Investigations on selected ecological parameters of Tuticorin Bay, Gulf of Mannar, south-east coast of India with emphasis on suitability for mariculture

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ABSTRACT

A study was conducted for a period of two years from 2017 to 2018 to assess the health of Tuticorin Bay, south-east coast of India. Water and sediment quality parameters, total clam density, heavy metal content in the sediment and clam tissue samples from four sites were used as the criteria for health assessment. High values of parameters like salinity (38.3±5.04 ppt) and ammonia (0.09±0.04 mg l\(^{-1}\)) were observed at the station close to the thermal power station and high nitrite (0.688±0.13 µg l\(^{-1}\)) and total suspended solids (380.3±0.04 mg l\(^{-1}\)) were observed at the station close to Koramballam freshwater creek. Most of the water quality variables were within the standard limit prescribed for aquaculture activities. The organic matter content in the sediment of the bay ranged from 0.26 to 5.17%. Comparatively low heavy metal concentration was observed both in the sediment and clam tissue samples. The metals were found accumulated in the order of Fe>Mn>Pb>Cu>Ni>Cd in the sediment samples and in the order Fe>Pb>Mn>Cu>Cd>Ni in clam tissue samples. The estimated levels were also within the permissible limits for most of the metals. The study indicated that Tuticorin Bay is suitable for mariculture activities.

Keywords: Clam density, Heavy metal concentration, Tuticorin Bay, Water and sediment quality parameters

Introduction

Tuticorin Bay (08°46’20”N; 78°10’46”E) enclosing a water area of 56 sq km, is situated in the Gulf of Mannar, in Tamil Nadu, south-east coast of India. Hare Island forms the eastern boundary of the Bay and the Tuticorin landmass is on its western side. The southern point of Tuticorin Bay extends to a creek with a wide mangrove area, which is under the influence of the Tuticorin Thermal Power Plant (TTPP) (Mohamed, 1998). Tuticorin Thermal Power Station (TTPS) was commissioned in 1978, with an area of about 160 ha. It produces 1050 MW electricity per day utilising 18,000 t per day of coal and causes severe pollution of air, water and land environment (Selvin et al., 2010). TTPS discharged fly ash into the Bay until the CRZ notification by the Ministry of Environment and Forests in 1991. Clara and Sugritha (2013; 2016a) have reported about the chemical changes that occurred due to fly ash released from TTPS, especially the trace element content when in contact with seawater. Heavy metals like arsenic, lead, nickel, cobalt, chromium, boron and antimony that leached from the fly ash were found to be hazardous for living organisms (Clara and Sugritha, 2016b). Leaching of metals from fly ash into the surrounding environment has been reported from different parts of India (Tripathi et al., 2002; Dwivedi et al., 2007; Rajarshi et al., 2009). Ganesan and Kannan (1995) reported a higher concentration of Fe and Mn in the seawater, sediment and algae in the vicinity of Tuticorin Port. Palanichamy and Rajendran (2000) indicated a high concentration of Cd and Pb in the bottom waters than the surface waters off the Tuticorin coast. Asha et al. (2010) reported a high concentration of heavy metals in the seawater, sediment and bivalves of Tuticorin coastal waters within the vicinity of TTPS.

Besides this, the TTPP discharges hot water effluent with temperature ranging between 40 and 44°C into the adjacent water body at a rate of 115 x 10\(^6\) l day\(^{-1}\) (Kailasam and Sivakami, 2004). The neutralisation of temperature has been noticed up to 2 km from the Bay (Easterson et al., 2000). The influence of hot water effluents on the hydrography has been studied in various locations of the Bay (Asha, 2002; Shelarpiyusha et al., 2017). Fish mortality due to high ammonia concentrations has been reported from Tuticorin Bay (Asha et al., 2009). Irrespective of all these health hazards, the Bay serves as a significant source of livelihood for the local villagers for its clam and polychaete worm resources.
Ammonia was estimated (1984). Carbon dioxide concentration was measured of Fig. 1. pH, salinity, chlorophyll, gross primary productivity for mariculture activities.

