ISSN 2394 - 7837

ARTICLE

POLLUTION ASSESSMENT OF VEMBANAD WETLAND ADJACENT TO THE SEAFOOD PROCESSING FACILITIES USING THEMATIC MAPPING

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Received 08/12/2018 Accepted 24/01/2019

Abstract

The seafood processing units found along the coast of Vembanad Lake are posing serious threat to water bodies by unloading their waste without any treatment. The present study was conducted in Cherthala-Aroor-Edakochi coastal belt, where most seafood processing plants are functioning. The water samples were collected from ten different stations for a period of two years on a monthly basis. The stations, S1-S9 were closely associated with the seafood processing discharge outlets and the S10, was kept as a reference site, which is free from the seafood processing discharge. The physico-chemical parameters such as atmospheric and water temperature, TDS, pH, EC, salinity, DO, BOD, alkalinity, COD, hardness and nutrients such as nitrate, phosphate, ammonia and silica. The present study was formulated to create thematic maps to understand the stress zones using the physicochemical parameters in and around the collection sites of this wetland. Parameters like TDS, alkalinity, BOD, COD and hardness exceeded the permissible limits in polluted stations. EC, TDS, hardness, alkalinity, BOD, COD and nitrate are found to be high during monsoon whereas high phosphate, ammonia, and silicate are reported in post monsoon season. Hypereutrophic status is high in the interconnected channels than the main water body.The increased levels of free CO_2, BOD, phosphate, nitrate, and ammonia in the selected stations confirms degrading lake water because of seafood processing effluents. High content of nutrients namely, nitrate and ammonia is associated with eutrophication. The thematic map prepared supported the laboratory analysis.

Keywords: Thematic maps, Seafood waste discharge, Pollution, Vembanad wetland

Introduction

Eutrophication, the biological response to the excess input of nutrients into a water body, arises rarely under natural conditions, but commonly recognized because of human activities (Moss, 1988). Changes in the aquatic environment accompanying anthropogenic pollution are a cause of growing concern and require monitoring of the surface waters and the organisms inhabiting them (Vandysh, 2004). Polluted water also represents a potential hazard to the aquatic environment (Rauf and Javed, 2007). Problems occur when the quantity of organic matter discharged exceeds the carrying capacity of the ecosystem and/or when its dispersion is constrained within coastal waters.

The different plant operations of the seafood processing industry generate large quantities of effluents. The characteristics of the waste water produced are defined and conditioned by the operations and production lines of the factory. Some factories work practically the whole year round and produce only one type of product (Veiga, 1989) such as tuna processing industries, others possess different mixed seasonal production systems (Soto, 1990). The pollution effect of these effluents is due to their high content insoluble organic matter and their different concentrations of suspended solids, depending on the raw material and the characteristics of the industrial process (Méndez et al., 1988). The discharge of these wastes without proper treatment may affect the water quality and the food chain. The current study reported on the ecology and pollution status of Vembanad lake in relation to the seafood processing plant effluents. The analysis of phytoplankton communities supported the interpretation of the results obtained from the physico-chemical analysis of the water and vice versa.

The analysis of water quality by its physical, chemical and biological properties is an age old practice. In the 21st century, geotechnology as one of the three “megatechnologies” along with nanotechnology and biotechnology (Gewin, 2004) has incompletely replaced the traditional methodologies. On the cusp of the second decade of the 21st century it is evident that recent developments in the geotechnologies of Geographic Information Science (GIS) and remote sensing have had a substantial impact on ecological research, providing spatial data and associated information to enable the further understanding of ecological systems (Rundell et al., 2009). In a digital society there is sometimes an expectation that information is just a click away and this may apply to spatial information in the domain of ecological informatics. Indeed, it has been in the

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last five years that developments in and relating to the fields of GIS and remote sensing, such as those seen in internet technologies have resulted in the revelation of previously unobservable phenomena and posing of what might be termed second generation of ecological questions. During this time we have also seen more support for the open exchange of data and software and infrastructure for location based services (Boyd and Foody, 2010).

Since analytical and environmental studies have gone beyond concentration measurements, the application of geo-statistical method is recommended (Chen et al., 2006; Kowalkowski et al., 2006). With the rapid development of computer technology, statistics and geographic information system (GIS), it is possible to combine these techniques for processing of data of complex hydrogeochemical systems that are difficult to explain and document (Kowalkowski et al., 2006).

In India especially Kerala, the environmental problems associated with the discharge of wastewater from seafood processing facilities are gaining attention. Unnithan et al. (1998) estimated the production and capacity utilization in the fish processing plants in Kerala. According to him, the seasonal production and capacity utilization indicated that trawl ban adversely affected the processing industry during June, July months (about 10.6% utilization) whereas the utilization increased substantially during post ban period (about 25%). The impact of waste discharge into the water system and hence phytoplankton from three important cottage industries namely, retting of coconut husks, fish peeling and liming of shells were documented by Alex, (2005). She reported that the highest pollution was recorded at retting zone followed by peeling shed zone and liming zone. Geethalakshmi, (2011) while studying the utilization capacity in fish processing industry in Gujarat reported that there was a gross under utilization of capacity installed for fish processing in Gujarat in the year 2006-07 to 2008-09. Sankpal and Naikwade, (2012) studied the physicochemical analysis of effluent discharge of fish processing industries in Ratnagiri and found that effluents from fish processing industries are the major sources of coastal environmental pollution and all the samples are polluted and having the values higher than the permissible limits. Quality management practices adopted in seafood processing sector in Cochin region was reported earlier by (Balasubramaniam et al., 2012). The study was conducted in 34 fish processing units in Ernakulam and Alleppey districts of Kerala and the results of the study revealed the general profile of the seafood processing units and the extent of adoption of various quality management practices.

