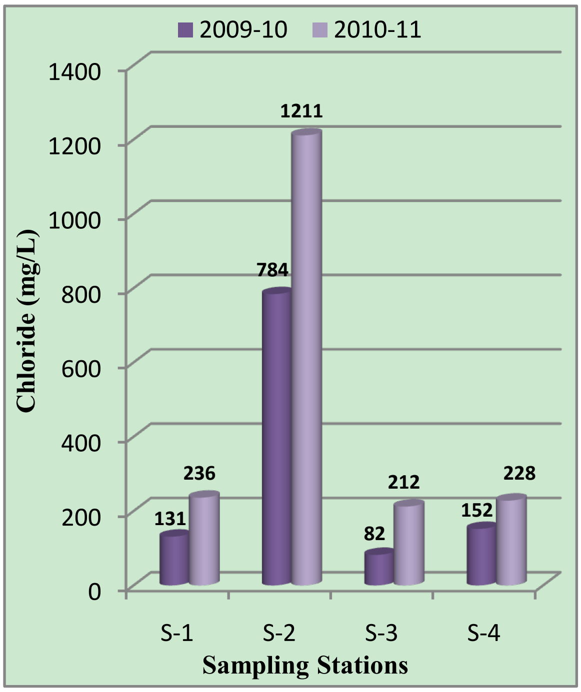

Figure 4. Variation in chloride content of sediment samples collected along Vasai Creek.

The sulfate pollution can be the result of prolonged high atmospheric deposition, sulfate containing fertilizers, and, probably the most important cause at many locations, oxidation of pyrite deposits in the deeper subsoil[33,34]. Sulfates can interfere with the disinfection efficiency by scavenging residual chlorine in the distribution system[35]. Sulfate reducing bacteria produce hydrogen sulfide and lower the aesthetic quality of the water by imparting an unpleasant taste and odour and increases corrosion of metal and concrete pipes[36]. Sulfates can affect industrial water supplies due to formation of hard scales in boilers and heat exchangers. High amount of sulfates in wastewater may lead to problems due to the formation of hydrogen sulfide gas[37]. High sulfate loads in polluted rivers and groundwater have led to increased sulphur fluxes and concentrations in fens and marshes, e.g. in New York[38]. In freshwater wetland systems, it may lead to suppressed growth and development, iron chlorosis, leaf necrosis, suppressed flowering, black and flaccid roots, root decay and even the death of the whole plant[39,40]. In the present investigation, the biyearly average concentration of sulfate in sediment samples collected at S-1, S-2, S-3 and S-4 sampling station was found to be 247 mg/L, 319 mg/L, 146 mg/L and 247 mg/L respectively. Similarly the sulfide concentration were found to be 25 mg/L, 14 mg/L, 24 mg/L and 27 mg/L respectively (Tables 1-4). It is important here to note that these pollutants which are accumulated in the sediments will get released in creek water under certain conditions. As a result the sulfate and sulfide concentration in water may increase above the permissible limit of 200 mg/L and 2 mg/L respectively set for inland surface water[41]. The results also indicate increase in average sulfate and sulfide concentration for the assessment year 2010-11 as compared to 2009-10 (Figures 5 and 6).

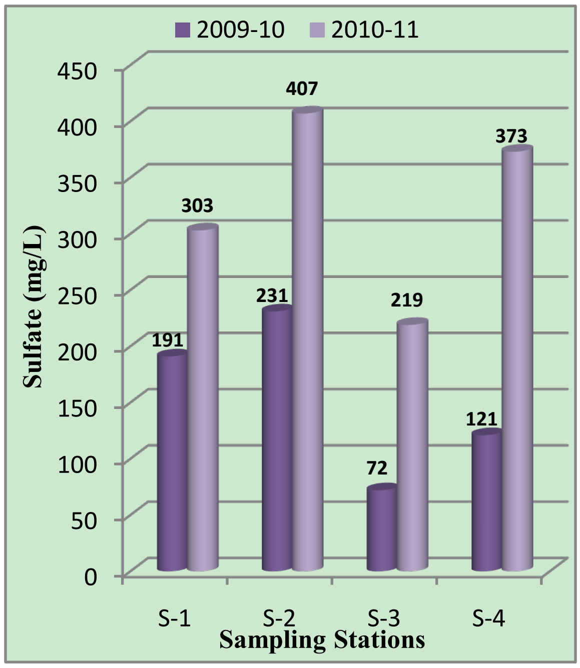

Figure 5. Variation in sulfate content of sediment samples collected along Vasai Creek.

