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An appraisal of the dissolved oxygen status of upstream and downstream waters of Ashtamudi estuary

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Abstract
Water, the most vital source for all kinds of life on this planet, is also the resource, adversely affected both qualitatively and quantitatively by all kinds of human activities on land, in air or in water. Estuaries, like the rest of the world are still not adequately protected from human disturbances. Having recognized the importance of Ashtamudi estuary a comprehensive monitoring and an evaluation of the pollution status of the estuary is inevitable. In the present study it is proposed to make an investigation on the Dissolved oxygen content of upstream and downstream waters of Thekkumbhagam Creek of Ashtamudi Lake. The main motive behind this study is to bring out the variations in the Dissolved oxygen characteristics of the water quality that leads to the ecological degradation of the Thekkumbhagam creek. In the present study, dissolved oxygen of surface water ranged between 0 to 7.68 mg/l and dissolved oxygen of bottom water from 0 to 7.12mg/l. Mean values of dissolved oxygen of surface water reached maximum during the monsoon season while dissolved oxygen of bottom water showed a maximum value during post-monsoon period. The decomposition of organic waste and oxidation of inorganic waste may reduce the dissolved oxygen to extremely low levels which may prove harmful to organisms in the aquatic environment. The deteriorating water quality has significantly affected the local tourism development. Present study focuses on conservation of natural resources and restoration of the water quality of the damaged estuary which is the most important way to sustain the estuary for present and future generations.

Keywords: hydrography, DO, physico-chemical, water quality

1. Introduction

The health status and biological diversity of the Indian estuarine ecosystems are deteriorating day-by-day by the dumping of enormous quantities of sewage in to the estuary that has drastically reduced the population of fishes. It has also caused considerable ecological imbalance and resulted in large scale disappearance of their flora and fauna. Having recognized the importance of these estuaries a comprehensive monitoring and an evaluation of the pollution status of the estuary is inevitable. Located in the beautiful southern Indian state of Kerala, the Ashtamudi Lake is an extensive palm shaped water body that lies in the district of Kollam. The very name of the lake points towards the branched topography of the lake, spread over an area of $32km^2$. The lake is located between latitudes 80^0 52′ and$80^0$60′ N and longitudes $76^0$30′ and $76^0$40′ E (Divakaran *et al*., 1982) [3]. All the arms converge into a single outlet at Neendakara to form the second largest estuarine system of Kerala. This estuary is replenished with fresh water brought by the Kallada River which originates in the Western Ghats region. It is the deepest estuary in Kerala with maximum depths 6.4 meters at the confluence zone.

Fresh water inflow occurs through the eastern side of the estuary together with the strong tidal influence from the western side (Narendra Babu *et al.,* 2010) [8]. The surrounding areas are thickly populated, leading to excessive human interferences and subsequent environmental degradations. The National Waterway-3 between Kollam and Kottappuram passes through this region, making it part of the inland navigation services. Dissolved oxygen is perhaps the most important limiting factor in aquatic ecosystems because most organisms other than microbes perish rapidly when dissolved oxygen level in water falls to zero. It is the most important parameter which can be used as an index for water quality, primary production and pollution. Dissolved oxygen concentration greater than 5 mg/l are considered "good" by the national estuary programmed, whereas dissolved oxygen levels below 5 mg/l are typically either stressful or lethal to most aquatic organisms (USEPA, 2007) [14]. The minimum acceptable limit of dissolved oxygen for fish life is 3 mg/l. Thus the measurement of dissolved oxygen and monitoring the changes in dissolved oxygen as a function of time and depth is essential to any study to aquatic ecology because it reflects the status of the dissolved oxygen balance, in turn reflecting the health of ecosystem

A perusal of literature shows that no sufficient study was carried out on the eco-biology of Thekkumbhagam Creek of Ashtamudi Lake. So in the present study it is proposed to make an investigation on the variations in the amount of Dissolved Oxygen content of the Thekkumbhagam Creek of Ashtamudi Lake. A close acquaintance with the hydrobiology of this estuary will help to know the strength of pollution experienced by aquatic resources. The main motive behind this study is to bring out the changes in the physico-chemical and biological characteristics of the water quality leading to the ecological degradation of the Thekkumbhagam creek.

