ASSESSMENT OF SURFACE WATER QUALITY OF VEMBANAD WETLAND ADJACENT TO THE SEAFOOD PROCESSING FACILITIES

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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. In the coastal belt of Vembanad lake, there are several seafood processing plants especially in the areas of Cherthala-Aroor-Edakochi belt. The present study analyzes the extent of degradation caused by the discharge of effluent from seafood processing units on physico chemical qualities of water. The physical-chemical parameters examined from the samples drawn from ten preselected locations for two years on monthly basis. The first nine stations are situated near the seafood processing plants whereas the last station is kept as the reference station. For the physico-chemical analysis, water samples were collected in plastic bottles, taken to the laboratory, refrigerated at 4° C and were analysed using standard procedures. The physico-chemical parameters (atmospheric and water temperature, TDS, pH, EC, salinity, DO, BOD, alkalinity, COD, hardness and nutrients such as nitrate, phosphate, ammonia and silica were studied. The mean and standard error of mean (SEM) values were calculated for all parameters in each station and season. The mean values of physico-chemical parameters except DO were low in the reference station when compared to the other nine (S1-S9) stations. The high values of BOD in nine stations (S1-S9) would be due to the presence of high biological waste in the water. 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. The increased levels of free CO₂, BOD, phosphate, nitrate, and ammonia in the selected stations confirms degrading lake water because of seafood processing effluents. The waste discharge from the seafood processing industry is a major reason for the alarming rate of organic pollution and eutrophication. 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.

INTRODUCTION

Seafood is a cottage industry which significantly contributed to the world's food supply and an important protein-providing food in terms of per capita consumption. The global seafood industry comprises activities relating to the culturing, catching, preserving, processing, selling and distribution of fish or fishery products. Seafood demand continues to increase globally and significant population growth in countries such as China, India and Brazil is an important demand driver for the seafood industry (Anon, 2013).

The seafood exports from India began in 1955 (SEAI, 2009). Indian seafood Industry has come a long way; shipping seafood products to more than 100 countries. Today Indian factories have grown to have world class facilities, with better quality control; meeting the stringent international norms.

India is blessed with abundant marine and inland fishery resources and the Indian fishery sector has now eked out an honourable place in the world marine product export market (Dixitulu and Paparao, 1994). India is the third largest fish producer in the world and is second in inland fish production (Singh et al., 1997). India has 388 processing plants with 191 of them approved by European Union (SEAI, 2010; MPEDA, 2015).

The fisheries sector has been recognized as a powerful income and employment generator as it stimulates growth of a number of subsidiary industries and is a source of cheap and nutritious food, at the same time it is an instrument of livelihood for a large section of economically backward population of the country (SEAI, 2011). Another key factor is the high women labour constituent in the total employment requirement of this sector. The fisheries sector, including aquaculture, which employs more than 5 million people, both direct and indirect, and affects the
livelihood of four times this number, with an income generation of nearly 50,000 crores of rupees annually, has been not given the desired importance by the Government of India (SEAI, 2010; MPEDA, 2015).

The seafood industry consists primarily of many small processing plants, with a number of larger plants located near industry and population centres. Seafood products form a considerable segment of the post-harvest utility of marine fish resources. There has been a considerable structural change in the seafood processing and export industry for the last few years. There is a growing demand for “ready to cook” or “ready to serve” type of seafood, hygienically prepared and attractively packed foods to match the changing needs of urban population. The seafood processing and marketing has become competitive all over the world and exporters are switching over to value addition to increase profit (Sathiadhas and Salim, 2012).

As in most processing industries, seafood-processing operations produce wastewater containing substantial contaminants in soluble, colloidal, and particulate forms. The degree of the contamination depends on the particular operation; it may be small (e.g., washing operations), mild (e.g., fish filleting), or heavy (e.g., blood water drained from fish storage tanks). A related factor, aggravating the pollution problem, is that the receiving water bodies do not have sufficient water for dilution. The problem of pollution of rivers caused by untreated urban sewage is compounded by the discharge of industrial effluents (Goldar and Banerjee, 2004).

Seafood-processing wastewater characteristics that raise concern include pollutant parameters, sources of process waste, and types of wastes. In general, seafood-processing wastewater can be characterized by its physicochemical parameters, organics, nitrogen, and phosphorus contents. As in most industrial wastewaters, the contaminants present in seafood-processing wastewaters are an undefined mixture of substances, mostly organic in nature (Tay et al., 2006). Important pollutant parameters of the wastewater are five-day biochemical oxygen demand (BOD5), chemical oxygen demand (COD), total suspended solids (TSS), fats, oil and grease (FOG), and water usage (Carawan et al., 1979). The degree of pollution of a wastewater depends on several parameters. The most important factors are the types of operation being carried out and the type of seafood being processed. In addition to it, the waste water may have pH (effluent pH from seafood processing plants is usually close to neutral), solid content (dissolved solids and suspended solids), odour (caused by the decomposition of the organic matter, which emits volatile amines, diamines, and sometimes ammonia), and temperature (Tay et al., 2006). Both liquid (effluent) and solid wastes are generated by most seafood processing technologies. Untreated effluents often contain varying amounts of solid matter including offal, skin, and bone (AMEC, 2003; Morry et al., 2003; Adams et al., 2005; Lalonde et al., 2007; Theriault et al., 2007).