The current status of the seafood pre-processing facilities in Alleppey district was envisaged by Sathyan et al. (2014). He conducted a survey to understand the socio-economic status and challenges faced by owners and women workers of shrimp pre-processing units located in Alleppey district of Kerala and to assess the presently available facilities at these units. The survey indicated that most of the sampled shrimp pre-processing centres lack many amenities required for maintaining the requisite hygiene standards at these units. The majority of the women employed were educated and in the age range 35-50 years. Many of the pre-processing centre owners are finding it difficult to develop infrastructure required for maintaining high hygiene standards owing to their indebtedness and low profit margin. The study showed that most of the pre-processing units are in the declining stage and if proper steps are not taken for recurrence many will be jobless. The physico-chemical characteristics of fish processing industry effluent discharge into veraval harbour waters of Gujarat was studied by Vaghela et al. (2015). He found that the fish processing industry effluent was eutrophic in nature and the increased contaminants in the fish waste volume resulted in environmental problems. The physico chemical analysis of the effluents from seafood processing industries are the major cause of water pollution in and around Aroor gramapanchayath, Alappuzha District was done by Thomas et al. (2015) and reported that all the samples are highly organic in nature and are highly polluted and can affect the aquatic ecosystem if it is released without adequate treatment.

A handful of studies were done in Vembanad wetland using GIS software. Notable works included were Chithra et al., (2015) who, mapped the change detection of built up impervious surfaces in and around Cochin area, Kerala using the GIS techniques and by Parvathy and Suresh (2016), whom studied the surface area change in the Vembanad Lake over four decades was estimated from Landsat satellite images using water indices and GIS techniques. However, a detailed investigation on this perspective of pollution and its impact on the Vembanad lake have not been done earlier. Hence, the present study has been formulated to create thematic maps to understand the stress zones in and around the collection sites of this wetland so that appropriate measures could be taken to protect them.

Materials and Methods

The present study conducted in Cherthala-Aroor-Edakochi coastal belt, where most seafood processing plants are functioning. The study was conducted for two years (October 2010-September 2012) from ten preselected stations (S1 - S10) on monthly basis. They are Pattanakadu (S1), Parayakadu (S2), Shankaranthodu (S3), Konkeri bridge (S4), Chandiroor (S5), Edakochi I (S6), Edakochi II (S7), Aroormukkam (S8), Aroorkutti bridge (S9), Panavally (S10). Nine of the selected stations near the effluent outlet of the seafood processing plants and one kept as the reference site (S10) which is free from seafood effluent discharge (Fig.I). The first five stations are in interconnected channels and the remaining including the reference station are in the main water body (Fig.II to Fig. XI). The collections were made on a monthly basis in all stations.

Water quality analysis

For the physico-chemical analysis, water samples were collected in plastic bottles, taken to the laboratory and re-

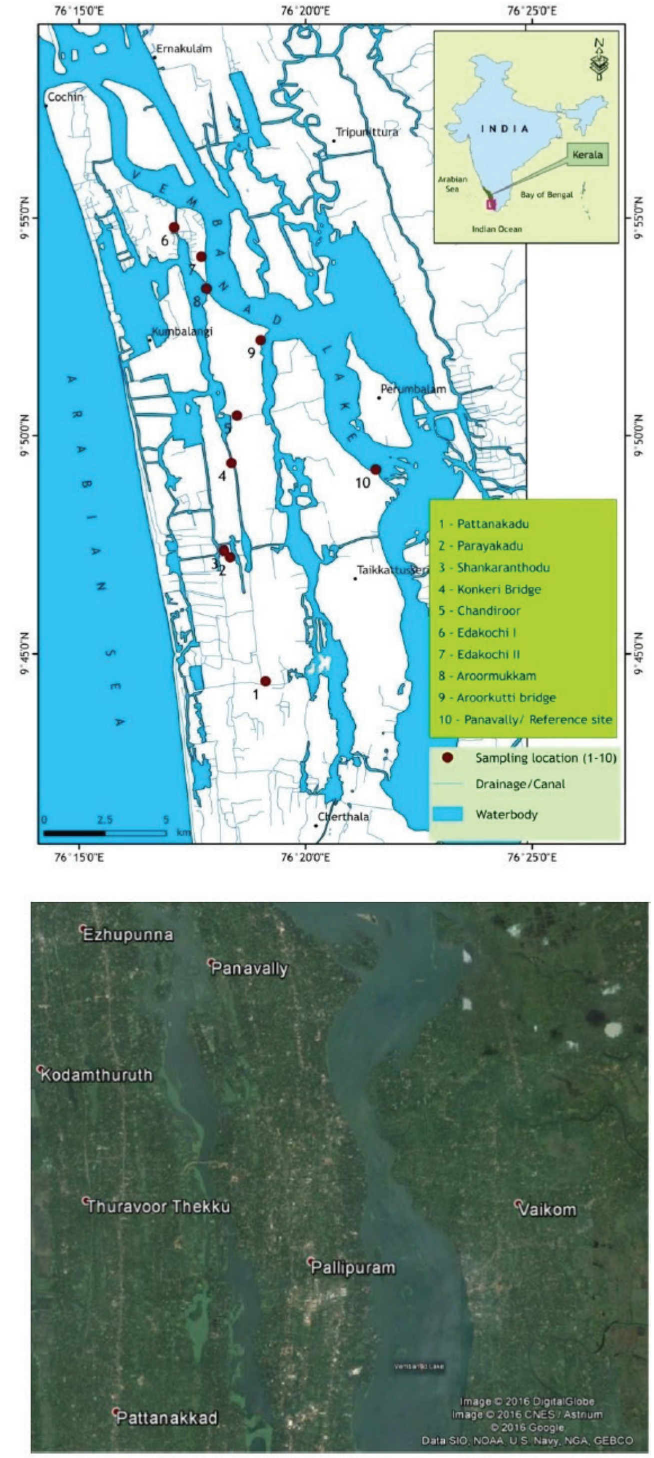

Figure 1 - Location Map

frigerated at 4°C. Salinity was measured using a hand refractometer. The titration method was adopted for testing dissolved oxygen and biological oxygen demand as recommended by Adoni (1985) and APHA (2005). The nutrients namely phosphate and ammonia were examined using a Bench photometer (Hanna Instruments C 200 series).