2. Materials and methods

Collection of water samples for hydrographical studies had been made from the four selected sites of the

Thekkumbhagam creek of Ashtamudi estuary in Kollam district for a period of two years (June 2008 to May 2010), covering three prominent seasons of the year (pre-monsoon, monsoon and post-monsoon).Dissolved oxygen was determined by Winkler's Iodometric method. (APHA, 1985) [1].

3. Result and discussion

In Station 1, the dissolved oxygen of surface water ranged from 2 to 7.5mg/l in 2008-2009 and from 2.08 to 7.68mg/l in 2009-2010. The mean values during monsoon, post-monsoon, pre-monsoon were 4.89 ± 1.17, 4.42 ± 0.47, 4.44 ± 0.39 respectively in the first year and 4.94 ± 1.18, 4.6 ± 0.44, 4.52 ± 0.36 respectively in the second year. The annual mean ± SE was 4.59 ± 0.04 in 2008-2009 and 4.68 ± 0.4in 2009-2010. (Table 1.1and Fig 1 & 2) In Station 1 the dissolved oxygen of bottom water ranged from 2.64 to 6.88 mg/l in 2008-2009 and from 2.56 to 7.12 mg/l in 2009-2010. The mean values during monsoon, post-monsoon, pre-monsoon were 4.2 ± 0.72, 5.25 ± 0.55, 4.66 ± 0.16 respectively in the first year and 4.1 ± 0.75, 4.95 ± 0.78, 4.64 ± 0.09 respectively in the second year. The annual mean ± SE was 4.7 ± 0.31 in 2008-2009 and 4.56 ± 0.34 in 2009-2010. (Table 1.1, and Fig 3 & 4). In Station 2, the dissolved oxygen of surface water ranged from 2.16 to7.04mg/l in 2008-2009 and from 2.4 to 7.04 in 2009-2010. The mean values during monsoon, post-monsoon and pre-monsoon were 5.6 ± 0.58, 5.33 ± 0.86, and 3.28 ±0.69 respectively in the first year and 5.7 ± 0.62, 5.86 ± 0.86, 3.2 ± 0.64 respectively in the second year. The annual mean ± SE was 4.74 ± 0.49 in 2008-2009 and 4.92 ± 0.52 in 2009-2010. (Table 1 and Fig 1 & 2).In Station 2, the dissolved oxygen of bottom water ranged from 1.68 to5.92 mg/l in 2008-2009 and from 1.7 to 5.84 in 2009-2010. The mean values during monsoon, post-monsoon and pre-monsoon were 4.72 ± 0.63, 4.66 ± 0.48, and 3.06 ±0.46 respectively in the first year and 4.82 ± 0.61,5.34 ± 1.24, 3.23 ± 0.54 respectively in the second year. The annual mean ± SE was 4.15 ± 0.36 in 2008-2009 and 4.46 ± 0.52 in 2009-2010. (Table 1 and Fig 3 & 4). In Station 3, the dissolved oxygen of surface ranged from 0.4 to 5.68 mg/l in 2008-2009 and from 1.52 to 6.16mg/l in 2009-2010. The mean values during monsoon, post-monsoon and pre-monsoon were 2.21 ± 0.69, 3.66 ± 0.75, and 2.22 ± 0.5 respectively in the first year and 3.06 ± 0.39, 4.28 ± 1, 2.82 ± 0.52 respectively in the second year. The annual mean ± SE was 2.69 ± 0.39 in 2008-2009 and 3.39 ± 0.41in 2009-2010. (Table 1 and Fig 1 & 2 b).In Station 3, the dissolved oxygen of bottom water ranged from 1.04 to6.08 mg/l in 2008-2009 and from 0 to 6.96 mg/l in 2009-2010. The mean values during monsoon, post-monsoon and pre-monsoon were 2.52 ± 0.84, 5.56 ± 0.42, and 2.36 ± 0.67 respectively in the first year and 2.6 ± 0.87, 5.24 ± 0.65, 4.3 ± 1.5respectively in the second year. The annual mean ± SE was 3.48 ± 0.56 in 2008-2009 and 4.05 ± 0.67in 2009-2010. (Table 1 and Fig 3 & 4).In Station 4, the dissolved oxygen of surface water ranged from 0.24 to2.6 mg/l in 2008-2009 and from 0 to 3.68 mg/l in 2009-2010. The mean values during monsoon, post-monsoon and pre-monsoon were 1.62 ± 0.49, 2.39 ± 0.13, and 0.72 ±0.44 respectively in the first year and 1.68 ± 0.48, 2.78 ± 0.3, 0.7 ± 0.44 respectively in the second year. The annual mean ± SE was 1.58 ± 0.29 in 2008-2009 and 1.72 ±0.33 in 2009-2010. (Table 1 and Fig 1 & 2).In Station 4, the dissolved oxygen of bottom water ranged from 0 to6.48 mg/l in 2008-2009 and from 0 to 6.96 mg/l in 2009-2010. The mean values during monsoon, post-monsoon and pre-monsoon were 2.3 ± 1.53, 3.54 ± 0.46, and1.82 ± 1.06 respectively in the first year and 2.34 ± 1.54, 3.24 ± 0.53, 1.84 ± 1.08 respectively in the second year. The annual mean ± SE was 2.55 ± 0.62 in 2008-2009 and 2.47 ± 0.61 in 2009-2010. (Table 1 Fig 3 & 4). ANOVA comparing dissolved oxygen of surface water between stations (2008-2009) showed variations between stations significant at 1% level and between seasons significant at 1% level and between seasons significant at 5% level. For the second year it showed variations between stations and seasons significant at1% level. ANOVA comparing dissolved oxygen of surface water between the years of study for station 1 showed significant variations between seasons and for periods within seasons at 1%level and between years significant at 5% level (Table 2 & 3). ANOVA comparing dissolved oxygen of bottom water between stations showed variations between stations and seasons significant at it1% level for 2008-2009 while showed no significant variations for 2009-2010. ANOVA comparing the dissolved oxygen of bottom water between the years of study for Station 1revealed significant variations between seasons and periods within seasons significant at 1% level. But Station 2 and Station 3 showed variations between years significant at1% level. Station 4 showed variations between years significant at 5% level (Table.4 & 5).

