The Scenario of Free Carbon Dioxide Availability in the Upper and Lower Strata of Ashtamudi Estuary

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***Abstract:-*Wetlands, the most productive ecosystems, and in terms of economic and ecosystem service values they outweigh forest ecosystems. The major reason for its drastic decline is the failure to consider wetland as a productive unit of land. They have always been at one time or other a community dumping site of waste of industrial, commercial, agricultural, municipal or domestic orgin, Ashtamudi estuary is one of the major estuarine systems of the south west coast of India. It is an open system as there is no sand bar formation in any season during the course of an year. The Thekkumbhagam creek of this fragile ecosystem that constitute a great potential for economic, cultural, scientific and recreational value to human. At present this estuary is facing many threats like pollution, over-fishing, sand mining, bank erosion and loss of mangroves. The present investigation was undertaken in the light of the lacuna that exists in our scientific understanding of the nature of the seasonal variations of free carbon dioxide in accordance with rainfall availability. The carbon dioxide of surface water values ranges from 0 to 20.68 ppm and bottom water from 0 to 17.62ppm. The study is particularly relevant in the context of the ever increasing threat to the estuarine ecosystem from various sources of pollution. Decisions concerning the protection of these wetland have to be undertaken.**

***Key Words*: - Dissolved oxygen, free carbondioxide, physico-chemical, sustainable, estuary**

I. INTRODUCTION

Estuarine ecosystems are very unique with respect to biodiversity as well as the services provided to the community. As an 'ecotone' between fresh and marine environments, estuaries generally contain a mixture of fresh water and oceanic species. With the sudden increase of population and rapid economic development, these areas are facing many ecological problems. The physico-chemical parameters of water and the dependence of all life process of these factors make it desirable to take water as an environment. A chain of brackish water systems exists in Kerala. The knowledge on the hydrographic parameters of an estuarine environment is of great importance while attempting to characterize its general features. It is important to have a comprehensive data of the seasonal variations of hydrographic features in an estuary.

Hydrographic features show wide variations from estuary to estuary and hence every estuary is unique. Thus hydrological and ecological studies of estuaries are important as these regions are fertile and are the most productive ecosystems of the planet (Jose, 1993)[5]. Estuaries host the complex mix of bio-geochemical processes that can vary temporarily and spatially within the system and often act as opposing or competing influence on nutrient distribution (Badarudeen *et al*., 1996)[1].With the sudden increase of population and rapid economic development, these areas are facing many ecological problems. Such problems have been designed mostly to an excess of nutrients, associated with industrial and municipal waste water, (Balls, 1992)[2] forestry and agriculture (Bell, 1991)[3]. It is important to have a comprehensive data of the seasonal variations of hydrographic features in an estuary.

Bio-monitoring is a thus a novel tool to evaluate water quality based on hydrobiological studies. Without proper conservation, future generations may be left with impoverished biological resources. The investigation was planned with the objective of studying the Thekkumbhagam creek of Ashtamudi estuary's seasonal fluctuation in the free carbon dioxide content with respect to the rainfall availability. This estuary is a tropical backwater habitat in the Kollam district of Kerala, situated on the south west coast of India along the Arabian sea. Carbon dioxide is amongst the common nutrients needed in relatively large quantities by aquatic organisms for their all development. Free carbon dioxide present in water is often formed from respiration of aquatic plants and animals. The decomposition of organic matter also added carbon dioxide to water. Fishery is the major direct use value and hence it should be the focal point for the economic development of the estuary since majority of people living around this estuary earns livelihood out of fishing. Due to the decline in fish availability, the study throws light on that there is a need of concerted effort to conserve the fish stock of the estuary in a sustainable manner.

II. MATERIALS AND METHODS

Monthly water sample collection for the estimation of free carbon dioxide content had been made from four selected sites of Thekkumbhagam creek of Ashtamudi estuary in Kollam district for a period of two years (From June 2008 to May 2010), covering three prominent seasons of the year (pre-monsoon, monsoon and post-monsoon). All collections were made invariably between 6 am and 8 am. Free carbon dioxide was estimated by titration method using sodium hydroxide and Phenolphthalein indicator (Chattopadhyay, 1998)[4]. The meteorological data related to rainfall was collected from the Meteorological Department (Govt. of India), Thiruvananthapuram. The data collected at monthly intervals from all the stations were statistically analysed, with a view to understand the nature of variations in the free carbon dioxide concentration between stations and seasons.