Thematic maps

Thematic maps were generated using ARC-GIS software

Results

As there was no significant variation between years, the data of the two year study (from October-2010 to September-2012) were pooled for three seasons and analyzed for seasonal variations, with respect to Pre-monsoon (February, March, April, May), Monsoon (June, July, August September) and Post monsoon (October, November December, January). Further, the mean and standard error of mean (SEM) were calculated for each station and season.

The station wise and season wise variations of salinity are shown in figure XII. In station 1, the values varied from 2.12 ± 0.83 (Post monsoon) to 6.75 ± 0.90 (Monsoon). Within station 2, it varied from 2.62 ± 0.56 (Post monsoon) to 10.00±0.89 (Monsoon) and in station 3 the values fluctuated between 4.12 ± 0.85 (Post monsoon) and 9.38 ±1.16 (Monsoon). With regard to station 4, it fluctuated between 2.88 ± 0.81 (Post monsoon) and 8.00 ±1.09 (Monsoon). In station 5, the values swung from 3.12 ±1.14 (Post monsoon) to 10.12 ± 1.91 (Pre-monsoon). The minimum and maximum value of salinity in station 6 varied from 5.75 ± 1.47 (Post monsoon) to 15.38 ±1.77 (Pre-monsoon) whereas in station 7, the minimum and maximum values were 7.38 ±1.86 (Post monsoon) and 12.62 ± 0.89 (Pre-monsoon) respectively. Regarding station 8, the rise and fall of salinity was 13.00 ± 1.05 (Pre-monsoon) and 8.38 ± 1.74 (Post monsoon) respectively. Within station 9, the value varied from 5.12 ± 1.42 (Post monsoon) and 9.00±1.21 (Pre-monsoon) while in station 10, the minimum and maximum values were 1.38 ± 0.94 (Post monsoon) and 5.38±0.96 (Pre-monsoon) respectively. Among the stations, the total mean value of salinity was found to be minimum in S1 (4.29 ± 0.59) and maximum in S8 (11.17 ± 1.01).

In the pre monsoon season, the lowest salinity was reported from S1 (4.00 ± 0.60) and the highest from S6 (15.38 ± 1.77). During the monsoon season the lowest value was reported from S10 (4.88 ± 0.44) and the highest from S6 (10.38 ± 2.19) and throughout the post monsoon season, the lowest salinity was reported from S10 (1.38 ± 0.94) and the highest from S8 (8.38 ± 1.74).

The minimum and maximum values of DO were 4.85 ± 0.86 (Monsoon) and 7.21 ± 0.33 (Post monsoon) respectively. While in station 2, the values varied from 5.67 ± 0.54 (Monsoon) to 7.29 ± 0.38 (Post monsoon). With regard to station 3, it varied between 5.78 ± 0.38 (Monsoon) and 6.80 ± 0.64 (Post monsoon). In station 4, the values varied from 6.11 ± 0.41 (Pre-monsoon) to 6.93 ± 0.48 (Post monsoon) whereas in station 5, it varied between 4.14 ± 0.52 (Monsoon) and 6.21 ± 0.46 (Post monsoon). Regarding station 6, the values fluctuated between 5.62 ± 0.46 (Pre-monsoon) and 7.70 ± 0.46 (Post monsoon). In station 7, the values ranged from 7.79 ± 0.30 (Post monsoon) to 6.76 ± 0.49 (Monsoon) respectively. With respect to station 8, it varied between 6.56 ± 0.53 (Monsoon) and 7.30 ± 0.18 (Post monsoon). The minimum and maximum values recorded in station 9 were 5.65 ± 0.46 (Monsoon) and 7.45 ± 0.33 (Post monsoon) respectively. In station 10, the values varied from

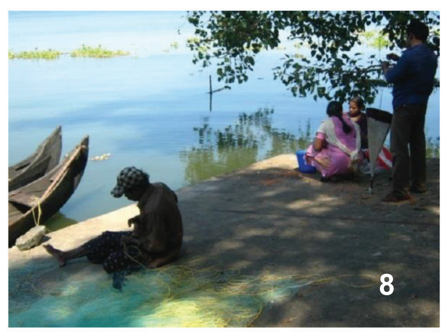

Figure 2 - Station 1; Figure 3 - Station 2; Figure 4 - Station 3; Figure 5 - Station 4; Figure 6 - Station 5; Figure 7 - Station 6; Figure 8 - Station 7; Figure 9- Station 8; Figure 10 - Station 9; Figure 11 - Station 10

8.38 ± 0.31 (Pre-monsoon) to 8.85 ± 0.37 (Post monsoon). Among the stations, the total mean value of DO was found to be minimum in S5 (5.36 ± 0.35) and maximum in S10 (8.60 ± 0.19).