Table 1: Dissolved Oxygen (mg/l) of water (2008-2010)

Year	Season	Month	Dissolved Oxygen (mg/l)							
			Station 1		Station 2		Station 3		Station 4	
			Surface	Bottom	Surface	Bottom	Surface	Bottom	Surface	Bottom
2008-2009	Monsoon	JUN	4.32	3.44	5.92	2.88	3.28	3.28	0.24	0
		JUL	2	2.64	6.88	5.04	3.28	3.44	1.84	0
		AUG	7.52	4.88	5.52	5.76	0.4	0	1.84	2.72
		SEP	5.75	5.84	4.08	5.2	1.88	3.36	2.56	6.48
	Post-Monsoon	OCT	4.88	6.88	6.48	5.92	5.68	6.8	2.48	2.72
		NOV	4.24	4.56	4.44	4.72	3.92	5.2	2	3.6
		DEC	3.2	4.6	7.04	4.4	2.48	5.04	2.6	4.8
		JAN	5.36	4.96	3.36	3.6	2.56	5.2	2.48	3.04
	Pre-Monsoon	FEB	5.44	5.04	5.28	3.44	3.6	4.24	1.12	3.36
		MAR	3.52	4.24	2.16	1.68	2.32	1.04	1.76	3.92

		APR	4.32	4.64	2.72	3.52	1.36	2	0	0
		MAY	4.48	4.72	2.96	3.6	1.6	2.16	0	0
2009-2010	Monsoon	JUN	4.24	3.2	6.08	3.04	3.44	3.44	0.32	0
		JUL	2.08	2.56	7.04	5.2	3.44	3.6	1.92	0
		AUG	7.68	4.8	5.6	5.84	3.48	0	1.92	2.88
		SEP	5.76	5.84	4.08	5.2	1.88	3.36	2.56	6.48
	Post-Monsoon	OCT	4.88	7.12	6.56	5.44	5.84	6.96	2.56	2.8
		NOV	4.56	3.4	6.8	3.68	6.16	3.84	3.68	2.4
		DEC	3.44	4.48	6.8	8.8	2.4	4.8	2.48	4.8
		JAN	5.52	4.8	3.28	3.44	2.72	5.36	2.4	2.96
	Pre-Monsoon	FEB	5.6	4.8	5.12	4.24	3.44	4.16	1.2	3.2
		MAR	3.68	4.4	2.4	1.7	2.48	8.8	1.6	4.16
		APR	4.48	4.72	2.56	3.36	1.52	1.84	0	0
		MAY	4.32	4.64	2.72	3.6	3.84	2.4	0	0

