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IMPACT OF INDUSTRIAL EFFLUENTS ON THE HYDROCHEMICAL CHARACTERISTICS OF KAYAMKULAM ESTUARY, SOUTH WEST COAST OF INDIA

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ABSTRACT

The present study was conducted to investigate the impact of industrial effluents on the water characteristics of Kayamkulam estuary, in the south west coast of India. The surface water samples from ten selected stations of the entire stretch of the estuary and also the effluents discharged from the industries (NTPC and KMML) were collected in the pre-monsoon and monsoon seasons of the year 2012. Various physico-chemical parameters of water and effluent samples have been determined following standard analytical methods. The values obtained were compared with surface water quality standards given by CPCB criteria. The values of EC, TDS, BOD, sodium, total alkalinity, total hardness, calcium, sulphates, chlorides, salinity and SAR of water samples in some stations exceeded the standard permissible limits of surface water quality. The effluent characteristics analyzed indicate that the concentration of pollutants were higher in KMML effluents than that of NTPC effluents. Results of the analyses showed that the water of the estuary is not suitable for irrigation and outdoor bathing without proper treatment. Recommendations to manage the pollution load of the Kayamkulam estuary are also mentioned in this study.

INTRODUCTION

Aquatic pollution and the resulting ecological imbalance are the undesirable side-effects of rapid industrialization and dense human settlements. Many industrial units in Kerala are situated in coastal zone because of the assumption that rivers, estuaries, beaches are the cheapest, convenient and safest areas for dumping the industrial waters. In order to safeguard the water bodies, there is a need to examine the physico-chemical characteristics of the water bodies (Aravindkumar, 2004). Many of the estuarine water bodies in our state are in a very pathetic condition due to various anthropogenic activities. The main contaminants are sewage, industrial waste, agricultural waste and physical pollutants, viz, heat (thermal pollution) and radioactive substances (Agarwal, 1996). Estuaries are the integral part of the coastal environment. Estuaries have variable physico-chemical properties. The fluctuation creates a stressful environment

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for aquatic organisms. One of the important variables in estuarine waters is the oxygen content since the solubility of oxygen in water decreases with increased temperature and salinity. Two-thirds of all fishes depend on the estuarine zone during some part of their life cycle. The study area, Kayamkulam estuary is one of the major estuarine systems in the southern coasts of India and it is one of the most scenic backwaters in Kerala and it is popular for inland fishing. Kayamkulam estuary has been subjected to pollution due to effluent discharge from factories like National Thermal Power Corporation (NTPC), Kayamkulam and Kerala Minerals and Metals Ltd. (KMML), Chavara. The sewage discharged is also causing severe damage to the fishery resources of the estuary. In the present study, an attempt has been made to evaluate the physico-chemical characteristics of Kayamkulam estuary and assess the extent of pollution caused by different anthropogenic activities and by industrial effluents.

MATERIALS AND METHODS

Study area and Sampling stations

Kayamkulam estuary located in the coastal land of Alappuzha and Kollam districts, is a linear water body stretching from Karthikapalli (Alappuzha) in the north and Chavara (Kollam) in the south. It meets the Lakshadweep Sea at Ayiramthengu in Alappuzha district. The Kayamkulam estuary has an area of 59.57 sq. km, length of about 30 km. The width of the estuary varies between a few tens of meters over a kilometer. It connects the Ashtamudi Lake by the Chavara - Panmana canal. The depth of the estuary at different sampling stations were measured and the average depth is recorded as 0.8558 m. The estuary lies between 09014'42.9''N to 08057'40.8''N latitude and 076025'25.8''E to 0760 32'18.3''E longitude. In the present study, ten sampling stations were selected. The location map of the study area and sampling stations are given in Fig.1.