Materials and methods

The study was carried out during the period 2017-2018. Four stations were fixed in the bay viz., Station-1 (St.1) at the northern side near Roche Park, (08°47’0.668”N; 078°09’6.265”E); Station-2 (St.2) 200 m away from St.1 nearer to the Koramballam freshwater creek (08°46’9.900”N; 078°09’5.897”E); Station-3 (St.3) (08°46’8.26’’N; 078°09’6.42’’E) 40 m away from St.2 on the southern side of the bay nearer to the seawater intake point of ICAR-CMFRI marine hatchery and Station 4 (St.4) (08°46’7.19’’N; 078°09’6.99’’E), 100 m away from St.3, towards the south, nearer to the TTPE plant (Fig. 1).

Seawater and sediment samples were collected from the four stations during four different seasons viz., summer, pre-monsoon, monsoon and post-monsoon. Water quality parameters such as dissolved oxygen (DO), carbon dioxide, biochemical oxygen demand (BOD), pH, salinity, chlorophyll, gross primary productivity (GPP), net primary productivity (NPP), ammonia, total suspended solids (TSS), total dissolved solids (TDS), alkalinity, carbon dioxide and nutrients like nitrite (NO₂⁻), nitrate (NO₃⁻), phosphate (PO₄³⁻) and silicate (SiO₄⁴⁻) were assessed by standard methods. In situ measurements of early morning air and sea surface water temperatures (AT and SST) were made using a high precision thermometer. Salinity was determined by Mohr’s titration method (Grasshoff, 1983). Dissolved oxygen and BOD were estimated by the modified Winkler’s method (Strickland and Parsons, 1972). Ammonia was estimated by the phenol hypochlorite method (Solarzano, 1969) and the nutrients were determined using spectrophotometer (Genesis 10 model) following the procedure given by Grasshoff et al. (1999). Primary production was estimated by the dark and light bottle method and Winkler’s method was employed for the estimation of oxygen. The same was converted into carbon equivalent using a PQ of 1.25 for obtaining the gross production. Total chlorophyll was estimated according to Parsons et al. (1984). Total suspended and dissolved solids were estimated by filtration technique and alkalinity by titration method (APHA, 2005). Carbon dioxide concentration was quantified by the acid-base titrimetry method (Dickson, 1998).

Core sampler of 20 cm length and 3 cm lumen diameter was used to collect subsurface sediment samples from the four stations. The samples were dried, pulverised and sieved for estimation of sediment quality parameters. Sediment texture was analysed by the pipette method (Lewis, 1984). Organic carbon, organic matter and nitrogen of the bottom sediments were estimated by Walkley-Black (1934) method. The benthic productivity of the bay was analysed in terms of clam biomass and density. For the clam productivity estimation, a quadrat (0.0625 m²) was placed at random in triplicates at the four stations and all the bivalves found in the quadrat were collected, washed thoroughly, counted and weighed. The mean of three quadrat samplings was considered to get the density and biomass per square meter. Different species of clams viz., Meretrix casta, Marcia opima, Gafrarium pectinatum and Protapes gallus (=Paphia malabarica) (10-35 nos.) collected from each station were washed and kept in filtered seawater to empty the gut. Whole-body tissue of animals was removed and washed in distilled water. The sediment and clam tissue samples were dried in an oven at 80±2°C. One gram of finely ground representative fraction of each sample was digested using HNO₃, HCl, 1:3 v/v and 6 ml of HF which was kept in a hot water bath for 3 h and then the digested precipitate was made up to 100 ml (Dalziel and Baker, 1984). The concentration of metals like Cd, Cu, Fe, Mn, Ni, Zn and Pb were estimated by an Inductively Coupled Plasma Optical Emission Spectrometer (Perkin Elmar Optima 5300 DV ICP-OES).
One-way analysis of variance (ANOVA) and correlation between all possible combinations were performed to test the significant seasonal and station-wise differences between parameters. Statistical analysis was performed using SPSS software ver. 20 (Chicago, USA).