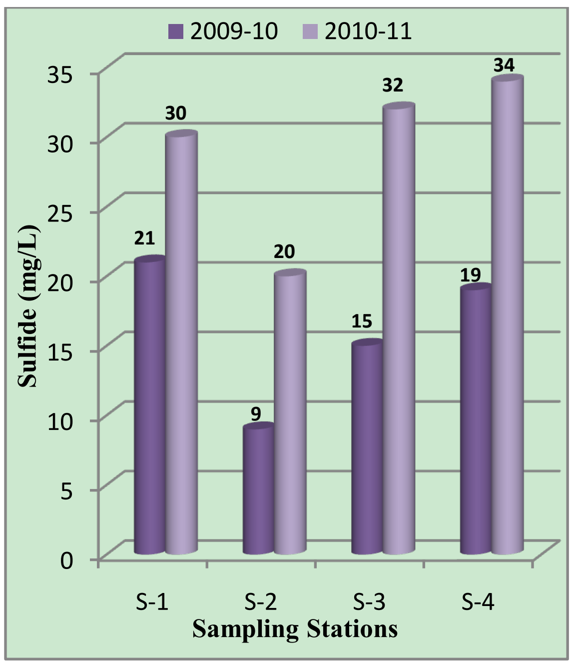

Figure 6. Variation in sulfide content of sediment samples collected along Vasai Creek.

Phosphorus pollution accelerates a process called eutrophication, which is essentially the process of a rivers biological death due to depleted bioavailable oxygen. Algal blooms caused by excess phosphorus impact fisheries because the blooms favour the survival of less desirable fish over more desirable commercial and recreation species. Phosphorus pollution caused enormous blooms of the Blue-Green Algae, a form of cyanobacteria, which produces toxins that damage aquatic ecosystems, fisheries, and water quality. Excess amounts of phosphorus and nitrogen cause rapid growth of phytoplankton, creating dense populations, or blooms. These blooms become so dense that they reduce the amount of sunlight available to submerged aquatic vegetation. Without sufficient light, plants cannot photosynthesize and produce the food they need to survive. The loss of sunlight can kill aquatic grasses. The results of present study indicates that the biyearly average phosphate level was low (0.07 mg/L) only at S-4 sampling station, while at S-1, S-2 and S-3 sampling stations the phosphate concentration was found to be relatively high of 0.14 mg/L, 0.10 mg/L and 0.35 mg/L. The phosphate pollutants will settle down and get accumulated in bottom sediments, under certain conditions they may get released back to surface water. Such release of phosphate pollutants may result in increase in the phosphate concentration above the permissible limit of 5 mg/L set for inland surface water[41]. The graphical representation showing average phosphate concentration in sediment samples collected at different sampling stations indicates higher concentration of phosphates during the assessment year 2010-11 as compared to 2009-10 (Figure 7).

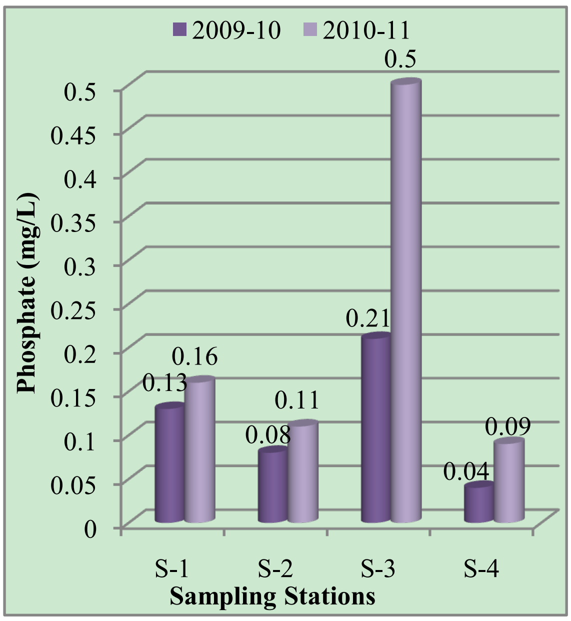

Figure 7. Variation in phosphate content of sediment samples collected along Vasai Creek.

4. Conclusions

Around the world as countries are struggling to arrive at an effective regulatory regime to control the discharge of industrial effluents into their ecosystems, Indian economy holds a double edged sword of economic growth and ecosystem collapse. The present experimental data indicates increasingly high level of pollution along the Vasai creek of Mumbai. The experimental data suggests a need to implement common objectives, compatible policies and programmes for improvement in the industrial and domestic waste water treatment methods. It also suggests a need of consistent, internationally recognized data driven strategy to assess the quality of waste water effluent and generation of international standards for evaluation of contamination levels. The existing situation if mishandled can cause irreparable ecological harm in the long-term well masked by short term economic prosperity.

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