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Dynamics of sediment nutrients of Manakudy and Thengapattinam estuaries in kanyakumari district – A Comparative assessment

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ABSTRACT

Assessment of sediments in a complex aquatic system gives a better understanding of the adverse impacts that contaminants in sediments pose to fish, wild life and humans who depend this impacted waterways. Therefore apart from polluted water, fate of contaminated sediment has been chosen as one of the aspects responsible for ecological decline. Hence, an attempt was made to study the sediment nutrients of Manakudy and Thengapattinam estuarine systems in Kanyakumari district for a period of two years from April 2011-March 2013. The present investigation included the estimation of pH, redox potential, electrical conductivity, total soluble salts, organic carbon, chloride, total nitrogen, phosphate-phosphorus, sulphate-sulphur, calcium, magnesium, sodium and potassium of these estuarine sediments. The specific objective is to compare the degree of environmental degradation in these ecosystems. The assessment clearly showed that the sediment in Manakudy estuary is contaminated with high level of nutrients when compared to sediment in Thengapattinam estuary. Hence remedial measures need to be taken for the sustainability of Manakudy ecosystem.

Keywords: Contaminated, organic carbon, redox potential, degradation, fluctuating, deterioration.

1. INTRODUCTION

Awareness on environment and related issues are alarming all around the world in the recent years. Studies on the role of sediments in a natural water body in element cycles, transportation of nutrients and contaminants and preservation of water quality are important for the understanding of an aquatic ecosystem. The nutrient economy of an aquatic system is mostly governed by the sediments and the knowledge on the role of sediment-nutrient is useful in determining the sediment-water interaction, which eventually affects the productivity[1]. Thus the sediment acts as a source and sink of nutrients and plays a vital role in changing the quality of the overlying water column. Further, sediment testing reflects the long term quality situation independent of current inputs[2,3]. Thus sediment quality indicates the extent of biological activity and indirectly the fertility of the overlying water and also the actual state of pollution of a water body[4]. Nutrient enrichment of rivers, lakes, ground waters and tidal waters is considered to be one of the major environmental problems in many countries[5]. Although it can stimulate the growth of plants in water, nutrient enrichment ultimately leads to the degradation of entire ecosystems if not controlled in a satisfactory manner. Sediment cores can be used to understand the history of contaminant inputs into a water body[6]. Estuarine sediment accumulation is a product of continental and marine processes[7]. The specific objective was to characterize the sediment quality of the two major estuaries, Manakudy and Thengapattinam estuary in Kanyakumari district and to understand qualitative and quantitative aspects of sediment nutrients. The fluctuation in the composition of sediments and its nature can indicate the stress on shallow aquatic environments[8]. Thus the study of nutrients in sediments represents a useful tool for determining the actual state of environmental pollution of a water body.

2. MATERIALS AND METHODS

Study Area

Manakudy estuary is one which naturally connects the Arabian sea and the Pazhayar river. It is the second largest estuary in Kanyakumari district. It has a total area of 145 hectares extending over 4 km bordered with vast stretches of salt pans on either side. It is situated about 15 km from Nagercoil, falling within the latitude 8°09' N and longitude 77°48' E on the south west coast of Kanyakumari district (Figure 1). The estuary gets the pollutant load when drainage from Thovalai, Ananthanar and Nanjilnadu Puthanar channel passing through Thazhakudi, Vellamadam villages. The deterioration of estuary can be attributed to the inflow of water from agricultural fields, coconut husk retting, lime-shell dredging, salt pan and untreated domestic sewage.

Thengapattinam estuary (8°14' N latitude and 77°10' E longitude) on the south-west coast of India (Fig.1) is situated in Paimkulam village of Kanyakumari district. It is the first largest estuary in Kanyakumari district and is situated at a distance of about 35 km from Nagercoil. The estuary spreads over an area of 400 hectares and extends over 5 km. It is formed by the confluence of river Tamiraparani with the Arabian Sea at Thengapattinam. Along the west coast line, the AVM canal with water inflow from nearby land and streams, is used for coconut husk retting activities. The estuary is connected with the sea during the rainy season and land locked for the rest of the year by sand bar similar to Manakudy estuary.