Results and discussion

Water quality conditions of the bay

An apparent seasonal variation was noticed in the air as well as sea surface temperatures between stations. At all the stations it was lowest during post-monsoon and highest during summer, however not much variation was noticed between stations. The air temperature ranged between 25.5 and 35°C and water temperature between 26 and 33.5°C. The highest mean value of air temperature (31.3±1.9°C) was recorded at St.3 and St.4 and water temperature (29.8±1.4°C) at St.4 (Fig. 2a). Kailasam and Sivakami (2004) have reported a more or less similar range (27.7-33.7°C) of water temperature in the bay away from the hot water discharge point. The estimated mean sea surface temperature at all the stations was within the range of 25-32°C prescribed for mariculture (FAO, 2006). The seasonal variation was statistically significant for air and water temperatures at all the stations (p<0.001). A high positive correlation was also noticed between the two temperatures (p<0.01). The salinity was exceptionally high during the monsoon season at St.2 and St.4. The unexpected higher salinity might be due to runoff from the neighbouring salt pans during the monsoon season. High salinity in Tuticorin Bay due to the neritic water dominance has been reported earlier (Clara and Sugritha, 2015). The most elevated salinity of 53.4 ppt and the maximum mean value of 38.3±5.04 ppt were noticed at St.4 nearer to the most elevated salinity of 53.4 ppt during the monsoon season. High salinity in Tuticorin Bay due to the neritic water dominance has been reported earlier (Clara and Sugritha, 2015). The most elevated salinity of 53.4 ppt and the maximum mean value of 38.3±5.04 ppt were noticed at St.4 nearer to the TTPS (Fig. 2a). Kailasam and Sivakami (2004) have reported a lower range of salinity (31.6-36.3 ppt) within the vicinity of power plant stations. Shelarpiyusha et al. (2017) have also reported a higher salinity range of 36.2-39.9 ppt in the bay. The pH was comparatively higher at all the stations during the pre-monsoon season and varied between 7.65 at St.1 to 8.46 at St.3 (Table 1). The present work reported a more or less similar range of pH (7.5-8.5) as reported by Clara and Sugirtha (2015) and Shelarpiyusha et al. (2017) and a higher range of pH (8.08-8.35) than the values reported by Kailasam and Sivakami (2004). The usual range of pH noticed at all the study sites also indicated the low influence of alkaline fly ash from the TTPS (Clara and Sugritha, 2016). All the stations reported a mean pH within the permissible range of 7-8.5 prescribed for marine hatchery works (Boyd, 2003). The seasonal variation was significant for all the stations (p<0.001). The mean value was highest (8.15±0.1) at St.4 (Fig. 2b).

The DO concentration ranged between 2.5 to 8.2 ml l⁻¹. The mean value was lowest (4.52±0.82 ml l⁻¹) at St.2 and highest (5.76±0.27 ml l⁻¹) at St.4 (Fig. 2b). Shelarpiyusha et al. (2017) also reported higher DO (8.14 ml l⁻¹) in the Tuticorin Bay and Kailasam and Sivakami (2004) reported more or less similar variations (3.55 to 5.7 ml l⁻¹) of DO within the vicinity of TTPS. The GPP was comparatively higher at St.4 with the highest mean value of 9.2±4.2 mg cm⁻³ day⁻¹. Carbon dioxide was absent at all the stations.

The ammonia concentration was comparatively higher at St.4 nearer to TTPS and the mean value was highest (0.09±0.04 mg l⁻¹) at St.4 (Fig. 2c). Except for the highest value of 0.197 mg l⁻¹ recorded at St.4, the ammonia concentration was well below the toxic limit of 0.1 mg l⁻¹ suitable for mariculture (Boyd, 2003) at all the stations. The ammonia concentration reported in the present study is more or less similar to the values reported by Selvin et al. (2010) and is comparatively lesser than the values reported by Shelarpiyusha et al. (2017). In general, the rain has positively influenced the nutrients like PO₄³⁻ and SiO₂, hence comparatively higher values were noticed during the post-monsoon season (Table. 1). The mean values were highest for NO₃⁻ (0.68±0.13 μg l⁻¹) at St.2, for NO₂⁻ (0.29±0.19 μg l⁻¹) at St.4., for PO₄³⁻ (1.06±0.51 μg l⁻¹) at St.1 and for SiO₂ (2.8±0.3 μg l⁻¹) at St.3 (Fig. 2c and d). The NO₃⁻, NO₂⁻ and PO₄³⁻ reported in the present study are more or less similar to the observation of Clara and Sugritha (2015). Significant seasonal variations were also noticed for PO₄³⁻, NO₃⁻ and SiO₂ between stations (p<0.001). Higher PO₄³⁻ values were seen during the post-monsoon season at St.2, which might be due to the river runoff from the Koramballam creek as observed by Selvin et al. (2010). The PO₄³⁻ content was positively correlated with SiO₂ (p<0.05). The estimated range of total inorganic nitrogen (0.008-0.012 mg l⁻¹) and inorganic phosphate (0.018-0.033 mg l⁻¹) at all the stations were also within the permissible range of 0.5-4.5 and 0.05-0.50 mg l⁻¹ for total N₂ and total phosphate respectively prescribed for aquaculture (FAO, 2006). Suspended solids (TSS) were relatively lower during the pre-monsoon season at all the stations. In general, TSS was higher at St.2, due to the influence of Koramballam creek and varied between 208 and 573 mg l⁻¹ (Fig. 2e). Seasonal variation was also significant at all the stations (p<0.001). The chlorophyll concentration was relatively better at St.1. The highest mean value of (1.415±0.525) mg m⁻³ was recorded at St.1 (Fig. 2f). There was a significant seasonal variation in chlorophyll content at all the stations (p<0.001).