III. RESULT

The monthly variation in rainfall data of the Kollam district and their seasonal mean values are given in table 1.1(Source: Meteorological Station, Thiruvananthapuram).The mean values during monsoon, post-monsoon and pre-monsoon were 293.5 ± 63.64, 127.825 ± 94.59 and 91.75 ± 34.91 respectively during the first year of study (2008-2009). The mean values during monsoon, post-monsoon, pre- monsoon were 275.025 ± 43.45, 167.525 ± 102.64 and 120.925 ± 62.62 during the second year of study 2009-2010.The highest mean values of rainfall were obtained during monsoon in both the years 293.5 ± 63.64 in 2008-2009 and 275.025 ± 43.45 in 2009-2010. The lowest mean values of rainfall were obtained during the pre-monsoon in both the years 91.75 ± 34.91 in 2008-2009 and 120.925 ± 62.62 in(2009-2010).(Fig 1.1a).

In Station 1, the Carbon dioxide of surface water ranged from 0 to 14.52 ppm in 2008-2009 and from 0 to 14.96 ppm in 2009-2010. The mean values during monsoon, post-monsoon, pre-monsoon were 5.56 ± 3.19, 5.72 ± 1.45, 6.82 ±1.81 respectively in the first year and 5.89 ± 3.23, 4.4 ± 0.9, 7.92 ± 1.55 respectively in the second year. The annual mean ± SE was 6.03 ± 1.2 in 2008-2009 and 6.07 ±1.19 in 2009-2010 (Table 1.2, 1.3,1.4 and Fig 1.2a & 1.2b).

In Station 1, the Carbon dioxide of bottom water ranged from 0 to 17.16 ppm in 2008-2009 and from 0 to 17.7 ppm in 2009-2010. The mean values during monsoon, post-monsoon, pre-monsoon were 7.26 ± 3.97, 3.74 ± 0.52, 4.73 ±1.34 respectively in the first year and 7.48 ± 4.01, 4.4 ± 0.65, 5.06 ± 1.14 respectively in the second year. The annual mean ± SE was 5.24 ± 1.35 in 2008-2009 and 5.65 ±1.33 in 2009-2010(Table 1.2, 1.5,1.6 and Fig 1.3a & 1.3 b).

In Station 2, the Carbon dioxide of surface water ranged from 3.52 to15.84 ppm in 2008-2009 and from 3.52 to 16.72 ppm in 2009-2010. The mean values during monsoon, post-monsoon and pre-monsoon were 7.7 ± 2.04, 7.15 ± 1.17, and11.44 ± 1.53 respectively in the first year and 5.72 ± 1.09, 4.36 ± 0.36, 11.33 ± 1.82 respectively in the second year. The annual mean ± SE was 8.76 ± 1.02 in 2008-2009 and 7.14 ± 1.12 in 2009-2010. (Table 1.2, 1.3,1.4 and Fig 1.2a & 1.2b).

In Station 2, the Carbon dioxide of bottom water ranged from 2.64 to11.44 ppm in 2008-2009 and from 3.52 to 12.32 ppm in 2009-2010. The mean values during monsoon, post-monsoon and pre-monsoon were 5.17 ± 0.94, 7.26 ± 1.44, and 7.26 ± 1.42 respectively in the first year and 5.5 ± 0.81, 6.93 ± 1.75, 7.81 ± 1.67 respectively in the second year. The annual mean ± SE was 6.56 ± 0.74 in 2008-2009 and 6.75 ± 0.82 in 2009-2010. (Table 1.2, 1.5,1.6 and Fig 1.3a & 1.3 b).

In Station 3, the Carbon dioxide of surface water ranged from 3.52 to11.88 ppm in 2008-2009 and from 2.64 to 11ppm in 2009-2010. The mean values during monsoon, post-monsoon and pre-monsoon were 7.15 ± 0.28, 7.92 ± 1.89, and 6.82 ± 1.2 respectively in the first year and 7.26 ± 0.38, 5.83 ± 1.84, 6.16 ± 0.95 respectively in the second year. The annual mean ± SE was 7.29 ± 0.69 in 2008-2009 and 6.42 ± 0.66 in 2009-2010. (Table 1.2, 1.3,1.4 and Fig 1.2a & 1.2b).

In Station 3, the Carbon dioxide of bottom water ranged from 2.2 to 8.8 ppm in 2008-2009 and from 1.32 to 9.24 ppm in 2009-2010. The mean values during monsoon, post-monsoon and pre-monsoon were 7.04 ± 0.86, 4.73 ± 0.9, and 3.74 ±0.96 respectively in the first year and 6.93 ± 1.05, 4.07 ± 1.27, 3.96 ± 1.05 respectively in the second year. The annual mean ± SE was 5.17 ± 0.63 in 2008-2009 and 4.99 ± 0.72 in 2009-2010. (Table 1.2, 1.5,1.6 and Fig 1.3a & 1.3 b).

