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ASSESSMENT OF SEASONAL AND SPATIAL VARIATIONS IN THE WATER QUALITY OF A TROPICAL URBAN WETLAND IN KERALA, INDIA.

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***Abstract**:* Wetlands are one of the most productive aquatic ecosystems on earth, and their water quality is an indicative of their suitability for maintaining various ecosystem services. In this study, physico chemical analysis is employed to access the status and spatiotemporal patterns in water quality of a tropical urban wetland, Kottuli wetland, Kerala, India. This study enhanced our knowledge about the spatiotemporal patterns in water quality and in the future will be helpful to the policymakers and concerned authorities for developing better water quality management strategies for these wetlands.

***Index Terms* – Kottuli wetland, Seasonal and spatial variation, Water quality parameters.**

I. INTRODUCTION

The unlimited and non-wise use of these water resources for economic developments, industrialization, and agricultural activities has resulted in water quality degradation (Deep et al. 2020; Kaur et al. 2020). The deterioration of water quality has taken the attention of scientists and social activists globally (Mishra et al. 2015). Wetlands are very productive ecosystems, which help in the regulation of biological cycles, maintenance of water quality, nutrient movement and support for food chains. So, conservation of wetlands is very much essential as wetlands are one of the most threatened habitats of the world. The most important step for conservation of wetlands is to maintain a proper water quality (Kamble et al. 2009). It is a well-established fact that domestic sewage and industrial effluent discharges result in changes of water quality and eutrophication. The other important sources of water pollution include mass bathing, rural waste matter, agricultural runoff and solid waste disposal. Now wetlands are shrinking rapidly because of urbanization and industrialization. Therefore, monitoring wetland water quality can identify areas where urbanization and agricultural practices are impairing water quality and if changes in water quality are occurring over time. Surface water bodies are highly susceptible to pollution due to their easy accessibility for wastewater disposal and other pollutants (Singh et al. 2004; Sharma and Bhattacharya 2017). If the surface water is polluted, it affects the groundwater and vice versa (Edet and Worden 2008). In India wetlands are distributed in almost all bioclimatic regions and biogeographic zones. The total wetland area of the country is about 4.1 million hectares. Nevertheless, for a range of anthropogenic pressures the wetland areas in the country are undergoing frightful depletion in the past couple of decades. Wetland diversion reclaiming the water-logged ecosystem to other uses especially for building construction is widespread in the country. Cities actually grow in area at the expense of the wetlands. The negative impacts of urbanization and development that is practically irreversible is visible on its environment, microclimate and biodiversity. To moderate such damaging consequences, it is more redeeming to build and conserve green areas inside urban centers. These green patches add the ecological value of the city, by conserving water, reducing air as well as noise pollution. The green spaces act as control for the local climate (Jansson et al. 2007a). Kerala stands up among all the states of India in having a large proportion of land under wetlands (Nayar and Nayar, 1997). The water quality is directly related to the health of the water body. So, proper management in water quality of aquatic environment is very much essential. Some of the most recent works on water quality of various aquatic environments was those of Gopalkrishna (Gopalkrishna et.al. 2011), Offemet al. 2011). In such studies the characteristics of water bodies were taken into consideration with reference to physical and chemical properties. Regular water quality monitoring is essential to develop strategies for improving the ecological conditions and conserving water bodies' status (De Troyer et al. 2016; Dinka et al. 2015). The water chemistry of any water body is subject to spatial and temporal variations around the year, as environmental conditions do not remain constant. The routine water sampling and analysis of a maximum number of the water body's physicochemical parameters are a must for reliable monitoring of water quality condition (Meybeck and Helmer 1989; Simeonov et al. 2003).