During the pre monsoon season, the lowest value was reported from S1 (5.47 ± 0.52) and maximum in S10 (8.38 ± 0.31). In the monsoon season, the lowest value was reported from S5 (4.14 ± 0.52) and the highest from S10 (8.57 ± 0.30). Throughout the post monsoon season, the lowest value was reported from S5 (6.21 ± 0.46) and the highest value from S10 (8.85 ± 0.37).

The station wise and season wise variations of BOD are shown in figure XIV. In station 1, the values ranged from 20.67 ± 4.86 (Pre-monsoon) to 27.84 ± 5.19 (Post monsoon) whereas in station 2, the values varied from 28.86 ± 6.93 (Post monsoon) to 35.71 ± 6.79 (Pre-monsoon). Inside station 3, the values fluctuated between 33.16 ± 3.93 (Pre-monsoon) and 45.61 ± 7.56 (Post monsoon). With respect to station 4, the values swung between 21.20 ± 3.02 (Post monsoon) and 26.50 ± 4.02 (Pre-monsoon). Regarding station 5, the value changed from 29.93 ± 3.17 (Monsoon) to 64.85 ± 4.60 (Post monsoon). In station 6, the BOD varied from 28.85 ± 3.28 (Post monsoon) to 35.27 ± 3.73 (Pre-monsoon). With respect to station 7, the value fluctuated between 27.61 ± 3.60 (Monsoon) and 34.81 ± 6.58 (Pre-monsoon). In station 8, the minimum and maximum BOD recorded were 25.04 ± 4.86 (Monsoon) and 29.90 ± 4.95 (Pre-monsoon) respectively. The station 9 showed a rise and fall from 42.70 ± 7.43 (Monsoon) to 31.23 ± 5.04 (Post monsoon). In station 10, the values varied from 4.58 ± 1.01 (Pre-monsoon to 6.38 ± 0.45 (Post monsoon). Amongst the stations, the total mean value of BOD was found to be minimum in S10 (5.42 ± 0.48) and maximum in S5 (44.48 ± 4.05).

During the pre monsoon season, the lowest value was reported from S10 (4.58 ± 1.01) and the highest from S5

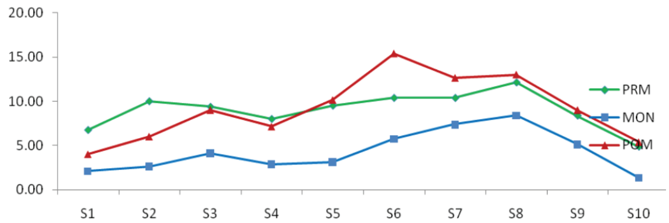

Figure 12 - Seasonal and site wise variation of salinity during 2010-2012

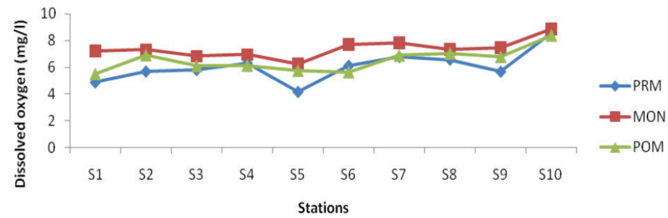

Figure 13 - Seasonal and site wise variation of DO during 2010-2012

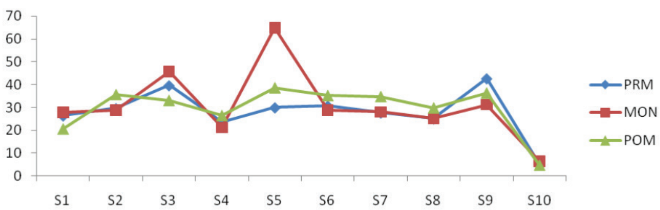

Figure 14 - Seasonal and site wise variation of BOD during 2010-2012

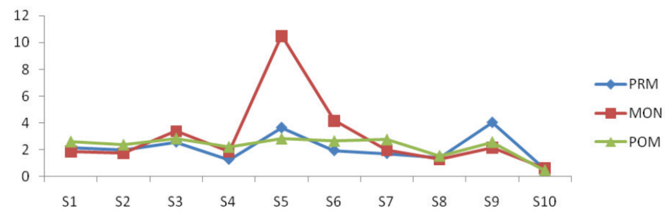

Figure 15 - Seasonal and site wise variation of phosphate during 2010-2012

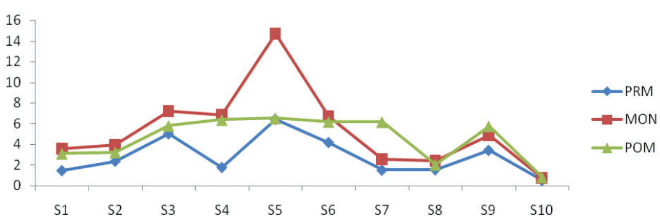

Figure 16 - Seasonal and site wise variation of ammonia during 2010-2012

(38.66 ± 5.98). Throughout the monsoon season, the lowest value was reported from S10 (5.02 ± 0.93) and the highest from S9 (42.70 ± 7.43). During the post monsoon season, the lowest value was reported from S10 (6.38 ± 0.45) and the highest from S5 (64.85 ± 4.60).