In Station 4, the Carbon dioxide of surface water ranged from 7.04 to20.68 ppm in 2008-2009 and from 2.64 to 11 ppm in 2009-2010. The mean values during monsoon, post-monsoon and pre-monsoon were 12.54 ± 2.34, 10.67 ± 1.51, and 14.19 ± 2.41 respectively in the first year and 12.65 ± 2.45, 10.89 ± 1.13, 14.19 ±2.86 respectively in the second year. The annual mean ± SE was 12.47 ± 1.19 in 2008-2009 and 12.58 ± 1.25 in 2009-2010. (Table 1.2, 1.3,1.4 and Fig 1.2a & 1.2b).

In Station 4, the Carbon dioxide of bottom water ranged from 3.08 to 14.96 ppm in 2008-2009 and from 3.52 to 15.84 ppm in 2009-2010. The mean values during monsoon, post-monsoon and pre-monsoon were 6.49 ± 1.73, 5.7 ± 0.77, and12.43 ± 1.08 respectively in the first year and 6.38 ± 1.53, 6.05 ± 0.63, 12.44 ± 1.44 respectively in the second year. The annual mean ± SE was 8.14 ± 1.13 in 2008-2009 and 8.29 ± 1.1 in 2009-2010. (Table 1.2, 1.5,1.6 and Fig 1.3a & 1.3 b).

ANOVA comparing Carbon dioxide of surface water between the stations, 2008-2009 showed variations between stations significant at 1% level and for periods within seasons significant at 5% level. But the results of ANOVA comparing Carbon dioxide of surface water between the stations, 2009-2010 indicated variations between stations, seasons, periods within seasons significant at 1% level. In the case of Station 1, ANOVA comparing Carbon dioxide of surface water between the years of study showed variations between seasons and for periods within seasons significant at 1% level. But for station 2 and 3 showed variations significant between years significant at 1% level and Station 4 showed variations between years significant at 5% level(Table 1.3 & 1.4).

ANOVA comparing Carbon dioxide of bottom water between the stations of 2008-2009 and 2009-2010 showed no significant variations. ANOVA comparing the Carbon dioxide of bottom water between the years of study to as such that Station 1 showed significant variation between seasons and for periods within seasons at 1% level. The stations 2, 3, 4 showed variations between years significant at 5% level (Table 1.5 & 1.6).

Table 1.1 Rain fall data of Kollam district 2008-2010

Rain fall (mm) - 2008-2009											
Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
207.1	454.8	265.1	247	360.8	122.7	25.6	2.2	3	105.7	121.9	136.4
Mean ± SE (2008-2009)											
Monsoon				Post monsoon				Pre monsoon			
293.5 ± 63.64				127.825 ± 94.59				91.75 ± 34.91			
Rain fall (mm) - 2009-2010											
Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
272.3	369.7	185.5	272.6	325.9	317	15.7	11.5	0	59.1	221.1	203.5
Mean ± SE (2009-2010)											
Monsoon				Post monsoon				Pre monsoon			
275.025 ± 43.45				167.525 ± 102.64				120.925 ± 62.62			

Table 1.2 Free Carbon dioxide (ppm) of water (2008-2010)