The negative impact of seafood processing effluent on water quality was investigated by Walden (1991); Park et al. (2001); Morry et al. (2003); Tchoukanova et al. (2003); Akan et al. (2008); Sankpal and Naikwade (2012). Thus, it is obvious that, the seafood associated pollutants led to the destabilization of aquatic ecosystem (DWAF and WRC, 1995; Morrison et al., 2001). The percent composition of insoluble to soluble compounds in seafood processing effluent is important as this will dictate the effectiveness of potential wastewater treatment technologies (Lim et al., 2003; Metcalf and Eddy, 2003). Several studies have characterized the effluent from fish processing plants (Riddle and Shikaze, 1973; Claggett and Wong, 1974; NovaTec and EVS, 1994; Jamieson, 2006).

The tremendous growth in the resources and infrastructure of seafood industry across the country is also being observed in Kerala. The development of fish and fishery products export from Kerala has gone hand in hand with the evolution of the fish processing sector. A distinct feature of the processing sector in Kerala is its dependence on the pre-processing sector, which is popularly known as “peeling sheds”. The seafood products exported from Kerala is dominated by frozen shrimp, cuttle fish and squids. Pre-processing is an extremely labour intensive operation, the success of which depends on the availability of experienced labour and raw material which in turn depends on with season (Sathyana et al., 2014).

Kerala is one of the most important maritime states in the country contributing significantly to the Indian seafood Industry. About 1/5th of its total landmass is wetlands (Kokkal et al., 2008). There are about 287 sea food exporters in Kerala with 124 processing plants and 169 cold storages. About 119 pre-processing units are located in Alappuzha (Alleppey) district, Kerala (Sathyana et al., 2014). Kerala accounted for 10, 8616 tonnes valued at Rs.1524.12 crores sharing 17.7% in quantity and 18.2% in value of marine export from India (KSIDC, 2013).

Vembanad wetlands have been acclaimed as the ‘Inland fish basket’ of the State (Padmakumar, 2003). In Kerala, seafood industry is growing over the years and is dominated by export of shrimps, cuttlefish, squids and finfish varieties.
Fishing is practiced all along the coastal line but intensive fishing activity is centered on Kochi mainly due to the port facilities for processed fish (Iyer et al., 1994). The Kochi region has a vast majority of export processing plants within the state. 173 out of the 206 registered exporters in Kerala are situated within the Kochi and Cherthala taluks (MPEDA, 2015).

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. 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 form 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 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 Sathyana 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 physico-chemical characteristics of fish processing industry effluent discharge into veraval harbour waters of Gujarat were 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 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.

The coastal belt of Vembanad lake is bordered by a number of seafood processing units. All the processing plants discharge their effluents together with solid waste into this lake. The volume of effluent discharged into this wetland system is unknown still. No routine monitoring is done to check the uncontrolled discharge of the seafood processing waste into the Ramsar site.

An integrated approach relating biological as well as physicochemical aspects with respect to seasons are not available for this unique backwater ecosystem (Radhika, 2013). Because of the aforementioned reasons, it was decided worthwhile to undertake a detailed study on this aspect of pollution. Hence, the present study has been formulated to understand the influence of seafood processing waste on the physico-chemical properties of water receiving the effluent discharge.

**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 station (S10) which is free from seafood effluent discharge (Table 1 and Fig.1). The first five stations are in interconnected channels and the remaining including the reference station is in the main water body. 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 refrigerated at 4°C. Atmospheric and water temperature, pH, electrical conductivity and total dissolved solids were measured using microprocessor based portable water quality testing meters. Salinity was measured using a hand refractometer. Transparency was measured using Secchi Disc of 20cm in diameter. The titration method was adopted for testing dissolved oxygen, alkalinity, hardness, chemical oxygen demand and biological oxygen demand as recommended by Adoni (1985) and APHA (2005). The nutrients namely nitrate, phosphate, silicate, and ammonia...
were examined using a Bench photometer (Hanna Instruments C 200 series).

The mean and standard error of mean (SEM) values were calculated for all parameters in each station and season and represented in graphs (Fig.2 -18).

RESULTS AND DISCUSSION

Physico-chemical parameters of water highly influence the occurrence and abundance of aquatic organisms. Each physico-chemical parameter has its own role and the interaction of factors finally produces the cumulative effect. Observations on the different parameters investigated are detailed below.

Atmospheric temperature (°C)
The station wise and season wise variations of atmospheric temperature are shown in figure 2. The total mean value of atmospheric temperature was noted to be minimum in S_1 (30.02 ± 0.82) and maximum in S_7 (33.04 ± 0.51). In the pre-monsoon period, the lowest mean temperature was noted in S_1 (28.75 ± 1.36) and the highest in S_10 (31.81 ± 1.00). Throughout monsoon season, the lowest temperature was reported in S_1 (32.31 ± 1.13) and the highest in S_7 (34.75 ± 0.45) while in post monsoon period the lowest temperature was reported in S_1 (29.00 ± 1.54) and the highest in S_7 (33.00 ± 0.76). ANOVA showed a significant variation in air temperatures between stations (Pd”0.05) and also among seasons (Pd”0.01).