The station wise and season wise variations of phosphate are shown in figure XV. In station 1, phosphate ranged from 1.90 ± 0.59 (Post monsoon) to 2.60 ± 0.12 (Pre-monsoon). Within station 2, the value varied from 1.75 ± 0.16 (Post monsoon) to 2.37 ± 0.24 (Pre-monsoon) whereas in station 3, it fluctuated between 2.58 ± 0.42 (Monsoon) and 3.40 ± 1.11 (Post monsoon). With respect to station 4, it varied between 1.30 ± 0.27 (Monsoon) and 2.20 ± 0.15 (Pre-monsoon). Regarding station 5, the values fluctuated between 2.82 ± 0.20 (Pre-monsoon) and 10.50 ± 1.10 (Post monsoon) and in station 6, the values fluctuated between 1.95 ± 0.40 (Monsoon) and 4.18±1.22 (Post monsoon). With respect to station 7, the phosphate values swung between 1.73 ± 0.37 (Monsoon) and 2.75 ± 0.43 (Pre-monsoon). The minimum and maximum values observed in station 8 were 1.29 ± 0.37 (Post monsoon) and 1.54 ± 0.19 (Pre-monsoon) respectively. In station 9, it fluctuated between 2.18 ± 0.49 (Post monsoon) and 4.04 ± 0.97 (Monsoon) and in station 10, the minimum and maximum values recorded were 0.47 ± 0.15 (Pre-monsoon) and 0.63 ± 0.18 (Post monsoon) respectively. The mean value of phosphate was found to be minimum in S10 (0.56 ± 0.09) and maximum in S5 (5.66 ± 0.91).

During the pre monsoon season, the lowest value was reported from S10 (0.47 ± 0.15) and highest in S 3 (2.84 ± 0.41). In the monsoon season, the lowest value was reported from S10 (0.59 ± 0.13) and highest from S9 (4.04 ± 0.97) and in the post monsoon season, the lowest value was reported from S10 (0.63 ± 0.18) and highest from S5 (10.50 ± 1.10).

The station wise and season wise variations of ammonia are shown in figure XVI. In station 1, the values ranged from 1.47 ± 0.47 (Monsoon) to 3.58 ± 0.99 (Post monsoon) while in station 2, the values varied from 2.37 ± 0.87 (Monsoon) to 3.94 ± 1.12 (Post monsoon). Within station 3, ammonia level varied between 5.01 ± 2.06 (Monsoon) and 7.20 ± 1.53 (Post monsoon). Within station 4, it fluctuated between 1.77 ± 0.51 (Monsoon) and 6.86 ± 1.69 (Post monsoon) and in station 5, the values varied from 6.42 ± 1.84 (Monsoon) to 14.72 ± 3.41 (Post monsoon). With respect to station 6, it swung from 4.18 ± 2.18 (Monsoon) to 6.72 ± 0.94 (Post monsoon). The minimum and maximum values observed from station 7 were 1.50 ± 0.36 (Monsoon) and 6.16 ± 1.83 (Pre-monsoon) respectively whereas in station 8, a minimum of 1.55 ± 0.54 (Monsoon) and a maximum of 2.42 ± 0.76 (Post monsoon) were noted. In station 9, the parameter varied from 3.42 ± 1.18 (Monsoon) to 5.75±1.39 (Pre-monsoon). The station 10 registered a minimum value of 0.52 ± 0.19 (Monsoon) and a maximum value of 0.80 ± 0.13 (Pre-monsoon). Among the stations, the mean value of ammonia was found to be minimum in S10 (0.68 ± 0.10) and maximum in S5 (9.22 ± 1.57).

During the pre monsoon season, the lowest value was reported from S10 (0.80 ± 0.13) and highest from S5 (6.52 ± 1.72). In the monsoon season, the lowest value was reported from S10 (0.52 ± 0.19) and highest from S5 (6.42 ± 1.84) whereas in the post monsoon season, the lowest value

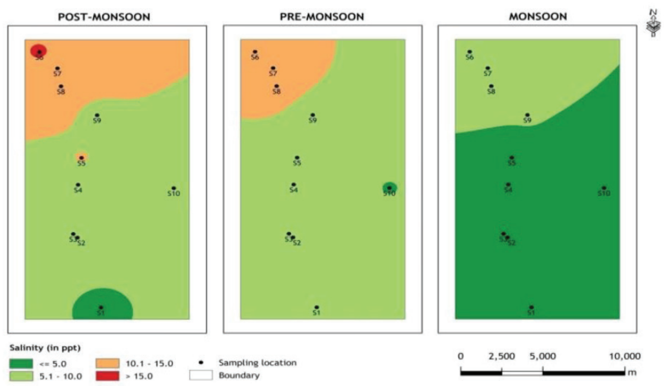

Figure 17 - The thematic map of salinity showing seasonal variations

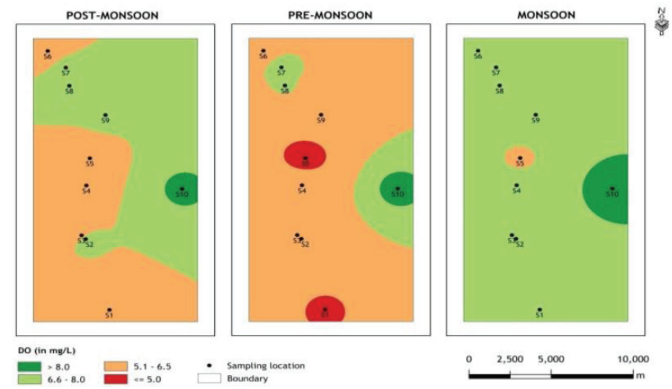

Figure 18 - The thematic map of dissolved oxygen (DO) showing seasonal variations

Figure 19 - The thematic map of BOD showing seasonal variations

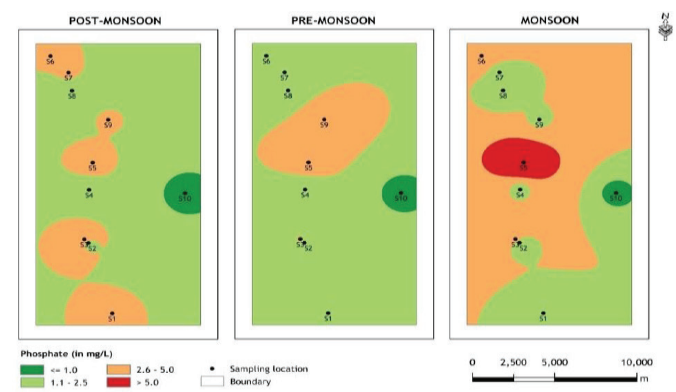

Figure 20 - The thematic map of phosphate showing seasonal variations

was reported from S10 (0.74 ± 0.22) and highest from S5 (14.72 ± 3.41).