II. MATERIALS AND METHODS

2.1. Study area

The Kottuli wetland is the largest eco-patch in the Kozhikode city limits. It is interlinked with the man-made Canoly canal which receives tidal influx from the Kallai and Korapuzha estuaries. The portion of the wetland, now intact, is mainly on the eastern periphery of the Eranhipalam-Arayedathupalam stretch of Canoly Canal (11^0 19’25.9” N & 75^0 50’ 24.3” E and 11^0 14’18.1” N & 75^0 47’43.6” E). It is major receptacles of flood water from the city, a primary recharge source for wells in the vicinity, sink for pollutants including city and hospital waste and a rich mangrove habitat. Kottuli wetland directly or indirectly influence the health, economy, and social set up of Calicut city However, in recent years, the canal has degenerated to an urban sewer, stagnant with municipal and other filth. The rich floral biodiversity of 250 floral species including unique mangroves and its rare water birds (Aziz et al.2009) also highly enriches tourism potential of the Kottuli wetlands. Originally, a part of this wetland with an area of about 87.04 hectares, of this, 22.5 hectares of land has been reclaimed for human settlement and the reclamation is continuing. Since Kottuli wetland located in the urban area of Kozhikkode, the industrial and domestic discharges in the adjacent areas have made unauthorized connection to the sewers to empty their untreated wastewater. The sewers on the other hand empty the water into the channels that later on join the wetlands. This is causing a deposition of the nutrients & heavy metals in the canals and ultimately led to the deterioration in the hydrochemical quality of wetlands. Thus, due to different levels of anthropogenic pressures /activities like urban development, encroachment, discharge of domestic sewage, pesticides fertilizers and industrial effluents, infestation with aquatic weeds and eutrophication, disturbances from excessive recreational activities and tourism, and diversion of irrigation water, domestic use or industrial uses, this wetland has been under threat from various directions and hence, learning to explicate them is inevitable. The wetland at Kottuli is one among the 94 wetlands of national importance identified by the Government of India for conservation action under National Wetland Conservation Programme (MoEF, 2006-2007).

2.2. Water sampling

In order to understand the water quality of Kottuli wetland and areas near to its vicinity, 14 surface water samples were collected and analyzed for different chemical parameters. The surface water samples were collected during pre-monsoon, monsoon and post monsoon period of year 2010 from the ponded area of Kottuli wetland near Sarovaram tourism area and nearby areas on the stretch of Cannoli canal for the present study. The details of the sampling stations were marked in the area map (Figure 2.2.1).

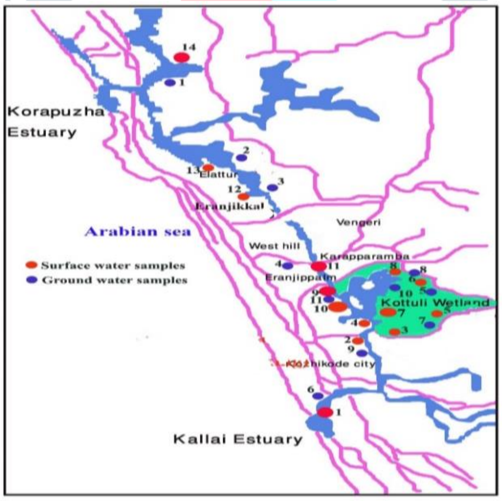


Figure. 2.2.1: Study area and location of the Kottuli wetland

III. RESULTS AND DISCUSSION

The results of seasonal and spatial water quality patterns on the basis of individual parameters in pre, post and monsoon seasons are given in Table .3.1 and detailed below,

Table.3.1: Seasonal and spatial variation of water quality parameters of Kottuli wetland
All values of parameters are presented in mg/l except- temperature (in 0C) and pH
ND: Not Detected