Year	Season	Month	CO_2(ppm)							
			Station 1		Station 2		Station 3		Station 4	
			Surface	Bottom	Surface	Bottom	Surface	Bottom	Surface	Bottom
2008-2009	Monsoon	JUN	0	0	13.2	2.64	7.92	4.84	10.56	9.68
		JUL	14.52	17.16	6.16	6.6	7.04	6.6	19.36	9.24
		AUG	2.2	1.76	7.92	4.84	6.6	8.8	8.8	3.08
		SEP	5.5	10.12	3.52	6.6	7.04	7.92	11.44	3.96
	Post-Monsoon	OCT	2.64	3.08	5.28	3.52	3.52	3.08	9.68	3.96
		NOV	7.48	2.64	7.92	6.6	11.88	5.28	11.88	7.04
		DEC	8.8	4.4	10.12	8.8	6.16	7.04	14.08	4.4
		JAN	3.96	4.84	5.28	10.12	10.12	3.52	7.04	6.6
	Pre-Monsoon	FEB	10.12	6.6	15.84	11.44	9.24	6.16	20.68	9.68
		MAR	9.24	7.48	11	5.28	3.52	2.2	14.96	14.96
		APR	2.2	2.64	8.8	5.72	7.04	2.2	10.12	12.76
		MAY	5.72	2.2	10.12	6.6	7.48	4.4	11	12.32
2009-2010	Monsoon	JUN	0	0	4.4	3.52	8.36	4.4	10.56	9.24
		JUL	14.96	17.6	6.6	7.04	6.6	6.16	19.8	8.8
		AUG	3.08	2.2	8.36	4.84	7.04	9.24	8.8	3.52
		SEP	5.5	10.12	3.52	6.6	7.04	7.92	11.44	3.96
	Post-Monsoon	OCT	3.52	3.52	5.28	3.96	3.96	3.52	10.56	4.4
		NOV	3.08	3.08	3.52	4.4	2.64	1.32	11.88	7.04
		DEC	7.04	5.28	4.24	7.92	5.72	7.48	13.2	5.72
		JAN	3.96	5.72	4.4	11.44	11	3.96	7.92	7.04
	Pre-Monsoon	FEB	11	4.4	16.72	12.32	8.8	7.04	21.56	8.8
		MAR	10.12	8.35	10.12	4.4	4.4	2.64	15.84	15.84
		APR	4.84	3.08	9.68	6.6	6.16	3.52	9.24	12.32
		MAY	5.72	4.4	8.8	7.92	5.28	2.64	10.12	12.76

Table 1.3 ANOVA testing dissolved Carbondioxide of surface water between the stations and seasons

	2008-2009				2009-2010			
Source	**DF**	**Sum of squares**	**Mean Sum of squares**	**F Ratio**	**DF**	**Sum of squares**	**Mean Sum of squares**	**F Ratio**
Total	47	859.20			47	952.50		
Between stations	3	279.20	93.10	10.1**	3	335.00	117.70	13.2**
Between seasons	2	34.40	17.20	1.86	2	100.40	50.20	5.93**
Periods within seasons	9	240.35	26.71	2.89*	9	237.63	26.40	3.12**
Error	33	305.22	9.24		33	279.46	8.47	

Table 1.4 ANOVA testing dissolved Carbondioxide of surface water between the years of study in stations

	Station 1				Station 2			
Source	DF	Sum of squares	Mean Sum of squares	F Ratio	DF	Sum of squares	Mean Sum of squares	F Ratio
Total	23	379.10			23	60195640.00		
Between years	1	0.00	0.00	0.00	1	30193250.00	30193250.00	22.2**
Between seasons	2	22.70	11.30	7.62**	2	2124174.00	1062087.00	0.78
Periods within seasons	9	340.06	37.78	25.42**	9	12890079.00	1432231.00	1.05
Error	11	16.35	1.49		11	14988140.00	1362558.00	

	Station 3				Station 4			
Source	DF	Sum of squares	Mean Sum of squares	F Ratio	DF	Sum of squares	Mean Sum of squares	F Ratio
Total	23	32977870.00			23	119016400.00		
Between years	1	15991190.00	15991190.00	20.7**	1	35114080.00	35114080.00	9.2*
Between seasons	2	805367.00	402683.50	0.52	2	7652076.00	3826038.00	1.00
Periods within seasons	9	7687724.00	854191.60	1.11	9	34285401.00	3809489.00	1.00
Error	11	8493584.00	772144.00		11	41964850.00	3814986.40	

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

Table 1.5 ANOVA testing dissolved Carbondioxide 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	604.30			628.30		
Between stations	70.20	23.40	2.00	74.90	25.00	2.00
Between seasons	25.10	12.50	1.06	31.10	15.50	1.27
Periods within seasons	119.20	13.24	1.12	119.18	13.24	1.08
Error	389.88	11.81		403.15	12.21	

Table 1.6 ANOVA testing dissolved Carbondioxide 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	476.50			23442.00		
Between years	1.00	1.00	1.90	19377.90	19377.90	133.4**
Between seasons	47.20	23.60	47.16**	769.70	384.80	2.65
Periods within seasons	422.83	46.98	93.88**	1697.55	188.62	1.30
Error	5.50	0.40		1597.38	145.22	

	Station 3			Station 4		
Source	Sum of squares	Mean Sum of squares	F	Sum of squares	Mean Sum of squares	F
Total	18038.80			27415.30		
Between years	13932.20	13932.20	84.8**	20551.40	20551.40	66.8**
Between seasons	1125.60	562.80	3.43	2167.10	1083.50	3.52
Periods within seasons	1174.39	130.49	0.79	1310.84	145.65	0.47
Error	1806.61	164.24		3386.02	307.82	