The first sampling station (S1) is at Karthikapalli (Alappuzha). In this station, three canals (Pulikkeezhu Ar, Thrikkunnapuzha and Karthikapalli Ar) join to form the Kayamkulam estuary. Station 2 (S2) is the effluent discharge point from NTPC. Station 3 (S3) is Kanakakunnu and there is domestic waste discharge in this area. Station 4 (S4) is Valiyazhikkal near to Pozhi, connecting to the Arabian sea. Station 5 (S5) is Govindamuttam and it is also receiving domestic wastes. Station 6 (S6) is Ayiramthengu near to the harbour. Station 7 (S7) is Thurayilkadavu and station 8 (S8) is Panickarkadavu, which are the sites of domestic waste water discharge. Station 9 (S9) is Chittoormekkadu and this site receives effluents from KMML. The station 10 (S10), Chavara is the joining point between Kayamkulam estuary and Ashtamudi Lake. The surface water samples were collected during the pre monsoon and monsoon seasons of the study period. The effluents discharged from the industries, NTPC and KMML were also collected in the monsoon season. Temperature of the water samples was measured at the sampling sites itself. Samples for DO and BOD determination were collected in BOD bottles, and the DO was fixed immediately in the field itself. All the samples were collected in labeled plastic bottles and transported to the laboratory for the analysis of various water quality parameters. The physico-chemical characteristics of the water samples were analyzed following the methods described in APHA (1995) and by Trivedy and Goel (1986) and by Saxeena (1998).

RESULTS AND DISCUSSION

The results of the physical and chemical analyses of water samples collected from the different study stations during the pre monsoon and monsoon seasons were given in Table 1 and 2 respectively. The water samples collected from S1, S2, S3, S4, S7 and S8 of Kayamkulam estuary were with unobjectionable colour and odour. The water samples from stations 5, 6 and 10 showed greenish colour with objectionable odour. The water samples from station 9 showed yellowish brown colour and with no specific odour. The surface water temperature of estuary ranged between 28^0C to 33^0C. The fluctuated values of water temperature were due to the mixing of effluents from different anthropogenic activities and seasonally. The temperature differences in the water body may affect the fish diversity. The majority of water samples showed alkaline pH except in stations 1, 9 and 10. The water samples collected from station 9, near KMML effluent discharge area was highly acidic in nature. The values of electrical conductivity varied in different stations and highest value was reported in station 4 (38860µS/cm). The high electrical conductivity value recorded in station 4, is due to the increased dissolved salt content in this station, that is near the Pozhi, which was connected to the sea during the monsoon season.

Table 1. Physico-Chemical characteristics of Kayamkulam Estuary Water during Pre-Monsoon season

Parameters	Sampling Stations									
	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10
Temperature (ºC)	30	30	30	31	33	31	31	31	32	32
pH	6.75	7.2	7.13	7.34	7.24	7.3	7.4	7.25	3.64	5.9
Electrical Conductivity (µS/cm)	31670	14400	27110	38860	32240	17770	1370	693.7	1293	3037
TDS (mg/L)	9936	4388	8396	14420	9888	5200	412	244	616	5608
DO (mg/L)	4.67	2.43	5.89	6.09	7.72	4.47	4.87	7.11	2.03	5.08
BOD (mg/L)	2.44	1.62	2.24	1.63	2.24	0.6	1. 21	3.45	1.22	3.25
Nitrates (mg/L)	6.25	2.64	1.91	4.6	3.08	2.05	9.04	5.29	28.38	4.85
Sulphates (mg/L)	181.15	138.93	198.93	410.97	219.29	189.02	75.66	0.97	8.31	215.66
Inorganic Phosphates (mg/L)	0.09	0.15	0.18	0.01	0.1	0.11	0.25	0.05	0.19	0.006
Sodium (mg/L)	82.6	150.3	302.2	583.3	382.5	190.8	11.7	6.4	5.2	367.3
Potassium (mg/L)	102.6	52.1	88.5	141.3	106.1	59.8	8.6	6.6	12	101.2
Total Alkalinity as $CaCO_3$ (mg/L)	120	240	140	140	160	120	80	40	20	120
Total Hardness as $CaCO_3$ (mg/L)	1600	800	1600	5300	1600	2500	300	100	160	1800
Calcium as $CaCO_3$ (mg/L)	200.4	240.48	200.4	184.36	120.24	72.14	16.03	32.06	56.11	96.19
Magnesium as $CaCO_3$ (mg/L)	5.36	1.46	5.36	14.61	0.48	7.79	0.48	0.48	0.48	2.92
Chloride (mg/L)	11360	8520	13490	16330	16330	9940	4970	5680	4260	13490
Salinity (mg/L)	20504.8	15378.6	24349.5	29475.7	29475.7	17941.7	8970.88	10252.4	7689.33	24349.5
SAR	8.143	13.665	29.794	58.48	49.233	30.181	4.072	1.586	2.3460	52.176