Seasons	Stations	pH	TDS, mg/l	Calcium mg/l	Magnesium mg/l	Sodium mg/l	Potassium mg/l	Chloride mg/l	Alkalinity mg/l	Nitrate-N mg/l	DO mg/l	BOD mg/l	Sulphate, mg/l	Inorganic phosphate-P mg/l
PRE-MONSOON	KTS1	5.8	73.75	28.80	2.91	13.60	2.20	24.00	20.00	12.67	ND	50.16	16.84	0.044
	KTS2	6.6	102.5	20.80	17.49	23.20	3.40	32.00	20.00	6.96	5.808	11.35	15.00	0.0383
	KTS3	6.30	82.14	27.20	1.944	13.60	2.60	28.00	24.00	8.32	ND	65.34	21.64	0.049
	KTS4	5.70	73.66	16.00	1.94	13.20	3.10	32.00	36.00	14.5	7.52	5.742	17.72	0.026
	KTS5	4.70	55.25	12.80	3.88	13.20	3.00	16.00	16.00	10.82	ND	29.7	18.68	0.041
	KTS6	6.30	68.13	16.00	3.88	18.80	2.80	20.00	16.00	8.7	9.76	6.20	21.04	0.02
	KTS7	6.90	79.86	19.20	10.69	15.06	2.50	24.00	12.00	13.75	8.646	6.01	19.04	0.030
	KTS8	6.60	83.42	32.00	5.83	18.00	3.10	24.00	12.00	5.2	4.68	1.52	17.72	0.043
	KTS9	8.00	85.93	35.20	1.94	18.40	2.40	20.00	8.00	4.9	8.31	5.14	18.40	0.044
	KTS10	6.00	75.78	25.60	0.97	15.60	2.60	28.00	12.00	10.75	8.58	6.20	18.44	0.034
	KTS11	6.40	63.2	22.40	1.94	16.80	2.50	12.00	16.00	6.86	5.87	3.96	18.88	0.032
	KTS12	5.9	91.58	28.80	17.49	14.40	1.70	16.00	16.00	9.72	10.09	6.79	22.64	0.035
	KTS13	6.7	84.68	28.80	7.77	25.20	2.20	16.00	16.00	4.25	10.75	7.59	17.36	0.043
	KTS14	6.3	77.73	25.60	18.46	20.40	1.20	8.00	16.00	3.55	9.504	7.656	17.80	0.036
MONSOON	KTS1	6.40	62.37	11.20	9.72	6.00	1.00	8.00	12.00	8.60	ND	73.26	14.32	0.86
	KTS2	7.50	84.58	19.20	11.66	17.2	1.6	20.00	16.00	12.60	8.81	5.80	11.38	0.76
	KTS3	5.90	75.52	20.80	1.94	11.20	1.40	12.00	16.00	17.80	ND	77.22	17.32	0.76
	KTS4	6.20	58.43	9.60	1.94	10.00	1.30	12.00	24.00	13.20	10.824	8.316	15.36	0.45
	KTS5	5.18	50.34	8.00	4.86	10.40	1.80	4.00	16.00	11.30	ND	37.62	15.04	0.76
	KTS6	6.50	61.34	6.40	7.77	14.00	1.40	8.00	8.00	16.67	10.626	5.808	16.16	0.46
	KTS7	7.40	62.73	8.00	9.72	10.80	1.00	12.00	4.00	7.65	9.9	5.808	15.36	0.56
	KTS8	7.80	80.88	25.60	4.86	12.00	1.60	12.00	8.00	8.83	7.59	3.762	13.00	0.75
	KTS9	7.80	71.23	22.40	4.86	13.60	0.70	8.00	12.00	14.6	9.57	5.346	13.60	0.76
	KTS10	6.40	70.23	20.80	1.94	11.60	1.10	12.00	16.00	11.34	10.758	7.194	14.36	0.55
	KTS11	7.50	56.33	16.00	0	10.40	1.10	8.00	16.00	13.62	7.656	5.28	15.12	0.65
	KTS12	6.60	81.58	24.00	11.66	10.40	0.8	12.00	12.00	5.50	12.408	7.59	17.44	0.52
	KTS13	6.80	74.5	22.40	8.74	18.40	1.4	8.00	16.00	7.40	11.154	7.458	13.92	0.61
	KTS14	6.80	68.90	19.20	13.60	16.00	0.5	8.00	8.00	16.12	10.032	5.148	14.56	0.55
POST MONSOON	KTS1	7.90	32.67	1.60	2.91	9.20	1.40	16.00	4.00	12.42	ND	55.44	6.88	0.054
	KTS2	8.04	66.12	16.00	2.92	13.60	2.70	24.00	4.00	13.30	6.79	4.68	8.60	0.04
	KTS3	6.40	56.99	12.80	3.88	8.00	2.00	24.00	12.00	20.35	ND	73.26	12.92	0.05
	KTS4	7.75	49.12	4.80	4.86	7.20	2.30	20.00	8.00	15.8	9.76	7.65	7.48	0.03
	KTS5	5.60	40.4	4.80	4.86	6.00	2.00	12.00	8.00	14.2	ND	33.66	8.20	0.05
	KTS6	7.08	47.41	3.20	5.83	11.20	1.80	16.00	4.00	19.25	10.03	5.47	11.28	0.03
	KTS7	8.00	48.1	4.80	2.91	8.00	1.80	16.00	8.00	11.34	9.50	5.74	8.00	0.046
	KTS8	8.11	64.93	14.40	9.72	9.60	2.30	20.00	4.00	13.28	5.74	2.17	7.48	0.056
	KTS9	8.21	60.98	16.00	5.83	10.40	1.80	12.00	4.00	16.7	9.04	5.41	7.00	0.054
	KTS10	7.21	53.78	11.20	4.86	10.00	1.60	20.00	8.00	14.41	10.23	7.12	7.28	0.042
	KTS11	8.01	47.31	3.20	6.80	7.20	1.80	12.00	4.00	16.58	6.40	4.42	7.76	0.040
	KTS12	7.50	70.8	17.60	10.69	6.00	1.50	16.00	8.00	9.37	10.62	8.38	12.96	0.046
	KTS13	7.20	56.6	12.80	4.86	15.20	1.80	12.00	8.00	10.26	11.28	7.78	7.84	0.05
	KTS14	7.21	57.64	11.20	7.77	11.60	0.90	8.00	8.00	16.12	10.82	6.60	6.12	0.043