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

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

Fig 1.1a Distribution of rainfall in Kollam district (2008-2010)

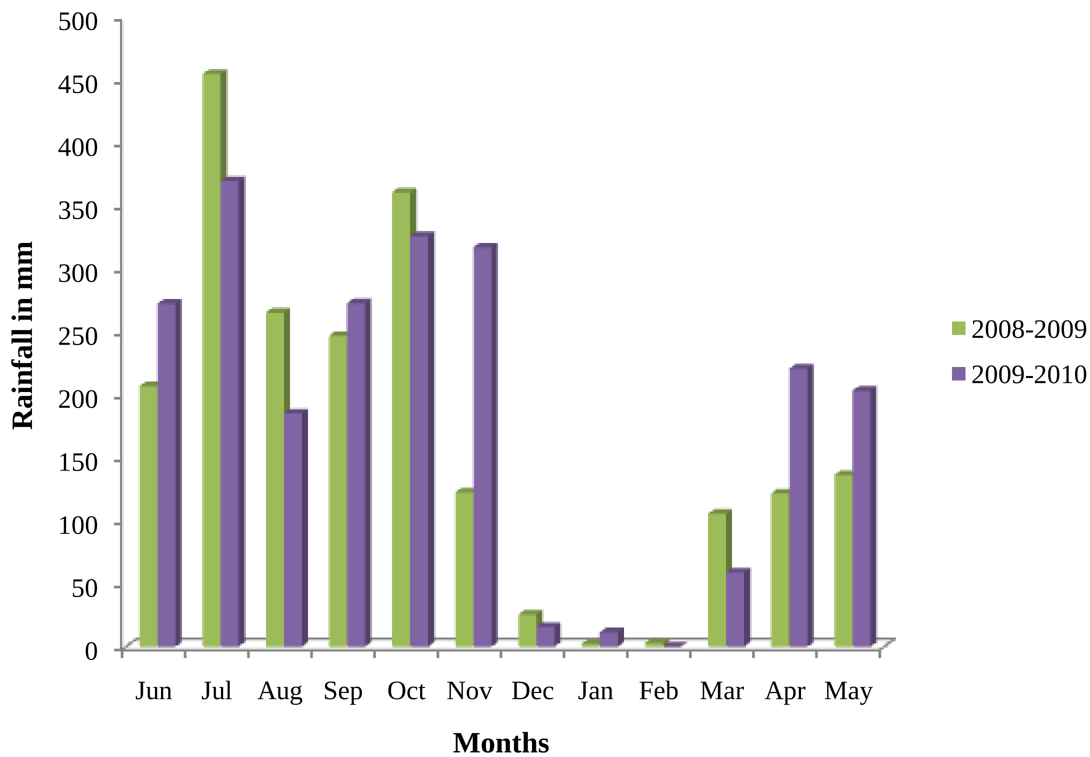
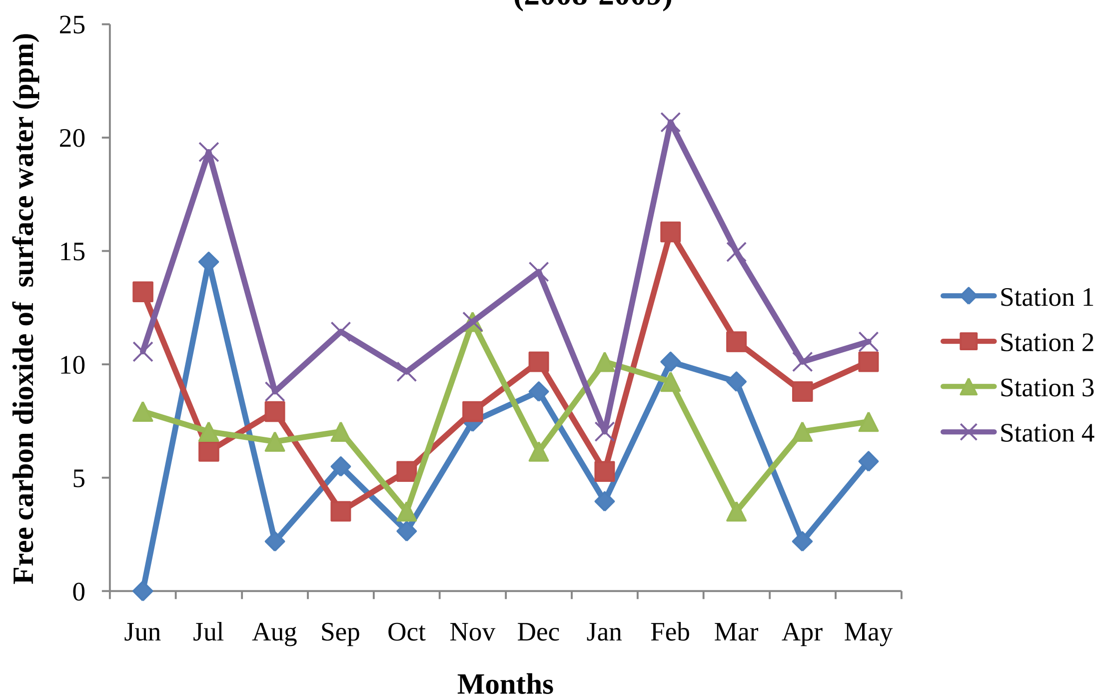