Table 2: ANOVA testing Dissolved Oxygen of surface water between the stations and seasons

	2008-2009			2009-2010		
Source	**Sum of squares**	**Mean Sum of squares**	**F Ratio**	**Sum of squares**	**Mean Sum of squares**	**F Ratio**
Total	169.10			171.90		
Between stations	84.10	28.00	16**	77.70	25.90	15.7**
Between seasons	14.00	7.00	4*	20.40	10.20	6.19**
Periods within seasons	13.10	1.46	0.83	19.42	2.16	1.31
Error	57.80	1.75		54.34	1.65	

Table 3: ANOVA testing Dissolved Oxygen of surface water between the years of study in stations

	Station 1			Station 2		
Source	**Sum of squares**	**Mean Sum of squares**	**F**	**Sum of squares**	**Mean Sum of squares**	**F**
Total	42.90			5185675.00		
Between years	0.10	0.10	6.6*	916546.80	916546.80	5.2*
Between seasons	1.00	0.50	51.78**	350409.50	175204.80	0.98
Periods within seasons	41.76	4.64	499.9**	1961176.00	217908.00	1.22
Error	0.10	0.01		1957543.00	177958.50	
	Station 3			Station 3		
Source	Sum of squares	Mean Sum of squares	F	Sum of squares	Mean Sum of squares	F
Total	1295753.00			78273620.00		
Between years	287667.40	287667.40	5.5*	8002445.00	8002445.00	2.60
Between seasons	228920.00	114460.00	2.20	13892580.00	6946290.00	2.22
Periods within seasons	206971.80	22996.86	0.44	22017600.00	2446400.00	0.78
Error	572193.90	52017.63		34361000.00	3123727.30	

* denote significance (p <.05)

** denote significance (p <.01)

Table 4: ANOVA testing Dissolved Oxygen of Bottom water between the stations and seasons

	2008-2009			2009-2010		
Source	**Sum of squares**	**Mean Sum of squares**	**F Ratio**	**Sum of squares**	**Mean Sum of squares**	**F Ratio**
Total	152.80			193.70		
Between stations	30.80	10.30	5.1**	33.70	11.20	3.90
Between seasons	27.20	13.60	6.82**	15.60	7.80	2.71
Periods within seasons	28.85	3.21	1.60	49.12	5.46	1.89
Error	65.96	2.00		95.21	2.89	

Table 5: ANOVA testing Dissolved Oxygen of Bottom water between the years of study in stations

	Station 1			Station 2		
Source	**Sum of squares**	**Mean Sum of squares**	**F**	**Sum of squares**	**Mean Sum of squares**	**F**
Total	28.10			22782930.00		
Between years	0.10	0.10	1.90	9845806.00	9845806.00	14.5**
Between seasons	3.60	1.80	28.91**	1046632.00	523316.00	0.77
Periods within seasons	23.67	2.63	42.08**	4444870.00	493874.00	0.73
Error	0.69	0.06		7445624.00	676874.90	
	Station 3			Station 4		

Source	Sum of squares	Mean Sum of squares	F	Sum of squares	Mean Sum of squares	F
Total	26142720.00			43611780.00		
Between years	9279707.00	9279707.00	11.3**	13086100.00	13086100.00	9.2*
Between seasons	1866433.00	933216.50	1.14	3990062.00	1995031.00	1.41
Periods within seasons	5993504.00	665944.90	0.81	10942722.00	1215858.00	0.86
Error	9003072.00	818461.10		15592900.00	1417536.40	

* denote significance (p <.05)
** denote significance (p <.01)

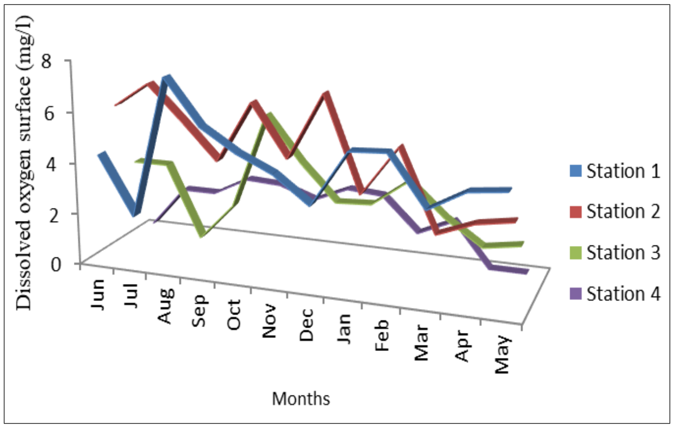

Fig 1: Monthly variations of dissolved oxygen surface 2008-2009)