3.1. pH

The pH of Kottuli surface water samples in the pre-monsoon varied from 4.7 to 8.0 with an average around 6.3, in monsoon it varied from 7.08 to 8.21 with an average of 7.6 and in the post- monsoon varies from 7.24 to 8.13 with an average around 7.0 (Fig. 3.1). The acidic pH in all season is shown by sample taken from the wetland site were coir retting activities were found. It was also noticed that the minimum pH values during pre-monsoon may be due to high photosynthesis of micro and macro vegetation resulting in high production of free CO_2, shifting the equilibrium towards alkaline side (Suthara 2005). This fact was also revealed the existence of aerobic conditions and lesser anthropogenic sources as compared to the other seasons.

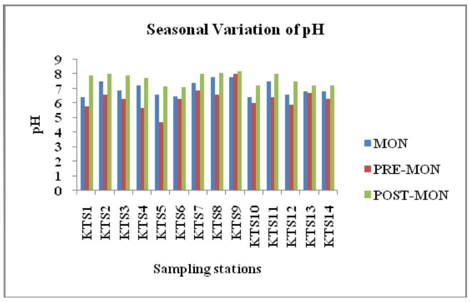


Figure 3.1. seasonal and spatial variation of pH in Kottuli wetland

3.2. Electrical Conductivity

In the study area, the conductivity ranged from 63-160µS, high during Post monsoon (86-160µS) and low in monsoon season (63-103µS). High conductivity during post monsoon might be attributed to low mixing of fresh water input. Low value during monsoon season was due to rain and mixing of more fresh water. The conductivity values decreased with an increase in rainfall. In the rainy season, the increased volume of water remarkably diluted the water (Izonfuo et al 2001).

3.3. Total dissolved solids (TDS)

In the study area, the concentration of TDS ranges from 55.25 to 102.45 mg/l with an average of 84 mg/l in pre-monsoon period, 32.67 to 66.12 mg/l with an average of 57.6 mg/l in post monsoon whereas in monsoon period ranges from 50.33 to 84.52 mg/l with an average of 68.5 mg/l (Fig. 3.2). The TDS value is found to be greater in the mixing point of the wetland system with Cannoli canal near Baby memorial hospital, which carries much of the drainage of Calicut city. The TDS concentration was again found to be more in pre-monsoon, which may be attributable to greater solubility of ions at higher temperature.

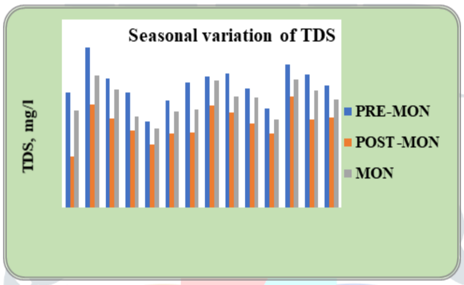


Figure 3.2. seasonal and spatial variation of Total dissolved solids in Kottuli wetland

3.3. Calcium

The concentration of calcium ranges from 6.4 to 25.6 mg/l with an average of 1.19 mg/l in monsoon and in pre-monsoon it ranges from 16 to 35.2 mg/l with an average of 25.95 mg/l (Fig. 3.3). Maximum calcium contents were observed during pre-monsoon and minimum during monsoon. The level of calcium was low in monsoon season probably due to its utilization by the biotic community. Evaporation of water due to high temperature, increase of calcium in summer is due to the decomposition of aquatic vegetation and low level of water. This has been corroborated by several workers such as Garg et al. 2006, Garg et al. 2009, Saxena et al .2009 and Jain et al.2011.