FIg 1.2 a Monthly variations of carbon dioxide of surface water (2008-2009)



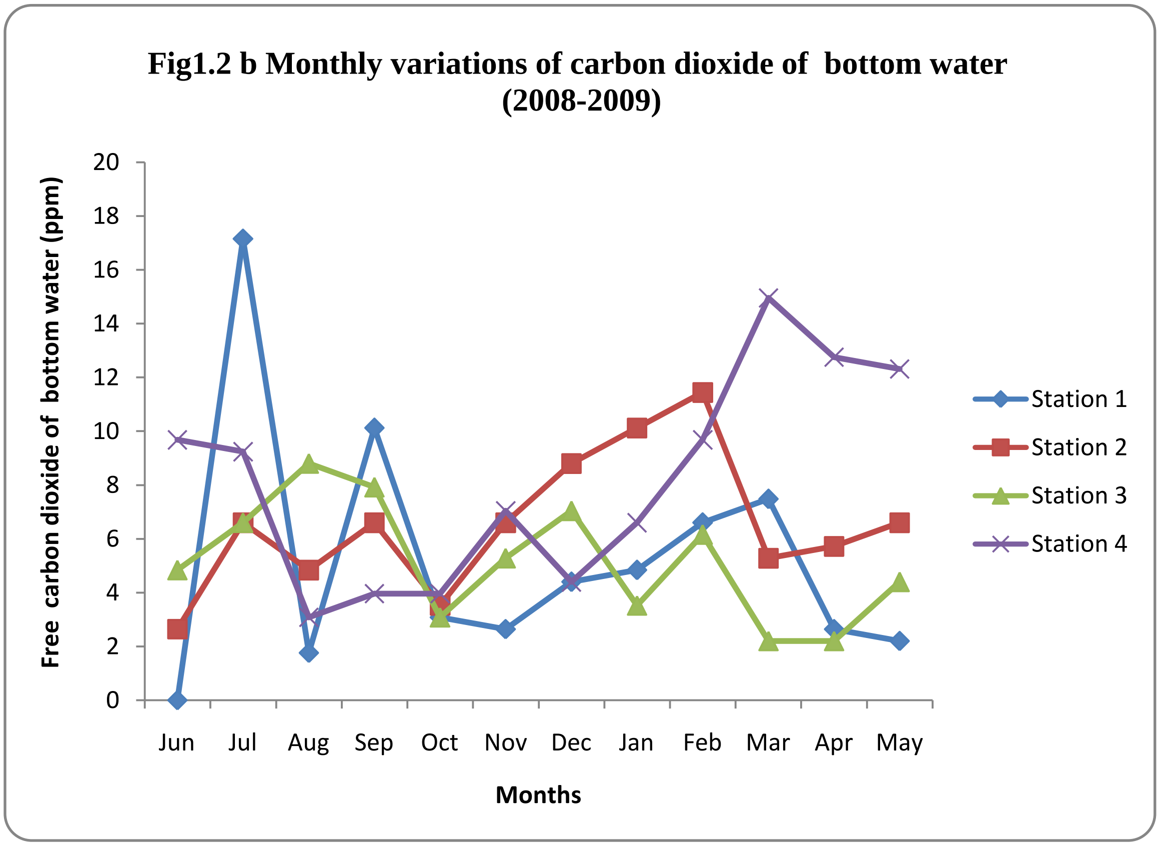


Fig1.2 b Monthly variations of carbon dioxide of bottom water
(2008-2009)
Free carbon dioxide of bottom water (ppm)
0
2
4
6
8
10
12
14
16
18
20
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Months
Station 1
Station 2
Station 3
Station 4