The temperature plays an important role in physico-chemical and biological performance of water ecosystem (Dwivedi and Pandey, 2002). No other factor has so much influence as temperature (Welch, 1952). The rise in atmospheric temperature caused enhancement in the evaporation rate, which resulted in a reduction in water depth. Atmospheric temperature showed significant variation among stations and seasons, whereas water temperature showed significant variation between seasons. The difference in the water temperature might be due to difference in sampling time and the influence of season as suggested by Desai (1995) and Jayaraman et al. (2003).

Water temperature (°C)
The station wise and season wise values of surface water temperatures are shown in figure 3. The total mean value of water temperature was observed to be low in S_1 (29.00 ± 0.31) and high in S_7 (30.85 ± 0.40).

For the duration of pre monsoon season, the lowest surface water temperature was reported in S_3 (27.50 ± 0.38) and the highest in S_9 (29.56 ± 0.65). During the monsoon season, the lowest water temperature was reported in S_1 (29.00 ± 1.54) and the highest in S_7 (33.00 ± 0.76). ANOVA showed a significant variation in air temperatures between stations (Pd”0.05) and also among seasons (Pd”0.01).

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Table 1. Characteristics of study sites

<table>
<thead>
<tr>
<th>Sl. No</th>
<th>Name</th>
<th>Geographic position</th>
<th>Source of pollution</th>
<th>Land utilisation</th>
<th>Colour</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Pattanakadu</td>
<td>9°44'22 N, 76°19'07E</td>
<td>Discharge from Sea food processing industry</td>
<td>Panchayath area/Residential</td>
<td>Turbid water</td>
<td>Interconnected canal</td>
</tr>
<tr>
<td>2</td>
<td>Parayakadu</td>
<td>9°47'13N,76°18'20E</td>
<td>Discharge from Sea food processing industry</td>
<td>Aquaculture farm</td>
<td>Turbid water</td>
<td>Interconnected canal</td>
</tr>
<tr>
<td>3</td>
<td>Shankaranthodu</td>
<td>9°47'22N,76°18'12E</td>
<td>Discharge from Sea food processing industry</td>
<td>Panchayath area/Residential</td>
<td>Heavily turbid water</td>
<td>Interconnected canal</td>
</tr>
<tr>
<td>4</td>
<td>Konkeri Bridge</td>
<td>9°49'22N,76°18'22E</td>
<td>Discharge from Sea food processing industry</td>
<td>Panchayath area/Residential</td>
<td>Turbid water</td>
<td>Interconnected canal</td>
</tr>
<tr>
<td>5</td>
<td>Chandiroor</td>
<td>9°50'28N,76°18'29E</td>
<td>Discharge from Sea food processing industry</td>
<td>Panchayath area/Residential</td>
<td>Heavily turbid water</td>
<td>Interconnected canal</td>
</tr>
<tr>
<td>6</td>
<td>Edakochi I</td>
<td>9°54'47N,76°17'06E</td>
<td>Discharge from Sea food processing industry</td>
<td>Panchayath area/Residential</td>
<td>Heavily turbid water</td>
<td>Main water body</td>
</tr>
<tr>
<td>7</td>
<td>Edakochi II</td>
<td>9°54'07N,76°17'42E</td>
<td>Discharge from Sea food processing industry</td>
<td>Boat building yard</td>
<td>Heavily turbid water</td>
<td>Main water body</td>
</tr>
<tr>
<td>8</td>
<td>Aroormukkam</td>
<td>9°53'23N,76°17'49E</td>
<td>Discharge from Sea food processing industry</td>
<td>Fallow land</td>
<td>Turbid water</td>
<td>Main water body</td>
</tr>
<tr>
<td>9</td>
<td>Aroorkutti</td>
<td>9°52'12N,76°19'01E</td>
<td>Discharge from Sea food processing industry</td>
<td>Panchayath area/Residential</td>
<td>Heavily turbid water</td>
<td>Main water body</td>
</tr>
<tr>
<td>10</td>
<td>Panavally/</td>
<td>9°49'13 N, 76°21'33E</td>
<td>Free from Sea food processing waste</td>
<td>Agriculture and Aquaculture</td>
<td>Clear water</td>
<td>Main water body</td>
</tr>
</tbody>
</table>
Throughout the post monsoon season, the lowest temperature was reported in S₁ (28.38 ± 0.56) and the highest in S₆ (31.69 ± 0.48). The ANOVA results showed significant variation of water temperatures between stations (P < 0.05) and also between seasons (P < 0.01). Water temperature plays a vitally important role in studying the distribution, metabolism, and life histories of aquatic organisms (Newell, 1965; Kinne, 1970; Hines, 1978). In the present study water temperature and atmospheric temperature did not show much variation and the values recorded were within a narrow range. Studies conducted in the retting zones by Remani (1979) in Cochin backwaters, Azis and Nair (1986) in Edava-Nadayara estuary and in Kadinamkulam-Anchuthengu estuarine system Nandan (1991) and Nandan and Aziz, (1994) showed that higher values of water temperature in the retting zones than non-retting zones. On the contrary, in the present study, the water temperature did not show such differences between polluted stations and the reference station. 