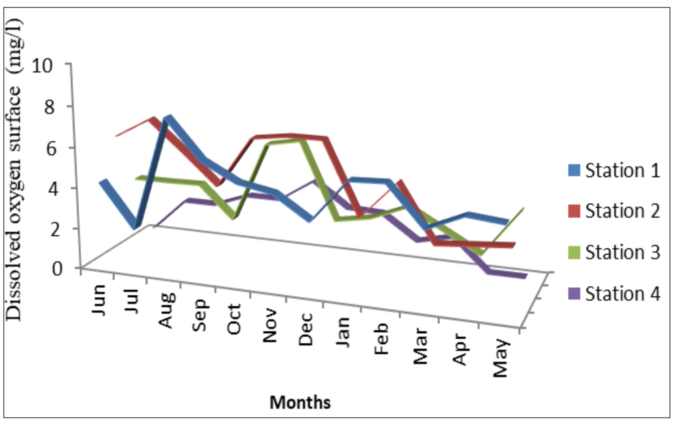

Fig 2: Monthly variations of dissolved oxygen surface (2009-2010)

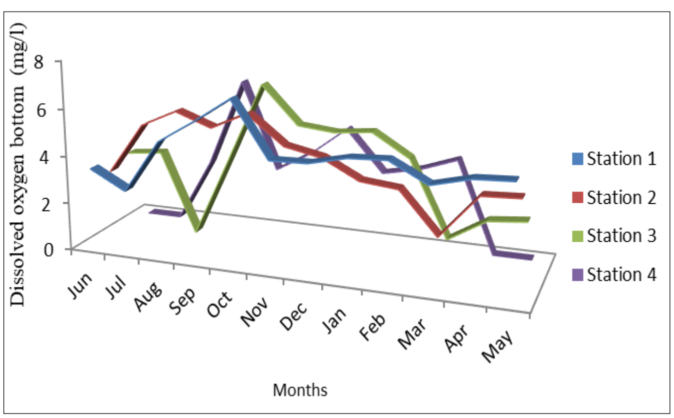

Fig 3: Monthly variations of dissolved oxygen bottom (2008-2009

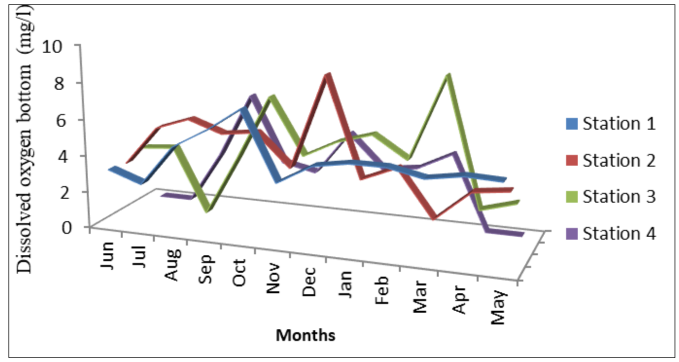

Fig 4: Monthly variations of Dissolved oxygen bottom (2009-2010)

