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Assessment of Coastal Surface Water Quality in Tien Giang Province, Vietnam

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Abstract

The study was conducted to assess the quality of surface water environment in the coastal area of Tien Giang province. The samples were collected in the dry season (March-June) and in the wet season (September-November) in 2020. The water quality variables of pH, dissolved oxygen (DO), total suspended solid (TSS), chemical oxygen demand (COD), ammonium ($N\text{-}NH_4^+$), sulfide (S^{2-}), chloride (Cl^-), Coliform, zinc (Zn), arsenic (As), chromium (Cr), oil & grease were compared with QCVN 10-MT :2015/BTNMT. CA and PCA are used to cluster water quality and define monitoring criteria. Research results show that pH, Zn, As, Cr, Oil and Grease, Coliform are still within the allowable limits. COD ranges from 7 to 18 mg/L; The sulfide concentration detected only in March was in the range of 0.8-1.6 mg/L; The Cl^- concentration at the sampling sites ranged from 6,447 to 12,752 mg/L. TSS at sampling locations exceeded the allowable limit of QCVN 10-MT:2015/BTNMT from 1-1.7 times while TSS between months exceeded the allowable limit from 1.12 to 1.9 times. $N\text{-}NH_4^+$ concentration exceeds the allowable limit of QCVN 10-MT:2015/BTNMT according to sampling location from 1-1.4 times and seasonally from 1-1.6 times. Overall results show that coastal seawater in Tien Giang province is lightly polluted with organic matter and $N\text{-}NH_4^+$. Water quality has seasonal fluctuations in which DO, TSS, S^{2-}, Cl^- in the dry season are higher than those in the rainy season. In contrast, COD, $N\text{-}NH_4^+$ in the rainy season were higher than those in the dry season. Water quality is classified into three clusters due to the difference of indicators COD, TSS, $N\text{-}NH_4^+$, Cl^-. Cluster 1 is more polluted than the other clusters. PC1-PC4 were the main component explaining 73.4% of water quality variation. The indicators having the main influence on water quality in the study area include pH, COD, DO, TSS, $N\text{-}NH_4^+$, S^{2-}, Cl^-, coliform, and Zn, which need to be continuously monitored. Further studies should focus on investigating sources of pollution in order to have a solution to better manage water quality in coastal areas.
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1. Introduction

Tien Giang is a province with potential and advantages of the sea, with 32 km of coastline stretching over many communes and towns bordering the sea (of which 21 km are in Go Cong Dong district and 11 km in Tan Phu Dong district). Tien Giang Sea has a fishing ground of nearly 490 km², large seafood reserves; It is home to many kinds of rare and valuable seafood. Along the coast of our province, there are many wind-tight areas that are favorable for port development, building repair areas, anchoring boats, and there are many beautiful beaches and

scenic spots that are favorable conditions for the development of eco-tourism. marine life [1]. Tien Giang province has taken measures to protect the environment, conserve and sustainably develop marine biodiversity; proactively respond to climate change, sea level rise and natural disaster prevention and control [2]. Accordingly, the master plan on exploitation and sustainable use of coastal resources has been implemented. The province's environmental sector has focused on biodiversity conservation and restoration of marine ecosystems, especially important marine ecosystems; ensure the integrity and natural relationship between terrestrial and marine ecosystems; control and prevent, prevent the occurrence of environmental pollution incidents, effectively reduce and handle pollution sources; improve the capacity to observe and monitor marine resources and environment, and the capacity to respond to environmental incidents and toxic chemicals at sea; marine waste management, especially plastic waste; improve and raise the quality of the sea and island environment of the province [1-2]. Therefore, monitoring the quality of surface water environment is very necessary. Monitoring of coastal marine environment is the task of coastal provinces [3]. Monitoring helps to detect pollution problems and take timely solutions to overcome them, contributing to economic development and environmental protection [4-5]. Previous studies have shown that multivariate statistical methods including cluster analysis and principal component analysis are used effectively in water quality analysis [6-8]. The information obtained from the analysis process includes the identification of sampling locations, potential sources of pollution, and criteria that have a major impact on water quality [6-8]. Currently, studies on the quality of coastal seawater environment are limited. This study uses multivariate statistical methods to cluster water quality, identify sources and criteria affecting water quality in coastal areas. The research results provide important scientific information to strengthen the coastal environmental monitoring system in Tien Giang province.