High levels of dissolved solids may aesthetically unsatisfactory for bathing and living. The study shows seasonal fluctuation in the concentration of total dissolved solids (TDS) in different stations and it was higher during monsoon. The concentration of total alkalinity during pre-monsoon and monsoon seasons varied from 20 mg/L to 240 mg/L as $CaCO_3$. Dissolved Oxygen content was much less in stations 2 (2.43 mg/L) and 9 (2.03 mg/L) during pre-monsoon season, and in station 5 (2.43 mg/L) during monsoon season. DO content of water samples in all other stations of the estuary are within the permissible limits of surface water quality standards (CPCB, 1999). The BOD values of water samples from most of the study stations of the estuary during pre-monsoon season, were within the standard permissible limits of surface water quality except in stations 8 and 10. It was also found that the BOD values of the estuary recorded during the monsoon season were within the desirable limits of surface water standards (CPCB, 1999). Nitrate values of the water samples collected during pre-monsoon were within the permissible limit except in station 9 (28.83 mg/L), and this may be due to addition of nitrates from the effluent discharged from KMML to this area. The concentration of sulphates in water samples ranged between 0.97mg/L to 1142.47mg/L during the study period. The highest values of sulphate content in water samples collected during pre-monsoon and monsoon seasons were at stations 4 (410.94 mg/L), near to the Pozhi and at station 6 (1142.47 mg/L), the Ayiramthengu harbour. The concentrations of inorganic phosphates in all the water samples were within the permissible of limits of CPCB.

The sodium content in water showed high values in most of the study stations of the Kayamkulam estuary. The concentration of sodium ions is remarkably high in saline and brackish waters. In pre-monsoon, the highest values for sodium were recorded at stations 4, which is near to the Pozhi. The concentration of potassium in the estuary water recorded high values during monsoon season. The highest values for potassium were recorded at stations 4 and 6, during the pre-monsoon and monsoon seasons. Hardness values obtained

Table 2. Physico-Chemical characteristics of Kayamkulam Estuary Water during Monsoon season