The BOD was nil at St.1 and comparatively higher at St.2 and St.4, with the highest mean of 1.63±0.23 mg l⁻¹.
Table 1. Seasonal variation in water quality parameters of four stations in Tuticorin Bay

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Pre-monsoon</th>
<th>Monsoon</th>
<th>Post-monsoon</th>
<th>Summer</th>
<th>p&lt;0.05</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>St.1</td>
<td>St.2</td>
<td>St.3</td>
<td>St.4</td>
<td>St.1</td>
</tr>
<tr>
<td>AT (°C)</td>
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<td>32.0</td>
<td>32.0</td>
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</tr>
<tr>
<td>SST (°C)</td>
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<td>27.0</td>
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</tr>
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<td>35.8</td>
<td>34.2</td>
<td>35.8</td>
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<tr>
<td>pH</td>
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<td>8.3</td>
<td>8.3</td>
<td>8.3</td>
<td>7.7</td>
</tr>
<tr>
<td>DO (ml l⁻¹)</td>
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<td>4.9</td>
<td>5.6</td>
<td>5.4</td>
<td>3.2</td>
</tr>
<tr>
<td>GPP (mg cm⁻³ day⁻¹)</td>
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<td>0.0</td>
<td>18.9</td>
<td>8.7</td>
</tr>
<tr>
<td>NH₃ (µg l⁻¹)</td>
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<td>0.1</td>
<td>0.1</td>
<td>0.2</td>
<td>0.1</td>
</tr>
<tr>
<td>TSS (mg l⁻¹)</td>
<td>426.0</td>
<td>573.0</td>
<td>494.0</td>
<td>440.0</td>
<td>418.0</td>
</tr>
<tr>
<td>Chlorophyll (mg m⁻²)</td>
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<td>0.2</td>
<td>0.2</td>
<td>0.2</td>
</tr>
<tr>
<td>NO₂ (µg l⁻¹)</td>
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<td>0.0</td>
<td>0.9</td>
<td>0.6</td>
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<tr>
<td>NO₃ (µg l⁻¹)</td>
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<td>0.0</td>
<td>0.0</td>
<td>0.2</td>
</tr>
<tr>
<td>PO₄ (µg l⁻¹)</td>
<td>0.3</td>
<td>0.5</td>
<td>0.2</td>
<td>0.2</td>
<td>0.4</td>
</tr>
<tr>
<td>SiO₂ (µg l⁻¹)</td>
<td>3.0</td>
<td>2.3</td>
<td>3.0</td>
<td>1.6</td>
<td>2.6</td>
</tr>
<tr>
<td>BOD (mg l⁻¹)</td>
<td>0.0</td>
<td>0.0</td>
<td>1.0</td>
<td>2.1</td>
<td>0.0</td>
</tr>
<tr>
<td>Alkalinity (mg l⁻¹)</td>
<td>86.4</td>
<td>91.3</td>
<td>90.6</td>
<td>93.4</td>
<td>126.0</td>
</tr>
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</table>

Fig. 2. Variations in the mean values of water quality parameters (a) pH, DO and GPP; (b) AT, SST and salinity; (c) NO₂, NO₃ and NH₃; (d) PO₄ and SiO₂; (e) Alkalinity and TSS; (f) BOD and chlorophyll, at four stations of Tuticorin Bay
noticed at St.4 (Fig. 2f). The BOD observed in the present study was relatively lower than the values reported by Selvin et al. (2010) and Shelarpiyusha et al. (2017) in the coolant water influenced areas of Tuticorin Bay. The estimated BOD values were also within the permissible limit of <15 mg l\(^{-1}\) prescribed for hatchery work (FAO, 2006). The total alkalinity was higher at all the stations during the monsoon season and ranged between 74.9 to 126 mg l\(^{-1}\) (Fig. 2e). The estimated alkalinity was found below the permissible limit of 600 mg l\(^{-1}\). The seasonal variation in alkalinity was significant at all the stations (p<0.001).