pH

The variations with respect to stations and seasons in pH are shown figure 4. Amongst the stations, the total mean value of pH was found to be minimum in S₁ (7.10 ± 0.14) and maximum in S₆ (8.99 ± 0.20). During the pre monsoon season, the lowest pH value was reported in S₁ (6.69 ± 0.11) and highest in S₆ (7.91 ± 0.53). Throughout the monsoon season, the lowest pH was reported in S₁ (7.21 ± 0.18) and the highest in S₉ (8.08 ± 0.22) and in the post monsoon season, the lowest value was reported in S₆ (7.32 ± 0.33) and highest in S₁ (8.99 ± 0.20). The ANOVA results showed significant variation of pH between stations (P < 0.01) and also between seasons (P < 0.01).

pH of water has given the idea of the intensity of pollution (Verma and Shukla, 1970) and polluted zones can be identified by monitoring pH values (Clarks et al., 1977). The pH during the study period was alkaline and it showed significant variation between stations, and seasons. The pH in the S₁ and S₂ were high when compared to the reference station (S₁₀). The low pH in the polluted stations (S₂–S₆) situated in the main water body might be because of the waves and its connection to the sea, which diluted the waste upon its discharge. While studying, the physico-chemical characteristics of seafood effluents from Aroor Grama Panchayath, Thomas et al., (2015) reported the pH variation from 6.8 to 7.5. Effluents from fish processing establishments are seldom acidic and are usually close to seven or alkaline (Alex, 2005; Chowdhury et al., 2010; Sankpal and Naikwade, 2012; Vaghela et al., 2015; Thomas et al., 2015) that is generally due to the decomposition of proteinaceous matter present in the effluent (Alex, 2005). On the contrary, Iyer et al. (1994) reported that the pH of effluents from eight seafood-processing factories in Cochin varied from 5 to 7.5. If the current situation of waste disposal continues, the water quality shifted to alkaline range over time, which affects aquatic life. Either highly acidic or alkaline water would kill marine life (Lokhande et al., 2011). Changes occurring in pH due to chemical and other industrial effluents render a stream unsuitable not only for recreational purpose but also for the rearing of fish and other aquatic life (Webb, 1982).

Total dissolved solids (ppt)

The station wise and season wise variations of TDS are shown in figure 5. The total mean value of TDS was found to be minimum in S₁ (2.36 ± 0.83) and maximum in S₇ (7.16 ± 0.82). The seasonal variation of TDS is shown in table 7. During the pre monsoon period, the lowest TDS value was reported from S₁ (2.36 ± 0.83) and the highest from S₇ (6.38 ± 0.77). For the monsoon season, the lowest value was reported from S₁₀ (4.14 ± 0.73) and the highest from S₇ (7.75 ± 0.82) whereas in the post monsoon season, the lowest value was reported from S₁ (0.58 ± 0.19) and the highest from S₉ (2.94 ± 0.83). Statistical analysis using ANOVA showed that there was significant variation of TDS between stations (P < 0.01) and also between seasons (P < 0.01) with the lowest value in the polluted stations.
Wastewater contains a high fraction of dissolved solids (Sankpal and Naikwade, 2012). The high TDS level is generally due to the accumulation of different pollutants (Rani et al., 2003; Regina and Nabi, 2004). In the present study, TDS expressed in ppt were well above the permissible limits prescribed by WHO (2004). Thomas et al., 2015 reported the total solids from the processing effluents ranged from 2211.5 mg/l to 3779.9 mg/l depending upon the type of fish processed. Sankpal and Naiwade, (2012) reported TDS from the fish processing industries in Ratnagiri ranged from 8200mg/l to 14,700mg/l. Vaghela et al. (2015) showed that the total dissolved solids from the fish processing effluent samples varied from 12750mg/l to 13128mg/l. In this study, the TDS in the main water body (S1-S5) was high, compared to the interconnected channels and the reference station. Higher values of TDS indicate maximum disturbance due to human activities as suggested by Thakur et al., 2013. The tidal influence and current patterns along with the effluent discharge in the polluted stations (S6-S10) might be the reason for its high TDS. According to Kataria et al. (1996), the rise in the value of TDS indicated pollution from unrelated sources. Khatavkar and Trivedy, (1993) proved that high concentration of suspended solids was not only due to high concentration of algae but also due to organic matter and silt load. The high organic matter in the seafood effluent discharge might be the reason for the higher total dissolved solids in the polluted stations. The total dissolved solids (TDS) affect the water quality by increasing the density of water and thereby retarding the palatability of water. In the present study, TDS was high in the monsoon season. According to Trivedy and Goel, (1984) an excess amount of TDS in water tends to disturb the ecological balance due to suffocation in aquatic fauna even in the presence of a fair amount of dissolved oxygen. The maximum values of total dissolved solids during monsoon might due to the gradual increase in the entry of domestic sewage, detergents, and industrial waste to the river stream as reported earlier by (Gonzalves and Joshi, 1946). The surface runoff during the rainy season might be the reason for increased TDS. On the contrary, Scaria (2004) reported the higher values of TDS in pre-monsoon season, Muvattupuzha river, Chitrapuruzha river and Cochin estuary. ANOVA test showed significant variation of electrical conductivity between stations (P<0.01) and also between seasons (P<0.01).