Figure – 1: Location map of the area of study.

Ten stations were selected based on different ecological conditions for the collection of sediment samples from estuarine mouth bed to river basin in Manakudy and Thengapattinam estuarine systems. The study was conducted for a period of two years from April 2011- March 2013. The collected sediment samples were transferred separately to clean, dry polythene containers, homogenized well and were brought to the laboratory for analysis. pH and redox potential of samples were taken as soon as the samples were brought to the laboratory using inert platinum electrode connected to pH – E*h* meter[9]. EC was determined by conductivity meter. A portion of these samples were air dried and finely powdered using agate mortar. Percentage of OC was determined by titration method[10]. Total soluble salt (TSS) and sulphate-sulphur were determined using 1: 2.5 water solution. Chloride content was determined by titrating with $AgNO_3$ using potassium chromate indicator. Calcium and Magnesium were estimated by titration with EDTA. Phosphate-phosphorus was determined by Olesen's method using spectrophotometer. Total nitrogen was estimated by modified Kjeldahl method. Sodium and potassium were determined by flame photometer. All the reagents and chemicals used were of analytical grade.

Statistical two-way ANOVA and correlation analyses were applied on the data to find out the inter-relation among different parameters.

3. RESULTS AND DISCUSSION

Mean results of sediment parameters in Manakudy and Thengapattinam estuary are summarized in Table 1 and Correlation matrix of sediment quality parameters in Manakudy and Thengapattinam estuary are computed in Table 2 and 3.

3.1. pH

The sediment was found to be alkaline in Manakudy estuary throughout the study period with a mean value of 7.97 whereas the sediment in Thengapattinam estuary was found to be acidic with a mean value of 5.74. The higher pH value in Manakudy estuary indicated that highly alkaline effluents were discharged during the rain fall time. The lower pH value 5.74 recorded.

Thengapattinam estuary may be due to the increased rate of decomposition of organic matter and conversion of released CO_2 into carbonic acid. This result is in accordance with earlier reports [11,12]. Further the low pH condition observed in Thengapattinam estuary was due to the sulphur compounds from coconut husk retting that characterize the brackish water environment [13].

In both estuaries, pH showed strong negative correlation with redox potential. Two-way ANOVA indicated the variation of pH between the seasons and the stations were statistically significant ($p < 0.05$) in both estuaries.

Table - 1: Mean value of Sediment Parameters

No	Parameters	Manakudy Estuary	Thengapattinam Estuary
1	pH	7.970 ±0.1516	5.74 ±0.8192
2	EC (mS/cm)	2.930 ±1.0960	2.070±1.087
3	E*h* (mV)	-60.06 ±9.9200	74.13±32.15
4	TSS (%)	0.132±0.0637	0.0589±0.022
5	OC (%)	0.363±0.1940	0.359±0.1556
6	Chloride (ppm)	2004±1143	937.9±467.4
7	Nitrogen(ppm)	360.7±204.2	405.0±198.9
8	PO_4-P(ppm)	89.55±20.12	77.92±28.88
9	Calcium (ppm)	209.5± 96.28	176.8±48.13
10	Magnesium(ppm)	91.17±47.35	131.9±53.35
11	SO_4-S (ppm)	165.8±97.32	265.1±87.44
12	Sodium (ppm)	746.7± 437.8	478.6± 153.3
13	Potassium (ppm)	72.61±41.32	37.50±13.20

3.2. Electrical Conductivity (EC)

EC is directly related to the soluble salt concentration of sediment. The mean EC values in Manakudy and Thengapattinam Estuary were 2.93 mS/cm and 2.07 mS/cm respectively. Accumulation of soluble salts in sediments is probably due to flushing of domestic and municipal sewage, salinity intrusion and fresh water influx from rivers[14]. In both estuaries, results of ANOVA indicated significant seasonal and locational variation in electrical conductivity. Sediment of Manakudy showed a strong positive correlation with all parameters except redox potential whereas sediment of Thengapattinam estuary showed a strong positive correlation with only chloride and sodium.