Preparation of Thematic maps

The thematic map prepared for salinity showed significant colour variation according to seasons (fig. XVII). In the post monsoon season, the S2, S3, S4, S9 and showed light green colour indicating the fact that salinity in these stations were ranged from 5ppt to 10ppt. The saffron colour in S5, S7 and S8 showed that the salinity ranged from 10ppt to 15ppt. The green colour in S1 meant that salinity reported from here is less than 5ppt whereas red colour in the S6 indicated that salinity exceeded 15ppt. In the pre-monsoon season, S1, S2, S3, S4, S5 and S9 showed light green colour in thematic map whereas the stations 6, 7 and 8 displayed saffron colour. The reference station showed green colour. In the monsoon season, the S1, S2, S3, S4, S5 and S10 coloured green in the thematic map while the stations 6, 7, 8 and 9 demonstrated light green colour.

For DO, the thematic maps prepared were showed significant colour variation among seasons (Fig. XVIII). In the post monsoon season, S1, S3, S4, S5 and S6 exhibited saffron colour, which indicated that DO value in these stations ranged from 5.1mg/l to 6.5mg/l. The stations 2, 7, 8 and 9 displayed light green colour, which indicated that the DO value varied from 6.6mg/l to 8.0mg/l. The green colour in the reference station pointed out that DO value was greater than 8mg/l. In the pre-monsoon season, S2, S3, S4, S6 and S9 exhibited saffron colour whereas S7 and S8 indicated light green colour. The station 10 displayed green colour whereas the red colour in S1 and S5 specified that DO values were less than 5mg/l in these stations. In the monsoon season, S1, S2, S3, S4, S6, S7, S8 and S9 demonstrated light green colour whereas S10 showed green colour. The station 5 showed saffron colour.

The thematic maps prepared for BOD are given in fig. XIX. In the post monsoon season, S2, S3, S5, S6, S7, S8 and S9 showed saffron colour, which denoted that the BOD in these stations varied from 30.1mg/l to 45mg/l. The stations 1 and 3 showed light green colour pointed out that BOD value ranged from 10.1mg/l to 30mg/l whereas the green colour in S10 indicated that the BOD values reported from here were less than 10mg/l. In pre-monsoon season, S1, S4, S5, S7 and S8 showed light green colour, while S2, S3, S6 and S9 displayed saffron colour. The reference station displayed green colour.

The thematic map prepared for phosphate is given in fig. XX. In the post monsoon season, S1, S3, S5, S6, S7 and S9 displayed saffron colour indicated that the phosphate value ranged from 2.6mg/l to mg/l. The light green colour in the stations 2, 4 and 8 pointed out that the phosphate value varied from 1.1mg/l to 2.5mg/l. The reference station displayed green colour, because less than 1mg/l of phosphate was reported from this station. In the pre-monsoon season, S1, S2, S4, S6, S7 and S8 demonstrated light green colour. The station 3 showed light green and saffron colour indicating that its phosphate value ranged from 1.1mg/l to 5mg/l. The station 5 and 9 exhibited saffron colour whereas station 10 displayed green colour. In the monsoon season, S1, S2, S4, S7, S8 and S9 displayed light green colour whereas S3 and S6 showed saffron colour. The station 10 exhibited green colour. The red colour displayed by S5 pointed out that phosphate value was above 5mg/l in the station.

For ammonia, the thematic map drawn is given in fig. XXI. In the post monsoon season, S1, S2 and S8 showed light green colour which pointed out that ammonia level varied from 2.1mg/l to 5mg/l. The stations 3, 4, 5, 6, 7 and 9 displayed saffron colour, which indicated that ammonia values ranged from 5.1mg/l to 8.0mg/l. The green colour in the reference station indicated that the ammonia reported from this station was less than 2mg/l. In the pre-monsoon season, S2, S3, S6 and S9 displayed light green colour whereas S1, S4, S7, S8 and S10 exhibited green colour. The station 5 showed saffron colour in the thematic map. In the monsoon season, S1, S2, S7, S8 and S9 displayed light green colour. The stations 3, 4 and 6 showed saffron colour, and S10 displayed green colour. The station 5 showed red colour indicating that the ammonia level in this station exceeded 8mg/l.