Electrical conductivity is a measure of ionic concentration. According to Kadam and Tiwari, (1990) a high value of EC designates the pollution status of the lake. The conductivity showed significant variation between stations and seasons. In the present study, conductivity was high in the interconnected channels (S5-S9) and in the main water body (S5-S7) when compared to the reference station. In lake, the increase in conductivity also may be due to inflow of wastewater from the surroundings (Hardikar, 2013). Sankpal and Naikwade, (2012) reported that the conductivity in the effluent discharge of fish processing industries ranged from 113.42ms to 18.02ms. In the present study, conductivity in the polluted stations ranged from 4.63ms (S1) to 11.95ms (S8). The mixing of the effluent discharge into the water may have lowered the conductivity in the polluted stations. The electrical conductivity is due to mainly the dissolved ions such as Bicarbonates, Chlorides, Sodium, Potassium, Magnesium and Sulphate (Peavy et al., 1986). The presence of high amount of chlorides, nitrate, ammonia in the fish processing waste were already established (Sankpal and Naikwade, 2012; Vaghela et al., 2015). The discharge of waste from the nearby seafood processing plants might have increased the conductivity.

Salinity (ppt)
The station wise and season wise variations of salinity are shown and figure 7. Among the stations, the total mean value of salinity was found to be minimum in S1 (4.29 ± 0.59) and maximum in S9 (11.17 ± 1.01). In the pre monsoon season, the lowest salinity was reported from S8 (4.00 ± 0.60) and the highest from S9 (15.38 ± 1.77). During the monsoon season the lowest value was reported from S9 (4.88 ± 0.44) and the highest from S8 (10.38 ± 2.19) and throughout the post monsoon season, the lowest salinity was reported from S9 (15.38 ± 0.94) and the highest from S10 (8.38 ± 1.74). The ANOVA results showed significant variation of salinity between stations (P<0.01) and also between seasons (P<0.01).

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; Gowda et al., 2001; Rajasegar, 2003) and due to the discharge of waste from the fish processing industries. 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 (S3, S5), 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.

Transparency (sdd)

The station wise variation of transparency is shown figure 8. Among the stations, the total mean value was found to be minimum in S4 (28.10 ± 1.76) and maximum in S10 (79.91 ± 3.27). In the pre monsoon season, the lowest value was reported from S5 (29.35 ± 6.78) and the highest from S10 (83.56 ± 3.71). During the monsoon season, the lowest value was reported from S5 (23.31 ± 1.31) and the highest from S5 (73.75 ± 5.39). Throughout the post monsoon season, the lowest value was reported from S4 (28.10 ± 1.76) and the highest from S10 (82.41 ± 7.37). The ANOVA results showed significant variation of transparency only between stations (P< 0.01).

Transparency of water is a measure of light penetration (Pickard and Emery, 1982; Goldman and Horne, 1983), which mainly depends on the turbidity of water. The transparency showed significant variation only between stations. In the present study, the highest transparency was reported in the reference station. Transparency of water is also affected due to total solids partly or fully decomposed organic matters, silts and turbulence caused by the currents, waves, human and cattle activities (Singh et al., 1999). The high organic matter in the seafood discharge reduced the transparency in the polluted stations. Fat, oil and grease are important parameters of the fish processing, wastewater (Chowdhury et al., 2010; Sankpal and Naikwade, 2012) hindered transparency in the seafood waste discharge affected stations. Transparency Oscillated on a seasonal basis, and was less during the monsoon season due to high current and suspended matter and dissolved particles associated with surface runoff. This is in agreement with the findings of Saksena et al. (2008) that high current in the monsoon season erodes the bank of the river due to turbid floodwater.

Free Carbon dioxide (mg/l)

The station wise and season wise variations of free CO2 are shown in figure 9. Amongst the stations, the total mean value of free carbon dioxide was found to be minimum in S10 (16.98 ± 2.08) and maximum in S4 (118.28 ± 16.31). During the pre-monsoon months, the lowest value was reported from S10 (19.69 ± 4.62) and the highest from S4 (73.12 ± 14.06). Throughout the monsoon season, the lowest value was reported from S10 (11.38 ± 1.45) and the highest from S4 (130.88 ± 39.01). In the post monsoon season, the lowest value was reported from S10 (19.88 ± 3.55) and the highest from S4 (163.00 ± 13.45). The ANOVA results showed significant variation of free CO2 between stations (P< 0.01) and also between seasons (P< 0.01).

The amount of free CO2 in water is generally maintained by diffusion from the atmosphere, respiration of animals along with plants and bacterial decomposition of organic matter (Misra et al., 1993). The free CO2 showed significant variation between stations and seasons. The free CO2 was comparatively high in the polluted stations (S1-S4) when compared to the reference station. Yakub, (2010) reported that the higher value of free CO2 in waste water from the milk processing unit was due to presence of a greater quantity of organic matter and its decomposition. Similarly Nandan, (2004) reported the highest concentration of free carbon dioxide in the rooting zone, which is due to the process of decomposition of organic matter. The free carbon dioxide was low in the reference station (S4) during all the seasons, which reflects less load of organic matter in water as reported by Pathani and Upadhyay (2006). The seafood processing effluent has resulted in the rise of free carbon dioxide in the selected study stations of the wetland.