3.3. Redox potential (E*h*)

Redox potential (E*h*) of sediments is a convenient index to understand whether or not the sediment is reducing in reaction. A positive E*h* reading result from a state tends towards oxidation and a negative E*h* indicates a system causing reduction. The negative mean value of E*h* of Manakudy estuary suggests that the sediments were in the reduced state. Further negative E*h* indicates that there was degradation of the natural environment due to discharge of sewage water. Negative E*h* value may be due to fine sediment rich in organic matter. Also negative E*h* values were found in areas with higher productivity and organic matter sedimentation[15]. The mean positive value of E*h* recorded in Thengapattinam estuary suggests that the sediments were in the oxidised state by strong water flow and high concentration of oxygen in the overlying water. Statistical analysis also proves this significant variation between seasons and within stations in both estuaries. In both estuaries, E*h* showed no significant correlation with other nutrients.

3.4. Total Soluble Salts (TSS)

The mean value of TSS in Manakudy and Thengapattinam estuary were 0.132 % and 0.059 % respectively. The higher value of TSS in Manakudy estuary may be due to the presence of ions like calcium, magnesium, sodium, potassium, chloride, nitrate, carbonate, bicarbonate and heavy metals. Results of ANOVA for Manakudy and Thengapattinam estuary indicated significant seasonal and spatial variation in TSS. In Manakudy estuary TSS showed a strong positive correlation with all parameters whereas TSS of the sediments of Thengapattinam estuary showed a weak positive correlation with all parameters.

3.5. Organic Carbon (OC)

Enrichment of OC indicates incorporation of organic materials from the river water. The mean value of organic carbon content of the sediments were 0.363 % and 0.359 % in Manakudy and Thengapattinam estuary respectively. The higher mean OC % can be ascribed to the heavy sewage discharges, adsorption of organic matter by the increased finer fractions of the sediment and hectic coconut husk retting activity[16].

Mixing of sewage is one of the principal sources of organic pollution in estuaries. In most unpolluted estuaries organic carbon of the sediment is < 5 % whereas in areas where organic pollutants are high, OC exceeds 5 % [4]. In the present study OC level was within the limit of < 5 % and hence both the estuaries are considered as unpolluted estuaries with respect to OC.

From ANOVA, in Manakudy estuary the variations of OC between stations were found to be significant and insignificant between seasons. In Thengapattinam estuary, OC indicated significant seasonal and spatial variation. In Manakudy estuary, OC showed strong positive correlation with all nutrients whereas in Thengapattinam estuary, it is positively correlated with nitrogen.

3.6. Chloride

The mean value of chloride content in Manakudy and Thengapattinam estuary were 2004 ppm and 937.9 ppm respectively. The high concentration of chloride in Manakudy estuary may be due to disposal of water from the neighbouring salt pan.

In Manakudy estuary, results of ANOVA indicated significant seasonal and locational variation in chloride content whereas in Thengapattinam estuary the variations of chloride content between stations were found to be insignificant and significant between seasons. In Manakudy estuary, chloride showed strong positive correlation with all nutrients whereas in Thengapattinam estuary, it showed strong positive correlation with calcium and sodium only.

3.7. Total Nitrogen

The mean nitrogen content of the sediment samples in Manakudy and Thengapattinam estuary were 360.7 ppm and 405 ppm respectively. The infiltration of fertilizer used in the nearby agricultural fields, retting of coconut husk and other anthropogenic activities facilitate an increase in the concentration of nitrogenous material in the sediment[14].

From ANOVA, in Manakudy estuary the variations of total nitrogen between stations were found to be significant and insignificant between seasons. In Thengapattinam estuary, total nitrogen indicated significant seasonal and spatial variation. In Manakudy estuary, total nitrogen showed strong positive correlation with all nutrients whereas in Thengapattinam estuary, it showed strong positive correlation with magnesium.