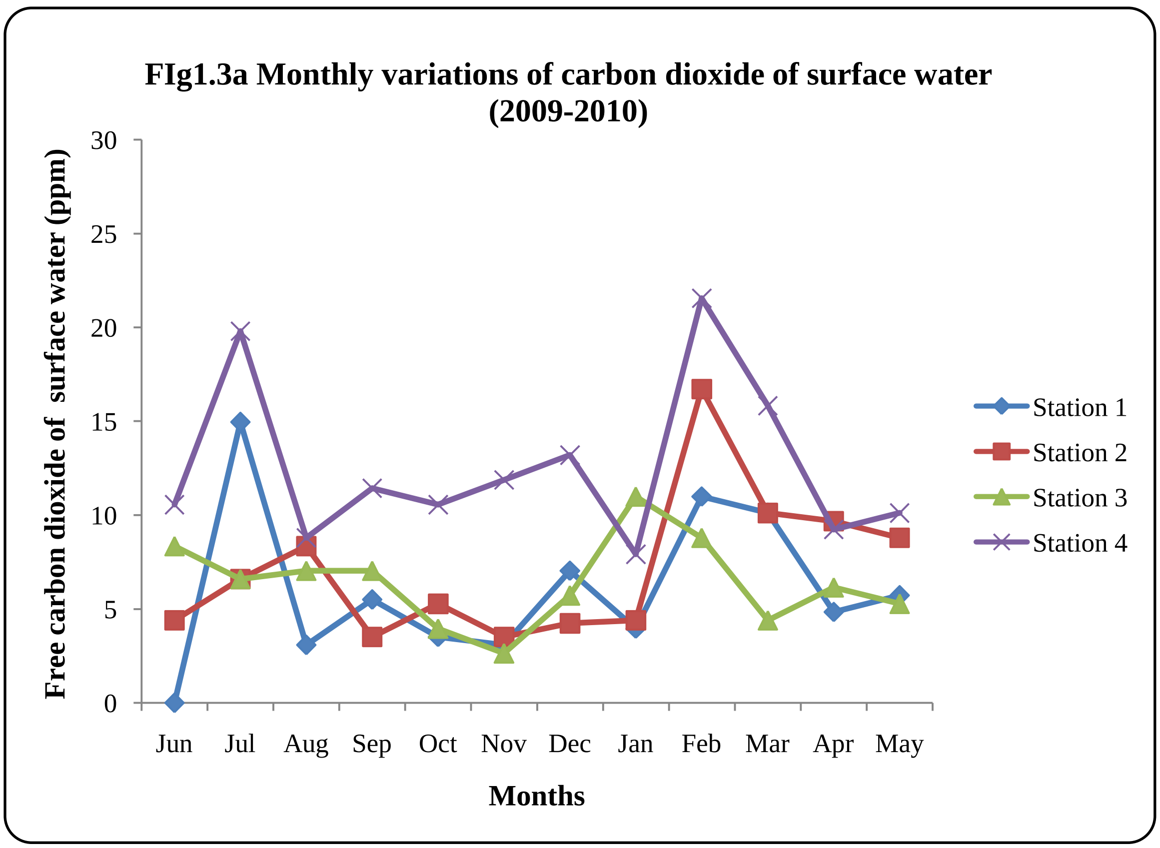
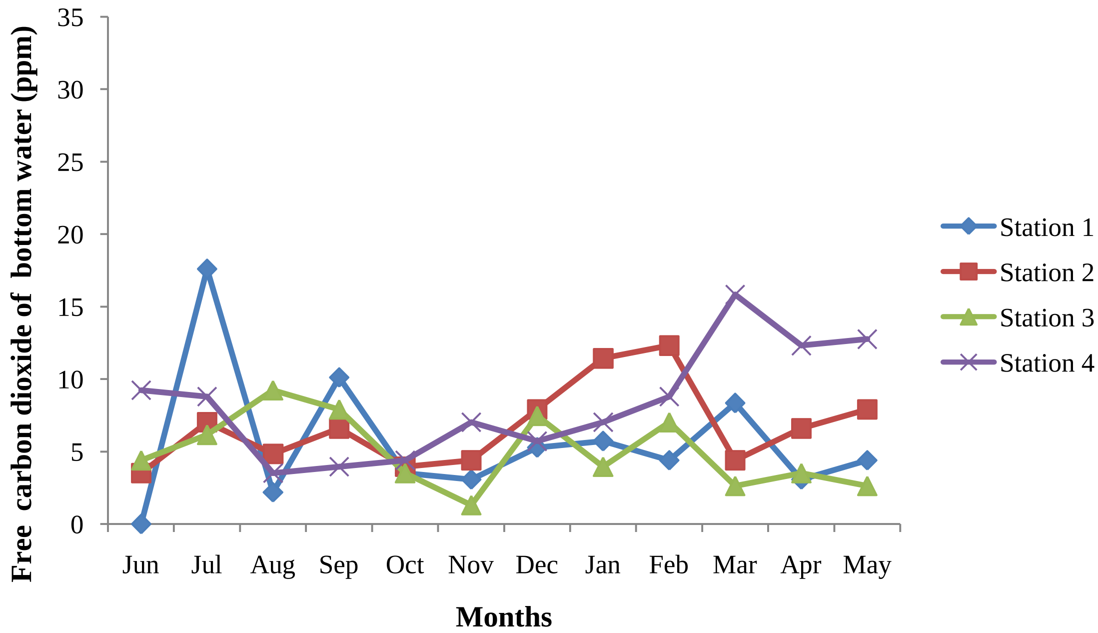