Discussion

Salinity plays a major role in controlling various physical, chemical, and biological activities occurring in the aquatic environment. Salinity acts as a limiting factor in the distribution of organisms and its variation may influence various fauna in the coastal ecosystem (Balasubramanian and Kannan, 2005; Sridhar et al., 2006). The salinity showed significant variation between stations and seasons. The lowest value reported from the reference station, whereas the highest value reported from Station 8, which is in the main water body. This may be due to the proximity to the sea. Fish processing industries use salt for the preservation of seafood products and hence the chloride content is increased in the discharged water. The average value of chloride reported in the fish processing effluent discharge was 8350mg/l (Sankpal and Naikwade, 2012). Vaghela et al. (2015) reported that the chloride concentration in the fish processing effluent discharge ranged from 8000 to 10,000mg/l. The salinity was found to be high during summer season. The recorded higher values could be attributed to the low amount of rainfall, higher rate of evaporation, neritic water dominance as reported by earlier workers in other areas (Govindasamy et al., 2000; Rajasegar, 2003) and due to the discharge of waste from the fish processing industries. According to Horn and Goldman, 1994, high salinity can reduce the diversity and density of plankton. The extreme drop in salinity with near freshwater conditions observed due to the dilution by large amounts of fresh water (Dehadrai and Bhargava, 1972; Nasnolkar et al., 1996), and the higher values of salinity usually depend on the intrusions of seawater through bar mouth. Salinity is also high in interconnected channel, where wastewater from seafood processing plants enters. Salinity may arise as a by-product of degradation. This is in agreement with the finding of Singh and Singh (1995) that, higher level of salinity might be due to increase in decomposition of organic matter.

The effect of wastewater released into a water body largely determined by the discharge of oxygen demanding waste and oxygen balance of the system. The exchange of oxygen across the air - water interface depends upon temperature, partial pressure of gases, solubility, photosynthetic activity of plant and respiration by bacteria, plants and animals in the water (Krishnaram et al., 2007). The dissolved oxygen showed significant variation between stations and seasons. The dissolved oxygen was less in the effluent discharge stations compared to the reference station. The introduction of oxygen demanding material either organic or inorganic, into wetland causes depletion of the dissolved oxygen (Ramana et al., 2008). The accumulation of organic matter from seafood waste will lead to the depletion of dissolved oxygen in the water column (Mazik et al., 2005). High DO was reported in the post monsoon season and low DO was reported during the monsoon season. High amount of Dissolved Oxygen in the post monsoon may be due to the intensive photosynthetic activity as reported by (Ganapati, 1962). Low DO in the monsoon season may be due to the surface runoff, which reduced transparency and hence resulted in low photosynthesis. Low DO was reported in the interconnected channels (S1-S5) when compared to the main water body (S6-S9). In the present study, high DO was reported in the post monsoon when compared to the monsoon season. The overall decrease in DO indicates the increase in eutrophic conditions (Sheela et al., 2011). The low temperature of surface water during the post-monsoon season enhances the solubility of atmospheric oxygen in the surface water (Riley and Chester, 1971). The tidal mixing and the current pattern in the main water body might have diluted the waste. The cooler water discharged along with the seafood waste might have increased the dissolved oxygen content of the surface water in the polluted stations. Dissolved oxygen depletion can also be attributed to the phytoplankton respiration and sediment oxygen demand (Raja et al., 2008). Thus, oxygen is the most important gas for the self-purification process of aquatic bodies (Boyd and Tucker, 1998; Ahmed et al., 2004). A reduction in dissolved oxygen because of nutrient load was also reported (Johannessen and Dahl, 1996). Singh and Singh (2001) and Medhi et al. (2011) also noticed a water quality degradation due to changes in values of dissolved oxygen of river Ami and in Nagaon paper mill effluents respectively.

Biochemical Oxygen Demand (BOD) is the measure of the quantity of oxygen consumed by microorganisms during the decomposition of organic matter. BOD is an indirect measure of biodegradable organic compounds in water (Osibanjo et al., 2011). In the present study, BOD showed significant variation among the stations and it exceeded the permissible limits prescribed by WHO (2004). A high BOD value occurs due to the discharge of domestic sewage and anthropogenic activity (Maheshwari, 2011). The lowest value reported from the reference station in main water body, and the highest from the station (Station 5) in interconnected canal. Raised BOD values may be due to dead organic matter and stagnant water condition. Similar results were reported (Sanap et al., 2006). The greater the decomposable matter present, the greater the oxygen demand and greater the BOD values (Ademoroti, 1996). In seafood-processing effluent, biological oxygen demand originates from the carbon compounds, which are used by microorganisms as their substrate, and from the nitrogenous compounds such as proteins and volatile amines (Thomas et al., 2015). The decomposable waste from the seafood industry might be the reason for the high BOD in the seafood effluent discharge affected stations. High BOD was reported in the pre monsoon season and then in the post monsoon season. High BOD during the pre monsoon season may be due to the presence of several microbes in water bodies, which accelerated their metabolic activities with the increase in concentration of organic matter in the form of municipal and domestic waste pouring into the pond with run off (Kaushik and Saksena, 1999). Prasannakumari et al. (2003) also stated that the higher values of BOD during rainy was also due to input of organic wastes and enhanced bacterial activity. The low biological oxygen demand in all seasons in the reference station suggests less organic pollution there. The low value of the BOD may be due to the lesser quantity of total solids, suspended solids in water as well as to the quantitative number of microbial population (Avasan and Rao, 2001). Thomas et al. (2015) reported that the overall mean value of BOD from seafood industry located in Aroor Grama Panchayath varied from 964mg/l to 2250mg/l. Sankpal and Naikwade, (2012) reported that the BOD in the effluent discharge of the fish processing industry ranged from 10mg/l to 266mg/l. Vaghela et al. (2015), reported that the BOD in the effluent discharge of the fish processing industry varied from 90mg/l to 105mg/l. Seafood processing operations produce wastewater containing substantial contaminants in soluble, colloidal and particulate forms, high organic matter, fat, oil and grease and ammoniacal-nitrogen (Tchoukanova et al., 2003; Islam et al., 2004; Sohsalam et al., 2008). Their high organic matter content frequently contributes to pollution and high-level biological oxygen demand of water bodies near seafood processing units (Morry et al., 2003; Tchoukanova et al., 2003; Ferjani et al., 2005; Sirianuntapiboon and Srikul, 2006; Moens et al., 2007; Sohsalam et al., 2008). An elevated value of BOD in polluted water body was reported earlier (Nandan and Aziz, 1990; Ademoroti, 1996; Usha et al., 2006; Elmaci et al., 2008; Meera and Nandan, 2010). Singh and Rai (1999) observed that high BOD was indication of organic pollution in the river Ganga at Varansi. According to Mulani et al., 2009, increasing trend of the BOD and the decreasing trend of DO clearly indicate the addition of pollution load. This is in conformity with the fact that the discharge of organic waste from the nearby seafood processing plants resulted in the high BOD in the polluted stations. As the primary water quality of bathing water prescribed by the Central Pollution Control Board, biological oxygen demand shall not exceed 3 mg/l. However, the average biological oxygen demand is more than 9 times than the standard values. The high values of BOD indicated high pollution levels due to discharge of industrial effluents and sewage wastes (Khan et al., 2005).