Alkalinity (mg/l)

The station wise and season wise fluctuations of alkalinity are shown in figure 10. The total mean value of alkalinity was found to be minimum in S10 (29.83 ± 2.92) and maximum in S4 (166.46 ± 30.63). In the pre-monsoon season, the lowest alkalinity was reported from S10 (35.25 ± 4.32) and the highest from S4 (130.75 ± 10.91). During the monsoon season, the lowest value was reported from S10 (26.88 ± 3.19) and the highest from S4 (234.38 ± 75.05) while in the post monsoon season, the lowest alkalinity was reported from S10 (29.83 ± 2.92) and the highest value was reported from S4 (186.46 ± 30.63). Statistical analysis using ANOVA showed significant variation between stations (P< 0.01) and also between seasons (P< 0.05).

The high value of alkalinity indicates the presence of bicarbonate, carbonate, and hydroxide in the water body.
Low DO was reported in the post monsoon when compared to the monsoon season. High amount of Dissolved Oxygen (DO) is necessary for aquatic life. (Jain, 2000). Adding waste in water bodies may also cause higher alkalinity level in that medium (Mulani et al., 2009). Alkalinity showed significant variation between stations and seasons. Alkalinity was low in the reference station (S_1) during all seasons signalling less pollution load. In the present investigation, the values of alkalinity at different sites were high during summer season and reduced during rainy periods due to dilution of effluents. High values of total alkalinity may be attributed to the increase in organic decomposition during which carbon dioxide is liberated. This reacts to form bicarbonate thereby increasing total alkalinity in summer (Mahadev et al., 2010). Jain et al. (1996) and Scaria, (2004) while studying Cochin backwaters and Saikia and Lohar, (2012) while studying the effect of pulp and paper mill effluent discharge on wetlands in Assam, observed similar results. The alkalinity values more than 100 mg/L is listed as eutrophic, and those with less than 50 mg/L as oligotrophic (Anon, 2001). As per this, the stations S_5, S_6, and S_9 are eutrophic. This suggests that over time, the other polluted stations might become eutrophic if the present situation of wastewater from the seafood industries persists. Thomas et al. (2015), while analysing the seafood processing effluents in Aroor reported that the alkalinity varied from 410 mg/l to 553.3mg/l. The discharge of untreated processing effluent into the wetland influenced the alkalinity value. In station 5, alkalinity exceeded the permissible limit of 200mg/l as described by BIS, (2003). Higher values of the alkalinity indicate the pollution load. According to Nayak et al. (1982) and Ghosh and George (1989) the higher alkalinity indicates pollution. Therefore, alkalinity values obtained during the study period confirmed that the water quality is deteriorated in the seafood waste discharge stations.

**Dissolved Oxygen (mg/l)**

The station wise and season wise variations of dissolved oxygen are shown in figure 12. Among the stations, the total mean value of DO was found to be minimum in S_5 (5.36 ± 0.35) and maximum in S_10 (8.60 ± 0.19). During the pre monsoon season, the lowest value was reported from S_5 (5.47 ± 0.52) and maximum in S_9 (8.38 ± 0.31). In the monsoon season, the lowest value was reported from S_5 (4.14 ± 0.52) and the highest from S_10 (8.57 ± 0.30). Throughout the post monsoon season, the lowest value was reported from S_5 (6.21 ± 0.46) and the highest value from S_10 (8.85 ± 0.37). The ANOVA results showed significant variation of hardness between stations (Pd" 0.01) and between seasons (Pd" 0.01).

The effect of wastewater released into a water body largely determined by the discharge of oxygen demanding waste and oxygen balance of the system. (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., 2007). 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 (Ganpati, 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 (S_1-S_5) when compared to the main water body (S_4-S_9). 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).

Hardness (mg/l)

The station wise and season wise variations of hardness are shown in figure 11. Amongst the stations, the total mean value of hardness was found to be minimum in S_10 (154.33 ± 18.88) and maximum in S_5 (1402.58 ± 232.24). During the pre monsoon season, the lowest value was reported from S_10 (146.75 ± 34.34) and the highest in S_4 (1043.50 ± 94.24). Throughout the monsoon season, the lowest value was reported from S_5 (214.00 ± 36.72) and the highest from S_10 (2827.50 ± 253.18) while during the post monsoon season, the lowest value was reported from S_10 (102.25 ± 9.08) and the highest from S_4 (743.25 ± 101.89). ANOVA results revealed that the hardness demonstrated significant variations between stations (Pd" 0.01) and also between seasons (Pd" 0.01).

**Hardness**

Hardness in water is derived from CO_2 released in bacterial action and by metabolic ions dissolved in wastewater (Chauhan and Sagar, 2013). The hardness showed significant variation between stations and seasons. Kannan, (1991) has classified water based on hardness values in the following – 60 mg/L, soft, 61–120 mg/L, moderately hard, 121–160 mg/L, hard and greater than 180 mg/L as very hard. The hardness in the stations (S_1-S_5) exceeded the permissible limits described by BIS of 300mg/l (BIS, 2003). The high hardness in the interconnected channels (S_1-S_5) and in the main water body (S_4-S_9) even after tidal mixing, points out the impact of seafood processing waste discharge on the receiving water body. Using these criteria, the water of the stations (S_1-S_5) can be considered as very hard. Similarly Cong (1999) and Junshum et al., (2007) observed a high value of water hardness in wastewater treatment plant, as compared with natural reservoirs.
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. A reduction in dissolved oxygen because of nutrient load was also reported (Johannesen and Dahl, 1996). Singh and Singh (2001) and Medhi et al. (2011) also noticed water quality degradation due to changes in values of dissolved oxygen of river Ami and in Nagaon paper mill effluents respectively.