**Sediment quality conditions of the bay**

The seasonal variation in sediment quality parameters and clam population parameters are given in Table 2. Coarse sand constituted a significant portion of sediment at St.1, St.3 and St.4 which formed the highest share in the sediment at all the stations - 23.4±9.9% at St.1, 27.6±5.8% at St.2, 25.5±6.9% at St.3 and 27.9±8.4% at St.4 (Fig. 3b). Relatively higher composition of silt was noticed only in the sediment at St.1 (16.05±13.9%), whereas in other stations, silt contributed only a meager percentage (Fig. 3b). Clay and fine sand were positively correlated at all the stations (p<0.05). Fine sand was the second dominant constituent at all the stations. The sediment constituents significantly varied seasonally at all the stations (p<0.001). Kailasam and Sivakami (2004) also indicated the dominance of sand particles in the sediment of Tuticorin Bay. The percentage of organic matter, organic carbon and nitrogen were comparatively higher at St.1. The organic matter ranged from a minimum of 0.259 at St.4 to a maximum of 5.17% at St.1. The highest mean values of organic carbon (1.59±0.49), organic matter (2.75±0.86) and nitrogen (0.137±0.06) were reported at St.1 (Fig. 3a). The organic carbon content noted at all the stations was lower (4.894%) than those indicated from the fly ash dumpsite of TTPS (Clara and Sugritha, 2016), which might be due to the low clay fraction of the bottom soil. This also indicated the low influence of organic matter rich fly ash in the study area. There was a significant seasonal variation noticed at all the stations (p<0.001). A significant positive correlation was seen between clay and organic matter content and between fine sand and organic matter content of the sediment samples (p<0.01). In contrast, a significant negative correlation was observed between coarse sand and organic matter content. The mean density and biomass of total clam were highest (52.7±16.3 nos. m\(^{-2}\) and 765.6±148.9 g m\(^{-2}\)) at St.1 and lowest at St.4 (Fig. 4). The range of clam density and biomass estimated in the present study was more or less similar to the estimates made by Kripa et al. (2012) and Kavitha (pers. comm).

**Heavy metal concentrations in the sediment and clam tissues**

The sediments of St.1 had the highest concentrations of heavy metals like Cd (0.17 mg kg\(^{-1}\)), Cu (0.172 mg kg\(^{-1}\)), Fe (63.8 mg kg\(^{-1}\)), Ni (0.078 mg kg\(^{-1}\)) and Pb (0.542 mg kg\(^{-1}\)).

![Fig. 4. Variation in the mean values of clam density and biomass at four stations of Tuticorin Bay](image-url)
Table 2. Seasonal variations in the sediment quality parameters and clam density of four stations at Tuticorin Bay

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Pre-monsoon</th>
<th>Monsoon</th>
<th>Post-monsoon</th>
<th>Summer</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>St.1</td>
<td>St.2</td>
<td>St.3</td>
<td>St.4</td>
</tr>
<tr>
<td>Organic carbon (%)</td>
<td>1.5</td>
<td>0.6</td>
<td>0.6</td>
<td>0.15</td>
</tr>
<tr>
<td>Organic matter (%)</td>
<td>2.58</td>
<td>1.03</td>
<td>1.03</td>
<td>0.25</td>
</tr>
<tr>
<td>Total nitrogen (%)</td>
<td>0.12</td>
<td>0.05</td>
<td>0.05</td>
<td>0.01</td>
</tr>
<tr>
<td>Clay (%)</td>
<td>7.9</td>
<td>4.4</td>
<td>4.8</td>
<td>4.6</td>
</tr>
<tr>
<td>Silt (%)</td>
<td>23.5</td>
<td>31.5</td>
<td>34.9</td>
<td>13.1</td>
</tr>
<tr>
<td>Fine sand (%)</td>
<td>6.7</td>
<td>37.8</td>
<td>17.6</td>
<td>31.4</td>
</tr>
<tr>
<td>Coarse sand (%)</td>
<td>0</td>
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</tr>
<tr>
<td>Clam density (nos. m(^{-2}))</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Clam biomass (g m(^{-2}))</td>
<td>0</td>
<td>0</td>
<td>0</td>
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</tbody>
</table>