FIg1.3a Monthly variations of carbon dioxide of surface water
(2009-2010)
Free carbon dioxide of surface water (ppm)
0
5
10
15
20
25
30
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Months
Station 1
Station 2
Station 3
Station 4

Fig 1.3 b Monthly variations of carbon dioxide of bottom water (2009-2010)



IV. DISCUSSION

Respiratory activity of aquatic organisms and process of decomposition are important sources of carbon dioxide in water bodies. Agitation and evaporation of water remove free carbon dioxide from water. Carbon dioxide is also used by aquatic plants for photosynthesis compared to other major constituents of air (Oxygen and Nitrogen). Carbon dioxide has a very high solubility in water which is due to partly the fact that Carbon dioxide reacts with water and the dissolved cations present in it, forming carbonic acid and carbonates. The solubility decreases significantly with temperature. The carbon dioxide of surface water values ranges from 0 to 20.68 ppm in 2008-2009 and bottom water from 0 to 17.16 ppm. In the second year, it ranges from 0 to 16.72 ppm for surface and 0 to 17.62ppm for bottom. In the present study carbon dioxide shows inverse relationship with oxygen. Similar findings were made by Laxminarayan (1965)[7] and Salve and Hiware (2006)[8]. Considerable rise in carbon dioxide values could be due to hospital discharges and the organic enrichment from retting areas.

Apart from diffusion in to water from atmosphere, the carbon dioxide enters water body through precipitation, infiltration and as products of metabolic activities of the organisms in water. The decomposition of organic matter also added carbon dioxide to water. Carbon dioxide dissolved in water is essentially the only source of carbon that can be assimilated and incorporated in to the body of the aquatic autotrophs. Aerobic decomposition of organic matter produces carbon dioxide while anaerobic decomposition produces carbon dioxide as well as methane, besides other gases in low concentration. Estuaries host the complex mix of bio-geochemical processes that can vary temporarily and spatially within the system and often act as opposing or competing influence on nutrient distribution (Badarudeen *et al*., 1996)[1]. The environmental conditions such as topography, Dissolved Oxygen, Free Carbondioxide, water movement, salinity, oxygen, temperature and nutrients characterizing particular water mass, also determine the composition of its biota (Karande, 1991)[6]. Human made debris, particularly plastics can have negative effects on marine and estuarine environment.

V. CONCLUSION

Hydro-biological studies have attained worldwide recognition in recent times, particularly in association with the ecological studies of the aquatic environments. Hydrology constitutes hydrochemistry and hydrobiology. Knowledge of the free carbondioxide content of the medium is essential for a scientific approach to the problem of organic production in the backwaters. A close acquaintance with the hydrobiology will help to know the strength of the pollution experienced by the aquatic resources. Present study elucidates the natural process of carbonbdioxide formation consisting biological uptake and regeneration apart from freshwater flushing time. Higher free carbondioxide concentration was associated with lower Dissolved oxygen content. Thus the system was delicately poised by the continuous release of pollutants by anthropogenic activities. Thus the backwaters of Kerala are unfortunately polluted by the persistent effects of globalization. Retting of coconut husk holds a serious threat to the backwaters of Kerala.The scientific knowledge of the economic values and benefits stresses on the need for achieving sustainable success in the protection of these wetland ecosystem.

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