3.8. Phosphate- phosphorus

Total phosphorus is an important sediment parameter since it acts as a reservoir for phosphorus by retaining it through adsorption and releasing it to the over lying water under favourable conditions. In the present study, mean phosphate concentration was 89.55 ppm in Manakudy estuary and 77.92 ppm in Thengapattinam estuary respectively. Higher concentration of phosphorus is due to the agricultural waste discharge from the paddy fields of the region, urban sewage and coconut husk retting activities. Further high values of phosphorus may be due to the dead organic matter settling from top[17].

The statistical analysis by two-way ANOVA carried out for sediment phosphate content in both the estuaries revealed that the variation among the seasons was significant and insignificant between the stations. In Manakudy estuary, phosphate showed strong positive correlation with magnesium, sulphur, sodium and potassium whereas in Thengapattinam estuary, it showed no significant correlation with any nutrient.

Table - 2 : Correlation matrix of sediment quality parameters in Manakudy estuary

	pH	*EC*	*Eh*	*TSS*	*OC*	*Cl*	*N*	*PO4-P*	*Ca*	*Mg*	*SO4-S*	*Na*	*K*
pH	1												
EC	0.245	1											
Eh	-0.99	-0.22	1										
TSS	0.25	0.999	-0.22	1									
OC	0.045	0.952	-0.03	0.949	1								
Cl	0.074	0.969	-0.05	0.967	0.931	1							
N	-0.11	0.912	0.123	0.911	0.941	0.956	1						
PO4-P	0.081	0.897	-0.08	0.899	0.93	0.903	0.946	1					
Ca	-0.12	0.846	0.167	0.836	0.87	0.877	0.839	0.735	1				
Mg	-0.16	0.887	0.18	0.888	0.884	0.948	0.959	0.856	0.812	1			
SO4-S	0.302	0.948	-0.27	0.947	0.928	0.88	0.839	0.886	0.834	0.754	1		
Na	0.217	0.981	-0.19	0.982	0.951	0.967	0.925	0.948	0.816	0.89	0.943	1	
K	0.319	0.962	-0.3	0.964	0.933	0.908	0.869	0.934	0.769	0.805	0.976	0.981	1

Table - 3: Correlation matrix of sediment quality parameters in Thengapattinam estuary

	pH	*EC*	*Eh*	*TSS*	*OC*	*Cl*	*N*	*PO4-P*	*Ca*	*Mg*	*SO4-S*	*Na*	*K*
pH	1												
EC	-0.06	1											
Eh	-0.97	0.184	1										
TSS	-0.24	0.636	0.222	1									
OC	-0.61	0.298	0.533	0.515	1								
Cl	-0.14	0.908	0.223	0.720	0.324	1							
N	-0.73	0.182	0.678	0.351	0.833	0.345	1						
PO4-P	-0.25	0.670	0.241	0.426	0.664	0.654	0.617	1					
Ca	-0.50	0.670	0.588	0.520	0.476	0.813	0.698	0.627	1				
Mg	-0.78	0.180	0.762	0.323	0.629	0.377	0.937	0.483	0.762	1			
SO4-S	-0.71	0.602	0.79	0.642	0.565	0.646	0.586	0.445	0.811	0.635	1		
Na	-0.60	0.776	0.665	0.622	0.397	0.815	0.441	0.56	0.773	0.533	0.837	1	
K	-0.60	0.63	0.655	0.435	0.651	0.561	0.478	0.619	0.604	0.396	0.825	0.756	1

3.9. Calcium and Magnesium

Calcium and magnesium are the two most abundant alkaline cations in sediment. Calcium being present in high concentration in the rock, it is leached from there to contaminate the water. Disposal of sewage and industrial waste also contribute to the content of calcium and has a great affinity to be absorbed on the soil particle and in turn affects the soil texture. In the sediment samples of Manakudy and Thengapattinam estuaries, the calcium content was found to be 209.5 ppm and 176.8 ppm respectively. The high calcium content in Manakudy estuary may be due to the leaching of dead shelled organisms.