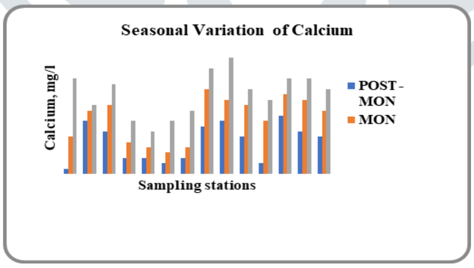
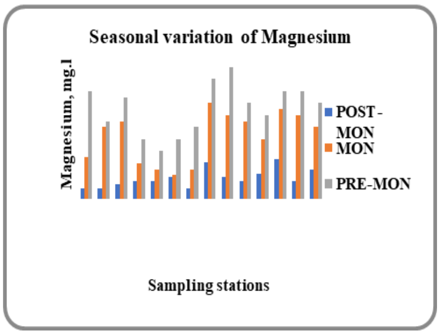


Figure 3.3. seasonal and spatial variation of calcium in Kottuli wetland

3.4. Magnesium

Magnesium is often associated with calcium in all kinds of waters, but their concentrations remain generally lower than the calcium. In the present study, the magnesium was varying from 0.97 to 18.46 mg/l having an average of 7.48 in pre-monsoon, whereas 2.9 to 7.77 mg/l with an average of 6.02 in post monsoon. (Fig. 3.4). The magnesium was higher in summer and lower in monsoon season. This may be due to the uptake of magnesium by phytoplankton and macrophytes in the formation of their chlorophyll-magnesium perphyrin- metal complex and is also used in enzymatic transformations. These results are consistent with the observations obtained by Garg et al .2006, Kumar et al .2009 and Verma et al .2012.



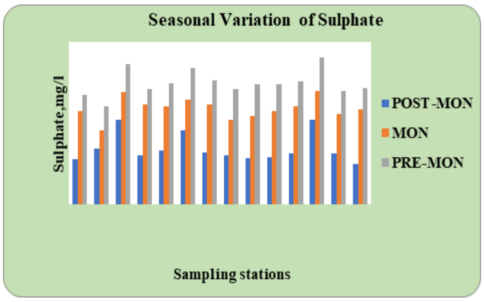


Figure 3.4. seasonal and spatial variation of magnesium in Kottuli wetland

3.5. Sodium

The sodium concentration ranges from6 to 15.2mg/l with an average mean of 0.67mg/l in post monsoon period whereas in pre-monsoon it ranges from 13.20 to 25.20 mg/l with an average mean of 18.36 mg/l (Fig. 3.5). An enrichment of sodium contents was found in rainy and pre-monsoon seasons, while its contents were lesser in post monsoon season. The low value of sodium recorded in post monsoon season in the present study is due to utilization by plankton and other aquatic organisms, while the high values were recorded in pre-monsoon & monsoon due to heavy flows of domestic & industrial discharges to the studied sites also may attribute to the effect of evaporation in summer. Above observations get support from the earlier findings of Garg et al.2006, Saxena et al. 2009 and Verma et al. 2012.