2. Materials and methods

Coastal surface water samples were collected at 10 sites designated from B1 to B10 (Table 1). The samples were collected in the dry season (March-June) and in the wet season (September-November) in 2020. The water quality variables of pH, dissolved oxygen (DO), total suspended solid (TSS), chemical oxygen demand (COD), ammonium ($N\text{-}NH_4^+$), sulfide (S^{2-}), chloride (Cl^-), Coliform, zinc (Zn), arsenic (As), chromium (Cr), oil & grease were analyzed in the collected water samples. pH and DO were measured in the field by hand-held meters while the other parameters were analyzed in the laboratory using standard methods [9] (Table 2).

Table 1. The locations of the sampling sites in the districts

Site	Description
B1	Gia Thuan commune, Go Cong Dong district
B2	Vam Lang town, Go Cong Dong Dong district
B3	Kieng Phuoc commune, Go Cong Dong district
B4	Tan Dien commune, Go Cong Dong district
B5	Tan Thanh commune, Go Cong Dong district
B6	Phu Tan commune, Tan Phu Dong district
B7	Tan Thanh commune, Go Cong Dong district
B8	Phu Dong district
B9	Fish port, Tan Thanh commune, Go Cong Dong district
B10	Vam Lang Fish Port, Vam Lang town, Go Cong Dong district

Water quality was assessed using national technical regulation on marine water quality (QCVN 10-MT:2015/BTNMT) [3]. The limit values are presented in Table 2. Principal component analysis

(PCA) was used to identify potential polluting sources and key variables affecting water quality in the study area. PCs are considered as potential polluting sources in which the eigenvalue of greater than 1 considered main polluting sources, eigenvalues of lesser than 1 considered minor potential polluting sources [8]. The weighted correlation coefficient between PCs and water quality parameters could be used to identify key water variables influencing on coastal water quality. The coefficient is rated at three levels of high, medium and weak, with absolute load values > 0.75, 0.75–0.50 and 0.50 – 0.30, respectively [8]. Cluster analysis (CA) was applied to classify coastal water quality based on similarity index [7]. PCA and CA were performed using Primer Software Version 5.2.

Table 2. Limits and analytical methods of coastal water quality

Variables		Unit	Analytical methods	Limits
pH		-	TCVN 6492:2011	6.5-8.5
DO	Dissolved oxygen	mg/L	TCVN 7325:2016	≥5
TSS	Total suspended solid	mg/L	SMEWW 6625:2000	50
COD	Chemical oxygen demand	mg/L	SMEWW 5220 C : 2012	-
$N\text{-}NH_4^+$	Ammonium	mg/L	SMEWW 4500 NH3.B&F : 2012	0.1
S^{2-}	Sulfide	mg/L	SMEWW 4500-S2.F : 2012	-
Cl^-	Chloride	mg/L	TCVN 6194:1996	-
Coliform	Coliform	MPN/100 mL	TCVN 6187-2:1996	1000
Zn	Zinc	mg/L	TCVN 6193:1996	0.5
As	Arsenic	mg/L	TCVN 6626:2000	0.02
Cr	Chromium	mg/L	SMEWW 3111C:2017	0.02
Oil & Grease	Oil and grease	mg/L	SMEWW 5520,F:2017	0.5