The Mn concentration (3.042 mg kg\(^{-1}\)) was highest in the sediment of St.4 (Fig. 5b). Concentration of metals viz., Cd, Ni and Pb were second-highest in the sediments of St.4 (Fig. 5c). Sediments of St.2 contained the second-highest concentration of Cu and Fe (Fig. 5c and a). Baskaran et al. (2002) and Clara and Sugritha (2015) also reported the dominance of metals like Cu, Fe, Pb and Cd in and around 5 km of ash slurry discharge point of the power plant. However, the present work reported comparatively lower values of metals like Cu, Fe, Pb and Cd than those reported by Srikanth et al. (2014) and Clara and Sugritha (2015). The clams of St.1 were found to contain the maximum concentration of Cd (37 mg kg\(^{-1}\)), Fe (7.58 mg kg\(^{-1}\)), Ni (0.064 mg kg\(^{-1}\)) and Pb (8.254 mg kg\(^{-1}\)). The Mn (3.042 mg kg\(^{-1}\)) (Fig. 6a) and Cu (0.366 mg kg\(^{-1}\)) (Fig. 6c) concentrations were highest in the clam tissues of St.3. Compared to all other elements, the lead concentration was found to be exceptionally higher in the clam tissues of St.1 (Fig. 6b). The present study reported comparatively lower levels of metals like Cd, Cu, Fe, Mn and Ni in both the sediment and bivalve tissue samples of fly ash-laden dyke of TTPS, as seen in a previous study by Asha et al. (2010), which confirmed the lower influence of fly ash in the study area and also confirmed a decrease in the impact of fly ash with an increase in the distance from the dumpsite (Khanra et al., 1998; Clara and Sugritha 2016). Scanning electron microscope (SEM) with energy-dispersive X-ray
suitability of Tuticorin Bay for mariculture

The purpose of the study was to assess the suitability of the bay water for mariculture activities including marine hatchery work of ICAR-CMFRI, Tuticorin Regional Station, since the area of seawater intake point is influenced by both, the effluent discharge from TTPS and the freshwater influx of Koramballam creek. The analysis of different quality parameters from four selected locations of the bay, including the intake area, indicated that neither TTPS nor the Koramballam creek significantly impacted the bay’s water and sediment quality conditions. However, a profound seasonal influence from precipitation and condensation phenomena of the monsoon and summer seasons was noticed among stations, as widely reported from various parts of the sea off Tuticorin. No significant difference was detected in the variations in water quality parameters between stations ($p>0.01$). Most of the water quality parameters, especially the seawater temperature, salinity, pH, BOD, ammonia, total N$_5$, and total PO$_4$, were within the standard limits prescribed for aquaculture activities (Boyd, 2003; FAO, 2006). Water quality indexing yielded a good quality standard for all the stations, confirming the same trend throughout the bay. Comparatively lower concentrations of toxic metals were noticed in the sediment and clam tissues at the sampling locations in the study. The estimated levels were also within the permissible limit for most of the metals. This observation confirms the minimal mobilisation of any fly ash constituents and low metal enrichment from the previously dumped fly ash into the current locations. The study thus proved the suitability of Tuticorin Bay for mariculture activities. However, it recommends the need for constant monitoring and the introduction of management strategies and practices for enhancing the bay water acceptability for mariculture purposes.

Acknowledgements

The authors are thankful to the Director, ICAR-CMFRI, Kochi and the Scientists-in-Charge, spectroscopy (EDXS) studies by Clara and Sugritha (2013) had indicated that the impact of fly ash was only within a few kilometres surrounding the dumpsite. The heavy metals were found to be accumulated in the order of Fe>Mn> Pb>Cu> Ni>Cd in the sediments and Fe>Pb>Mn>Cu>Cd>Ni within the bivalve tissue samples, which conforms to the earlier findings of Asha et al. (2010) in the surrounding areas of TTPS. Except for the concentration of Mn in the bivalve-tissue samples of St.1 and St.3, all the other metals recorded in sediment and clam tissues were found to be below the permissible limit prescribed by European Union countries.
Tuticorin Regional Station of ICAR-CMFRI, Thoothukudi for the support and facilities provided during the execution of this work.

References