In the sediment samples of Manakudy and Thengapattinam estuaries, the magnesium content was found to be 91.17 ppm and 131.9 ppm respectively. Statistical two-way ANOVA showed significant variation in calcium and magnesium between seasons and within stations in both estuaries. In Manakudy estuary, both calcium and magnesium showed significant positive correlation with other nutrients whereas in Thengapattinam estuary, calcium showed a strong positive correlation with sulphur and magnesium showed no such correlation with any nutrient.

3.10. Sulphate- sulphur

Sulphate concentration in lake sediments play an important role in the release of phosphorus which leads to eutrophication of lakes[18]. Under anoxic conditions, sulphate reduction takes place and promotes the release of phosphorus from sediments. Sulphate concentration for sediment samples in Manakudy and Thengapattinam estuary were 165.8 ppm and 265.1 ppm respectively. Higher value of sulphur in Thengapattinam estuary was due to the coir retting pits where hydrogen sulphide is released. The hydrogen sulphide formed by most decomposing bacteria is oxidized to sulphate and finally to elemental sulphur[19]. Results of ANOVA for Manakudy and Thengapattinam estuary indicated significant seasonal and spatial variation in sulphate-sulphur. In Manakudy estuary, sulphate-sulphur showed a strong positive correlation with all nutrients whereas sediment of Thengapattinam estuary showed a strong positive correlation with calcium, sodium and potassium.

3.11. Sodium and Potassium

Sodium is an important constituent in sediment. The carbonate, sulphate, nitrate and chloride of sodium are found abundantly in nature. The analysis of sodium in sediments of Manakudy and Thengapattinam estuary showed that its value was 746.7 ppm and 478.6 ppm respectively. The high concentration of 746.7 ppm reported at Manakudy estuary indicates high degree of pollution due to the intervenes of human activities, inflow of water from salt pan and the application of fertilizers in the adjacent areas. Domestic sewage is rich in sodium and this would increase its concentration in the natural water after disposal of waste[20].

Like sodium, potassium is also a naturally occurring constituent in sediment. The major source of potassium in fresh water is weathering of rocks but the quantity increases in the polluted water due to the disposal of domestic wastes. The potassium content in the sediment samples of Manakudy and Thengapattinam estuary were 72.61 ppm and 37.50 ppm respectively. The high mean value of potassium in Manakudy estuary may be due to inflow of untreated sewage and leaching of potassium through rain water from the surrounding coconut fields, which has potassium

as one of the constituent of fertilizer[21]. The statistical analysis by two-way ANOVA carried out for sediment sodium and potassium content in both the estuaries revealed that the variation among the seasons and stations were significant in Manakudy estuary.

In Thengapattinam estuary, the variation was significant between the seasons and insignificant between the stations. In Manakudy estuary, sodium and potassium showed strong positive correlation with all nutrients whereas in Thengapattinam estuary, sodium showed strong positive correlation with sulphur and chloride and potassium strong positive correlation with sulphur.

4. CONCLUSION

Based on the above experimental results and discussions, the present assessment clearly indicates that the estuarine sediments of Manakudy are more contaminated than Thengapattinam estuary since the sediment samples of Manakudy showed higher concentration of nutrients. This implies an increase in pollution load in Manakudy estuary due to small scale industrialization like coconut husk retting, lime-shell dredging, salt pan and run off from the agricultural fields, fish processing unit etc. So, extensive addition of nutrients would neither be economical nor safe from environmental points of view. Further higher nutrient concentration was associated with lower oxygen content and higher salinities. This would affect fish and shell fish production. The nutrient supply can initiate eutrophication in the estuary causing degradation of the entire ecosystem. Hence remedial measures need to be taken for sustainability of Manakudy ecosystem.

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