Parameters	Sampling Stations									
	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10
Temperature (°C)	29	29	31	30	28	31	31	30	31	31
pH	6.33	6.65	6.8	7.24	7.32	7.33	7.37	7.93	7.48	7.18
Electrical Conductivity (µS/cm)	5706	4244	9211	21960	5238	22950	8524	1249	1324	16010
TDS (mg/L)	2800	220	5476	17296	1068	18272	5832	688	888	10648
DO (mg/L)	4.065	4.471	6.097	6.91	2.43	4.471	5.691	6.097	5.691	4.838
BOD (mg/L)	2.442	2.037	2.04	2.042	2.032	2.037	2.445	1.229	2.032	2.849
Nitrates (mg/L)	0.073	0.073	0.147	0.073	0.22	0.441	0.147	1.102	5.073	6.25
Sulphates (mg/L)	51.504	68.849	97.787	976.106	48.672	1142.47	124.867	16.814	28.141	209.292
Inorganic Phosphates (mg/L)	0.098	0.048	0.022	0.025	0.154	0.052	0.123	0.102	0.029	0.025
Sodium (mg/L)	90.3	62.3	154.4	455.9	75.7	486.6	138.6	16.6	21.1	288.9
Potassium (mg/L)	283.7	194.5	496.2	1476	237.7	1567	438.8	48.2	63	920.1
Total Alkalinity as $CaCO_3$(mg/L)	120	220	160	180	200	240	180	100	100	120
Total Hardness as $CaCO_3$(mg/L)	1100	800	1100	1200	1100	2500	1600	1200	400	1800
Calcium as $CaCO_3$(mg/L)	160.32	160.32	120.24	200.4	80.16	480.96	160.32	40.08	160.32	160.32
Magnesium as $CaCO_3$(mg/L)	3.411	1.949	3.898	3.411	2.923	6.288	5.847	2.436	1.461	6.822
Chlorides (mg/L)	14910	7810	9230	36210	8520	26980	9940	4260	7100	17750
Salinity (mg/L)	26912.58	14097.08	16660.18	65359.08	15378.63	48698.93	17941.73	7689.33	12815.53	32038.78
SAR	9.980	6.916	19.597	45.161	11.745	31.175	15.205	3.6003	2.3460	31.602

for most of the water samples collected during pre-monsoon season, and for all the samples studied during the monsoon season are within the category of hard water. The concentration of calcium ranged between 16.03mg/L to 240.48mg/L as CaCO3 during pre-monsoon, and 40.08mg/L to 480.96mg/L as $CaCO_3$ during monsoon season. The concentration of magnesium in estuary water is comparatively less than the calcium content. The distribution of chloride in estuary water during the two seasons exceeded the permissible limits of surface water quality standards (CPCB, 1999). During monsoon season, the salinity of water from all the stations recorded very high values. Salinity is mainly due to the presence of chlorides. SAR values obtained for most of the water samples exceeded the standard limits prescribed by CPCB (1999).

The concentration of heavy metals in water samples collected during pre monsoon were analysed, and the results of the cadmium, chromium and iron content estimated are given in Fig. 2. Highest value for cadmium content was recorded as 0.21mg/L, and the chromium content ranged from 0.08mg/L to 0.231mg/L in the estuary water. The iron content in water varied from 0.093mg/L to 0.474mg/L. The concentration of chromium in all the study stations exceeded the permissible limits of surface water quality standards. The concentration of iron in surface water sample from station 9 was found beyond the standard limit, and it may be due to the addition of iron salts in the effluents discharged from KMML industry.

The physico-chemical characteristics of the National Thermal Power Corporation (NTPC), Kayamkulam and the Kerala Minerals and Metals Ltd., Chavara (KMML) industrial effluents were given in Table 3. Effluent from NTPC was colorless and that from KMML showed yellowish brown colour. Most of the physico-chemical parameters from NTPC are within the standard limits for the discharge of industrial effluents to inland surface water (Raman and Devotta, 2006). In the case of KMML effluents, the values recorded for BOD, total hardness, chlorides and iron were high compared to that of NTPC effluents. The values obtained for pH and

Table 3. Physico-chemical Characteristics of NTPC and KMML Effluents

Parameters	NTPC	KMML
Temperature (°C)	33	32
pH	6.21	5.45
Electrical Conductivity (μS/cm)	1092	1.380
TDS (mg/L)	436	1048
DO (mg/L)	6.504	4.878
BOD (mg/L)	2.439	5.691
Nitrates (mg/L)	8.23	10.955
Sulphates (mg/L)	14.336	92.831
Inorganic Phosphates (mg/L)	0.052	0.020
Sodium (mg/L)	10.0	12.2
Potassium (mg/L)	6.7	34.7
Total Alkalinity as $CaCO_3$ (mg/L)	440	40
Total Hardness as $CaCO_3$ (mg/L)	196	600
Calcium as $CaCO_3$ (mg/L)	40.08	200.4
Magnesium as $CaCO_3$ (mg/L)	23.390	0.480
Chlorides (mg/L)	82.36	6390
Salinity (mg/L)	148.68	11533.98
Cadmium (mg/L)	BDL	BDL
Chromium (mg/L)	BDL	BDL
Iron (mg/L)	0.101	2.95