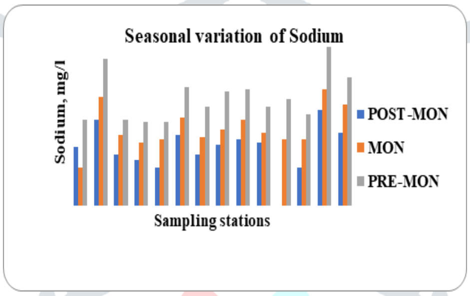


Figure 3.5. seasonal and spatial variation of sodium in Kottuli wetland

3.6. Chloride

The concentration of chloride ion varies from 8 to 24 mg/l with an average of 16 mg/l in post monsoon period whereas in it varies from 8 to 32 mg/l with an average of 23 mg/l in pre-monsoon period and in monsoon the values varies from 4 to 16 mg/l with an average of 10 mg/l (Fig. 3.6). The high chloride contents might be attributed to the presence of large amount of organic matter of both allochthonous and autochthonous origin. High chlorides contents in the study area were observed during summer months and low in monsoon months which were due to increased temperature and consequent evaporation of water from the water body especially in summer and dilution effect of runoff water from catchment area in monsoon (Sharma et al. 2010, Sinha et al. 2011 and Verma et al 2012). During monsoon, the Cl- content in the wetland region is quite low indicating cleaner water.

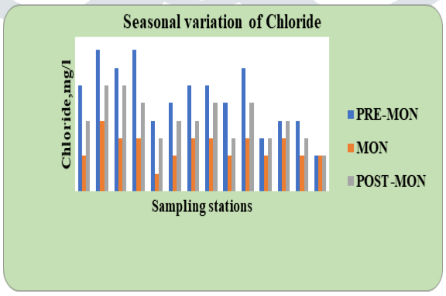


Figure 3.6. seasonal and spatial variation of chloride in Kottuli wetland

3.7. Sulphate

The value of sulphate ranges from 11.28 to 17.44 mg/l with an average of 14.77 mg/l in monsoon period, where as it ranges from 15 to 22.64 mg/l with an average of 19.98 mg/l in pre-monsoon period and it ranges from 6.12 to 12.96 mg/l with an average of 8.55mg/l in post monsoon period (Fig. 3.7). It may be mentioned that higher sulphates levels were recorded in summer season and lower in post monsoon season during the periods of study. The major source of sulphate in the water may be the prolonged high atmospheric deposition, weathering, and sulphate-containing fertilizers which can be added via surface runoff (Geurts et al. 2009; Pande and Moharir 2018). The relatively low values of sulphates were measured during post monsoon mainly because of its uptake and accumulation by plankton and aquatic macrophytes as well as bacteria (Kirubavathy et al.2005, Khare et al.2007, Klein et al. 1972, Krishnamoorthi et al2011 and Prabhakar et. al.2012).

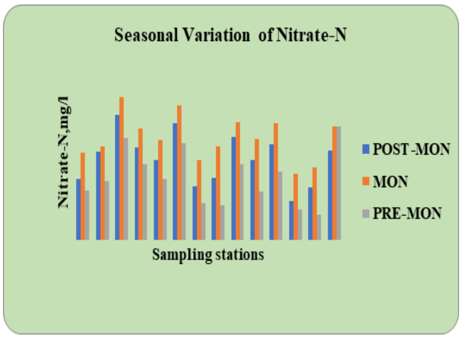


Figure 3.7. seasonal and spatial variation of sulphate in Kottuli wetland

3.8. Nitrate

Most of the stations showed high rate of nitrate concentration irrespective of season. This clearly showed the presence of nitrate carrying waste discharge to the wetland system. In the present study on Kottuli wetland, the nitrate concentration varies from 3.55 to 16.12 mg/l with an average of 8.88 mg/l in post monsoon period whereas it varies from 5.58 to 16.8 mg/l with an average of 11.55 mg/l in monsoon period and it varies from 9.37 to 20.35 mg/l with an average of 15.56 mg/l in pre-monsoon period (Fig. 3.8). Nitrates were present in higher concentration during pre-monsoon and monsoon while lowest in post monsoon season. Similar opinions were also expressed by workers working on different water bodies (Dagaonkar et al.1992, Garg et al.2006, Sinha et al .2011 and Prabhakar et al. 2012. Regarding nitrogen, the predominant species is nitrate, suggesting that it is relatively a stable environment with low nitrogen production related to organic matter degradation process (Klump et al.1989). Regarding station wise variations station 3 (20.35 mg/l) is the polluted station with the direct discharges of coconut husk retting wastes and dumping of wastes. Most of the nitrate might have been derived from the decomposition of organic wastes (Ravaniah et al .2010).