### Biological Oxygen Demand (mg/l)

The station wise and season wise variations of BOD are shown in figure 13. Amongst the stations, the total mean value of BOD was found to be minimum in S_{10} (5.42 ± 0.48) and maximum in S_{4} (44.48 ± 4.05). During the pre monsoon season, the lowest value was reported from S_{10} (4.58 ± 1.01) and the highest from S_{4} (38.66 ± 5.98). Throughout the monsoon season, the lowest value was reported from S_{10} (6.02 ± 0.93) and the highest from S_{9} (42.70 ± 7.43). During the post monsoon season, the lowest value was reported from S_{10} (6.38 ± 0.45) and the highest from S_{5} (64.85 ± 4.60). The ANOVA results showed that significant variation of BOD exists only between stations (Pd > 0.01).

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 (Chaudhary et al., 2004; Sanap et al., 2006). The greater the decomposable matter present, the greater the oxygen demand and greater the BOD values (Adermoroti, 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; Goldar and Banerjee, 2004; 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; Adermoroti, 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).

### Chemical Oxygen Demand (mg/l)

The station wise and season wise variations of COD are shown in figure 14. Amongst the stations, the mean value was found to be minimum in S_{10} (6.68 ± 0.83) and maximum in S_{4} (48.29 ± 6.95). Throughout the pre monsoon season the lowest value was reported from S_{10} (7.45 ± 1.42) and the highest value was reported from S_{4} (52.05 ± 10.47). In the monsoon season, the lowest value was reported from S_{10} (5.94 ± 1.52) and the highest value was reported from S_{5} (54.47 ± 13.15) whereas in the post monsoon season,
COD is used to measure pollution of domestic and industrial waste. The waste is measured in terms of equality of oxygen required for oxidation of organic matter to produce CO2 and water (Sankpal and Naikwade, 2012). Chemical oxygen demand (COD) showed significant variation between stations and seasons. The COD was reported high in the seafood waste discharge affected stations (S1-S9). Jayraman et al. (2003) reported the influence of organic matter, thermal power, effluents, and anthropogenic activities for high COD. In a fish processing industry, the effluent COD is usually higher than BOD (Chowdhury et al., 2010). In the present study, the BOD and COD values were unusually higher and exceeded the permissible limits prescribed by WHO (2004). High amount of BOD and COD cause oxygen depletions, which leads to the suffocation of aquatic life (Verma et al., 1984). The high values of BOD and COD reflected high pollution levels due to discharge of industrial effluents and sewage wastes (Khan et al., 2005). Thomas et al. (2015) reported that COD in the seafood processing effluents in Aroor Panchayath varied from 1442 mg/l to 2700mg/l. Sankpal and Naikwade, (2012) reported that the COD in the effluent discharge of the fish processing industry in Ratnagiri varied from 1200mg/l to 2200mg/l. Similarly, Vaghela et al. (2015) reported that the COD in the effluent discharge of the fish processing industry in Veravel harbour varied from 100mg/l to 250mg/l. The discharge of the high pollution load from the seafood industry might have increased the COD level in the interconnected channels (S1-S9) and in the main water body (S6-S9) when compared to the reference station (S10).

**Phosphate (mg/l)**

The station wise and season wise variations of phosphate are shown in figure 15. The total mean value of phosphate was found to be minimum in S10 (0.56 ± 0.09) and maximum in S6 (6.65 ± 0.91). During the pre monsoon season, the lowest value was reported from S10 (0.47 ± 0.15) and highest in S3 (2.84 ± 0.41). In the monsoon season, the lowest value was reported from S10 (0.59 ± 0.13) and highest from S6 (4.04 ± 0.97) and in the post monsoon season, the lowest value was reported from S10 (0.63 ± 0.18) and highest from S6 (10.50 ± 1.10). The ANOVA results showed significant variation between stations (Pd" 0.01) and also between seasons (Pd" 0.05).

Phosphate acts as nutrient for plant growth and high concentration of this nutrient indicate of eutrophication. 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.

**Nitrate (mg/l)**

The station wise and season wise variations of nitrate are shown in figure 16. Between stations, the total mean value of nitrate was found to be minimum in S10 (2.17 ± 0.30) and maximum in S6 (14.78 ± 2.17). During the pre monsoon season, the lowest value was reported from S10 (2.95 ± 0.70) and highest from S6 (12.73 ± 2.28). Throughout the monsoon season, the lowest value was reported from S10 (2.48 ± 0.32) and highest from S6 (17.55 ± 6.06) while in the post monsoon season, the lowest value was reported from S10 (1.09 ± 0.08) and the highest from S6 (14.05 ± 1.61). The ANOVA results showed significant variations in nitrate between stations (Pd" 0.01) and seasons (Pd" 0.05).