BDL- Below Detectable Limit

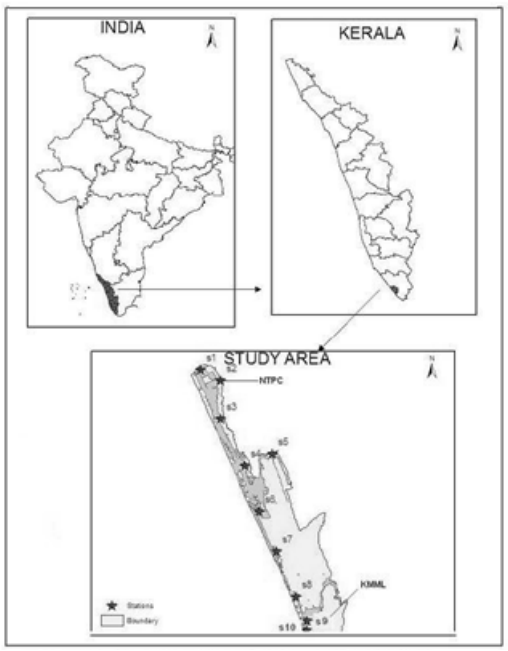

Fig. 1 Location map of study area showing sampling stations

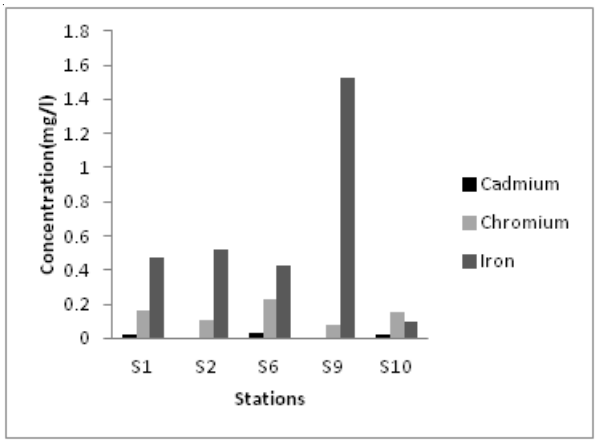

Fig. 2 Concentration of Heavy metals in Surface Water

nitrates in KMML effluent are not satisfying the general standards for the discharge of effluents to inland surface water (Raman and Devotta, 2006). The analyses of NTPC and KMML effluent characteristics also showed that the electrical conductivity of both the effluents was high. Therefore the study reveals that the concentration of pollutants is higher in KMML effluents than in NTPC effluents discharged to the Kayamkulam estuary.

CONCLUSION

The present investigation concludes that the hydrochemical characteristics of the Kayamkulam estuary water showed spatio-temporal changes during the study period. Effluents discharged from the NTPC and KMML industries cause changes in the physical and chemical properties of the estuary. Most of the physico-chemical parameters of estuary water were beyond the standard permissible limits of inland surface water quality and this shows that the Kayamkulam estuary is polluted by different anthropogenic activities. It was found that the stations near to the Ayiramthengu harbour and KMML industry are the most polluted stations of the estuary. The hardness values and SAR values obtained show that the water is not suitable for outdoor bathing and for irrigation. The baseline informations generated through the study on the physico-chemical parameters in water, are useful tools for further ecological assessment and bio-monitoring studies of the Kayamkulam estuary.

RECOMMENDATIONS

- Check the quality of effluents generated from the nearby industries by Pollution Control Board authorities before it is discharged to the estuary.
- Proper treatment should be done before using the water of the Kayamkulam estuary for irrigation purposes.
- Awareness programmes should be conducted among the Public in Alappuzha and Kollam districts to manage the water quality of Kayamkulam estuary.

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