Figure 3.8. seasonal and spatial variation of nitrate in Kottuli wetland

3.9. Dissolved oxygen (DO)

In the present study, DO vary from ND (Not detected) to 10.7 mg/l in pre-monsoon and 0 to 11.6 in post monsoon (Fig. 3.9). Value of DO increased during monsoon (0- 12.40mg/l) due to circulation of cold water as well as high solubility of oxygen at low temperature (Redfield 1948). In Kottuli wetland, higher values of dissolved oxygen were recorded in summer, this was due to the optimum water temperature regime enhances photosynthesis activities resulting into liberation of oxygen (Esmaelli et al .2005, Gonjari et al. 2008 and Singh et al.2010). During pre-monsoon and the winter, the level of dissolved oxygen was quite satisfactory, perhaps due to good aeration caused by un expected rain water. It was observed that in all seasons, the wetland water found lesser polluted as the DO content was increased up to 12.73 mg/l, enhanced the better aquatic life for animals and plants. The enhanced DO level decreased the level of BOD and DO because of lesser organic matter for biological aerobic decay. The sites having D.O with ND (Not Detected) values were found to be dominant of waste dumping activity.

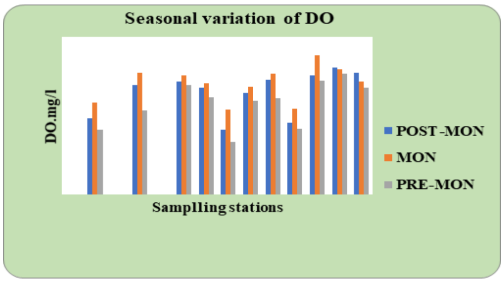


Figure 3.9. seasonal and spatial variation of DO in Kottuli wetland

3.10. Phosphate

In the present study on Kottuli wetland, the maximum value of phosphate (0.86 mg/l) was obtained in monsoon and the minimum (0.029 mg L-1) in post monsoon (Fig. 3.10). Low values of phosphates during the post monsoon season could be attributed to the limited flow of fresh water, high salinity and utilization of phosphate by phytoplankton. (Rajasegar 2003). High concentration of phosphate observed during monsoon season might be due to the intrusion of sea water as well as heavy rainfall, mixing of land run off from agricultural fields contaminated with super phosphates and alkyl phosphates from soap and detergents used by the public for bathing and washing clothes (Senthilkumar et al 2021). When the criterion of inorganic phosphorus was applied, Kottuli wetland can be placed under eutrophic water body (Lee et al.1981). The wetland can be considered as eutrophic especially during monsoon period due to the inflow of high inorganic phosphates. In the current study, it has been observed that the content of nitrate and phosphate was comparatively higher in the samples collected from the waste dumping sites and entry point of Cannoli canal as these sites receive higher amount of nitrate and phosphates in their watersheds as agricultural runoff in comparison to the other studied wetlands. A higher concentration of nitrate and phosphate in water bodies may stimulate the rapid growth of algae which results in lowering water quality condition (Omer 2020).

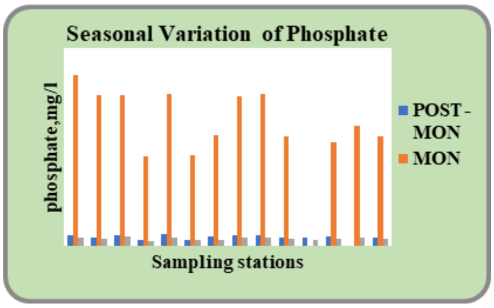


Figure 3.10. seasonal and spatial variation of phosphate in Kottuli wetland

IV. CONCLUSIONS

The investigation in the spatial and temporal variation of water quality characteristics of Kottuli wetland system is important in understanding the environmental status of the anthropogenically threatened ecosystem. The water quality parameters of surface water samples showed seasonal variation, i.e., maximum in pre-monsoon and minimum in monsoon except sulphate & nitrate-N. The low dissolved oxygen concentration reported in certain sites might be occurred due to the discharge of untreated municipal water to the wetland system. Many areas of Kottuli wetland was found to be eutrophic in nature if phosphorous is considered as the limited factor. The analytical results of water quality data indicated that sewage entry through cannoli canal and urbanization is one of the major sources of pollution in Kottuli wetland.

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