Among the nutrients nitrate play an important role in balancing various biological processes occurring in aquatic ecosystems. High nitrate concentrations are frequently encountered in treating wastewater, because of ammonium nitrogen. High nitrate levels in wastewater could also contribute to eutrophication effects, particularly in freshwater (OECD, 1982). The nitrate showed significant variation between stations and seasons. The lowest value was reported in the reference station irrespective of the seasons. Nitrate was high in the main water body (S6-S9) when compared to the interconnected channels (S1-S9). The nitrate content was higher in the seafood discharge affected stations when compared to the reference station. The high nitrogen levels in seafood waste are likely due to the high protein content (15–20% of wet weight) of fish and marine invertebrate (Sikorski, 1990). Sankpal and Naikwade, (2012) reported that the nitrate in the effluent discharge of the fish processing industry ranged from 126-168mg/l whereas Vaghela et al. (2015) reported that the COD in the effluent discharge of the fish processing industry varied from 28.5-30mg/l. Higher nitrate points out adding processing effluent into the wetland. Osibanjo et al. (2011) recorded a high nitrate in the river, which receives industrial effluents and urban runoff. Another possible way of nitrate entry might be
through oxidation of ammonia (Rajasegar, 2003). The highest concentration of nitrate is an indication of organic pollution and eutrophication (Maheshwari, 2011).

**Ammonia (mg/l)**

The station wise and season wise variations of ammonia are shown in figure 17. Among the stations, the total mean value of ammonia was found to be minimum in $S_{10}$ (0.68 ± 0.10) and maximum in $S_5$ (9.22 ± 1.57). During the pre monsoon season, the lowest value was reported from $S_{10}$ (0.80 ± 0.13) and highest from $S_5$ (6.52 ± 1.72). In the monsoon season, the lowest value was reported from $S_{10}$ (0.52 ± 0.19) and highest from $S_5$ (6.42 ± 1.84) whereas in the post monsoon season, the lowest value was reported from $S_{10}$ (0.74 ± 0.22) and highest from $S_5$ (14.72 ± 3.41). The ANOVA results showed significant variations in ammonia between stations (P≤ 0.01) and seasons (P≤ 0.01).

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 ammonification. 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).

**Silica (mg/l)**

The station wise and season wise variations of silica are shown in figure 18. Among the stations, the total mean value was found to be minimum in $S_{10}$ (1.46 ± 0.26) and maximum in $S_5$ (4.43 ± 0.64). During the pre monsoon season, the lowest value was reported from $S_{10}$ (0.64 ± 0.10) and highest from $S_5$ (2.80 ± 0.65). In the monsoon season, the lowest value was reported from $S_{10}$ (1.47 ± 0.39) and highest from $S_5$ (4.18 ± 0.91). During the post monsoon season, the lowest value was reported from $S_{10}$ (2.28 ± 0.55) and highest from $S_5$ (6.93 ± 1.18). The computation of ANOVA showed significant variations between stations (P≤ 0.01) and seasons (P≤ 0.01).

Silica showed significant variation between stations and seasons. Comparatively high values were observed in the seafood waste discharge stations. According to Livingstone (1963), worldwide mean value is 13.0 mg/l for silicates. In the present study, average value did not exceeded 4.60 mg/l, and this could be because of its use by diatoms. Among the stations, the lowest value was reported in the reference station during all seasons. The observed lower values of silicate could be attributed to uptake of by phytoplankton for their biological activity (Mishra et al., 1993; Ramakrishnan et al., 1999). The higher value of silica is a sign of waste from industrial effluents and of the death of diatoms.

**SUMMARY AND CONCLUSION**

In India especially in Kerala, the environmental problems associated with the discharge of wastewater from seafood processing facilities are gaining attention only recently. The processing of seafood products can require significant volume of water, which has a direct consequence in the generation of contaminated effluents. The seafood industries in Kerala are particularly limited to the narrow coastline areas of the Vembanad Lake aremainly due to the ease of transport. All the processing plants discharge their effluents together with solid waste into this lake. The volume of effluent discharged into this wetland system is unknown and no routine monitoring is done to check the uncontrolled discharge of the seafood processing waste. The purpose of the present study was to understand the influence of seafood waste discharge on the physico-chemical properties of water.

The extent of pollution impact of seafood waste discharge on nearby water bodies was done by studying the physicochemical parameters. Parameters like TDS, alkalinity, BOD, COD and hardness exceeded the permissible limits in polluted stations. Among polluted stations, the effect was pronounced in the interconnected channels because of less surface runoff. The stagnated
Fig. 2. Station wise and season wise variation of atmospheric temperature

Fig. 3. Station wise and season wise variation of water temperature

Fig. 4. Station wise and season wise variation of pH

Fig. 5. Station wise and season wise variation of TDS

Fig. 6. Station wise and season wise variation of EC

Fig. 7. Station wise and season wise variation of salinity

Fig. 8. Station wise and season wise variation of transparency

Fig. 9. Station wise and season wise variation of free CO₂

Fig. 10. Station wise and season wise variation of alkalinity

Fig. 11. Station wise and season wise variation of hardness
nature of the lake may add on the ruinous effect. 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. High levels of ammonia existed in the interconnected canals and in the main water body.

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 TDS, alkalinity, BOD, COD and hardness nutrients and pollution indicators showed wide fluctuations according to the pollution load.

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.

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