4. Discussion

In the present study, dissolved oxygen of surface water ranged between 0 to 7.52 mg/l and dissolved oxygen of bottom water from 0 to 6.88mg/l in the first year and dissolved oxygen of surface water was 0 to 7.68 mg/l and dissolved oxygen of bottom water from 0 to 7.12 mg/l in the second year. Mean values of dissolved oxygen of surface water reached maximum during the monsoon season while dissolved oxygen of bottom water showed a maximum value during post-monsoon period. Dissolved oxygen concentration was low during the pre-monsoon season but increased during summer and monsoon season. The low dissolved oxygen concentration observed during the pre-monsoon season could be attributed to the lesser input of fresh water in to the study area. Higher value of dissolved oxygen concentration observed in the monsoon was due to the heavy rainfall and the result of fresh water mixing. This was in agreement of the findings of Zingde *et al.*, (1985) [15]; Ramaraju *et al.*, (1987) [12]; Mitra *et al.*, (1990) [6]; Nandan and Abdul Aziz (1994) [7] and Rajasegar (2003) [11].In the monsoon season the estuary was dominated with fresh water flow from Kallada River and land run off, while in the non-monsoon season, the water in the estuary showed predominantly saline characteristics. The concentration of hydrographic parameters was governed by river water flow, sea water intrusion and other input from different human activities, urban sewage, industrial effluents, and coconut husk retting etc. However, during the non-monsoon season, a different context arises due to reduced flow through Kallada River together with the addition of different types of waste materials in large quantities which lead to the depletion of dissolved oxygen and subsequent non oxidation of organic materials. Station 3 and station 4 exhibited mostly the less abundance of oxygen leading to anoxic condition noticed in certain months. This may be due to the uncontrolled deposition of domestic waste, slaughter house wastes, hospital wastes, plastic wastes, poultry wastes, retting activity, co-tourist waste etc. The decomposition of organic waste and oxidation of inorganic waste may reduce the dissolved oxygen to extremely low levels which may prove harmful to organisms in the aquatic environment. The depletion of oxygen content in water lead to undesirable obnoxious odours under anaerobic conditions (Nelson, 1978) [9] and damage to aquatic life. From the study it was observed that in some months the amount of dissolved oxygen in surface waters is usually greater than that in bottom water. This may be attributed to the partial utilization of dissolved oxygen by organic rich sediments. The variation in the amount of dissolved oxygen is also attributed to the seasonal and tidal fluctuations of both surface and bottom waters (Pillai *et al.*, 1975) [10]. High monsoonal values decreased as the season advanced to post-monsoon and premonsoon. Similar patterns in the variation of dissolved oxygen were reported in other estuaries (Kumaran and Rao, 1975) [4]. Low values recorded during pre-monsoon may be due to the discharging effluents and low solubility of oxygen in high saline water. Dissolved oxygen less than 2.5 mg/l was discovered to be hypoxic (Laponite & Clark, 1992) [5]. Another reason for the lesser oxygen content in the bottom water maybe i.e. higher value at the surface could be due to higher photosynthetic activity at the euphotic zone, the inputs from the atmosphere and higher solubility of oxygen in the lower salinity surface water. The lower dissolved oxygen might be attributed to the low solubility of oxygen in saline waters and supports with the previous studies conducted by Sankaranarayanan & Panampunnayil (1979) [13]. Main source of oxygen is aquatic plants, that also provides atmosphere, but during photosynthesis oxygen may fall to unhealthy levels if water is polluted (Clark, 1996) [2]. Dissolved oxygen depletion could suppress respiration cause death of fish, depress feeding or affect embryonic development and hatching success due to oxygen starvation (Clark, 1996) [2]. This could lead to reproductive failures, changes in the composition, abundance and diversity of species at the community level.

5. Conclusion

Dissolved oxygen is a key parameter of interest in water quality monitoring, because nearly all aquatic life needs oxygen to survive. The source of oxygen in water is atmospheric aeration and photosynthesis while the routes of oxygen removal or the “oxygen sinks” are respiration, decomposition of organic matter and losses to atmosphere. Coastal waters typically require a maximum of 40 mg/l and also do better with 5mg/l of oxygen to provide ecosystem function and highest carrying capacity. While dissolved oxygen levels from 1-3 mg/l indicate hypoxic condition and dissolved oxygen below 1 mg/l indicates anoxia, a condition in which no life that requires oxygen can be supported. Thus oxygen distribution provides a good index of productivity and quality of the environment. Higher oxygen concentration is indicative of higher photosynthetic efficiency and phytoplankton production. Thus dissolved oxygen concentration determination is regarded as one of the best methods to assess water quality. Any extraneous influence shifts the balance of this estuarine ecosystem and the variations appear through either changes in abiotic or biotic conditions or both. A knowledge of the seasonal fluctuations of Dissolved oxygen content is thus essential for identifying the suitability and fertility of this estuarine system. Thus for improving the conditions, proper management is required. It is thus, further suggested that all effluents should be treated properly before discharging into the water body’s people should be properly educated dispose of their wastes in a scientific manner.

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