Phosphate acts as nutrient for plant growth and high concentration of this nutrient indication of eutrophication. Phosphorus is an important limiting nutrient in freshwater and its influences profusion of plankton. The phosphate showed significant variation between stations and seasons. While comparing stations, lowest, value reported in the reference station during all seasons. High phosphate content was reported in interconnected channels. The higher values of phosphates confirmed the polluted status, which could be due to the untreated unload of waste from the nearby seafood industry. Vaghela et al., 2015 reported that the phosphate content in the waste discharge from the fish processing industry ranged from 10mg/l to 16.5mg/l. The high phosphate in the seafood effluent discharge stations (S1-S9) points out the role played by nearby seafood industry in deteriorating water quality. The higher level in monsoon may be because of surface runoff carrying untreated effluent. Hutchinson (1957), Welch, (1952) and Ruttner, (1953) found the little amount of phosphates in natural waters free from human interference.

Ammonia is the preferred source of nitrogen for algae (Lobban and Harrison 1994). The ammonia showed significant variation between stations and seasons. The high amount of ammonia was reported from the seafood waste discharge affected stations. The lowest value reported from the reference station. The ammonia is also formed as a result of the decomposition of organic nitrogen by ammonfication. So, the high amount of ammonia can be used to understand the duration of exposure of waste. High levels of ammonia exist in the interconnected canal and in the main water body suggest that these stations were experiencing pollution for a while. Ammonia in natural waters is generally absent or present at very low levels (Maheshwari, 2011). Water pollution by sewage or industrial wastes containing nitrogenous organic water may contain high concentration of ammonia (Goel, 1997). Davies and Jaja, (2014) reported that if the ammonia in the natural water bodies exceeded international acceptable levels of 0.10 mg/l, which indicated high nutrient status, organic matter and potential pollutants. Thomas et al., (2015) reported that the ammonia concentration in the seafood processing effluents in Grama Panchayath varied from 29.1mg/l to 36.2mg/l. The degradation of the waste discharged from the seafood plants resulted in the rise in ammonia. The high content of ammoniacal nitrogen in seafood processing effluent is mainly responsible for its rise in the wetland. The decay of fish and shellfish has also released significant amounts of ammonia and nitrate (Leffler, 1997). The death and subsequent decomposition of phytoplankton and the excretion of ammonia by planktonic organism may also result in a rise in ammonia (Segar and Hariharan, 1989). The high ammonia concentration in fish processing, wastewater is due to the high blood and slime content in wastewater streams (FREMP, 1994; Chowdhury et al., 2010).

Conclusion

The extent of pollution impact of seafood waste discharge on nearby water bodies was done by physicochemical parameters, namely salinity, DO,BOD and nutrients like phosphate and ammonia. BOD exceeded the permissible limits in polluted stations. Among polluted stations, the effect was pronounced in the interconnected channels because of less surface runoff. High phosphate and ammonia were reported in post monsoon season. Hypereutrophic status is high in the interconnected channels than the main water body. The increased levels of BOD, phosphate and ammonia in the selected stations confirms degrading lake water because of seafood processing effluents. High levels of ammonia existed in the interconnected canals and in the main water body.

The coloration of thematic map supported the physico –chemical data analysis. Thus, a three dimensional view of the pollution status of the vembanad lake is obtained by visual analysis of thematic maps. The study has identified three stress zones, namely S3, S5 and S9 based on physico-chemical data and thematic maps.

The study revealed that hyper eutrophication existed near the effluent discharge points because of the indiscriminate waste dumping.The physico-chemical characters of selected stations evaluated in the present work demonstrates that the changes in the properties are due to both monsoon and direct discharge of effluents from surrounding environment. The nutrient loading into the water from the nearby seafood industry has been considered as one of the major cause for eutrophication. The parameters like BOD and nutrients (phosphate and ammonia) showed wide fluctuations according to the pollution load. The thematic map prepared supported the laboratory analysis.

The waste discharge from the seafood processing industry is a major reason for the alarming rate of organic pollution and eutrophication. If the condition persists, water quality will degrade subsequently, questioning the existence of aquatic organisms including fishes. This will adversely affect the seafood industry.The study suggests that it would be undesirable for the further expansion of seafood industry in the Cherthala- Aroor-Edakochi coastal belt of Vembanad lake.

Acknowledgements

The financial aid for the present study was obtained from the Directorate of Environment and Climate Change, Government of Kerala, which is greatly acknowledged. The author is also thankful to the UGC for providing a BSR/RFSMS fellowship for pursuing the work.

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