3. Results and discussion

3.1 Evaluating coastal water quality

The pH value measurement results are presented in Figure 1. The lowest pH at the studied sites is in the range of 7.16-7.83 and the highest is in the range of 7.84-8.30, reaching the average value from 7.34-7.92. The pH in the study area ranges from neutral to slightly alkaline. The previous study showed that the pH value in the salt water area of Bac Lieu province is in the range of 6.98 – 9.2 [10], and has a larger fluctuation amplitude than the pH value in the study area. The pH in freshwater bodies ranges from 6.5 to 8.5 and has little variation [11-14]. The pH value has little seasonal variation, however, the pH in the rainy season tends to be lower than in the dry season. The pH value in the coastal area of Tien Giang is still within the allowable limit of QCVN 10-MT:2015/BTNMT (6.5-8.5). This pH value is still within the appropriate range for coastal aquatic life conservation [3].

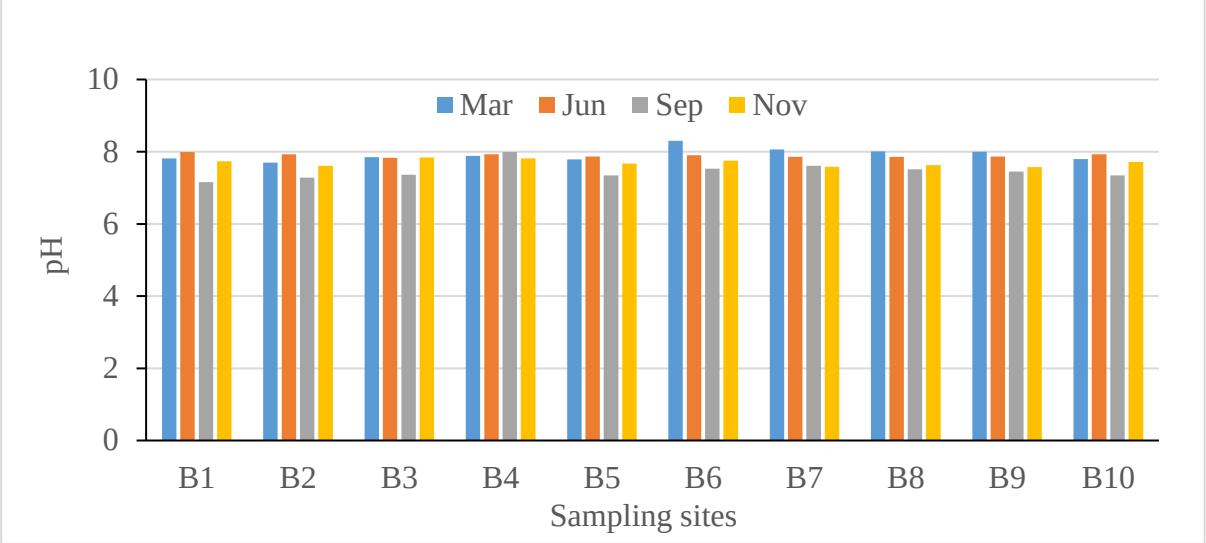

Figure 1. pH in coastal water in Tien Giang province

Dissolved oxygen (DO) concentration in the coastal area in March, June, September and November is in the range of 6.21-0.785, respectively; 4.97-6.14; 4.45-6.52; and 5.73-7.61 mg/L. DO in March tends to be higher than in rainy months (Figure 2). The lowest DO was found in September. The average value of DO in September was lower than the allowable limit of QCVN 10-MT:2015/BTNMT (DO ≥ 5 mg/L) especially at positions B5, B9 and B10. Low DO is due to the presence of organic matter. The results of previous studies showed that DO in the seawater environment in the southern region ranged from 4.7 to 7.4 mg/L [10]. In the coastal area of Bac Lieu province, DO is in the range of 4 - 6.8 mg/l [10]. DO at sites in this study has a larger variability than in previous studies. The DO concentration in coastal areas depends on salinity, diffusion, and presence of organic matter [9, 10, 11]. Therefore, some locations in the coastal area have shown signs of organic pollution.

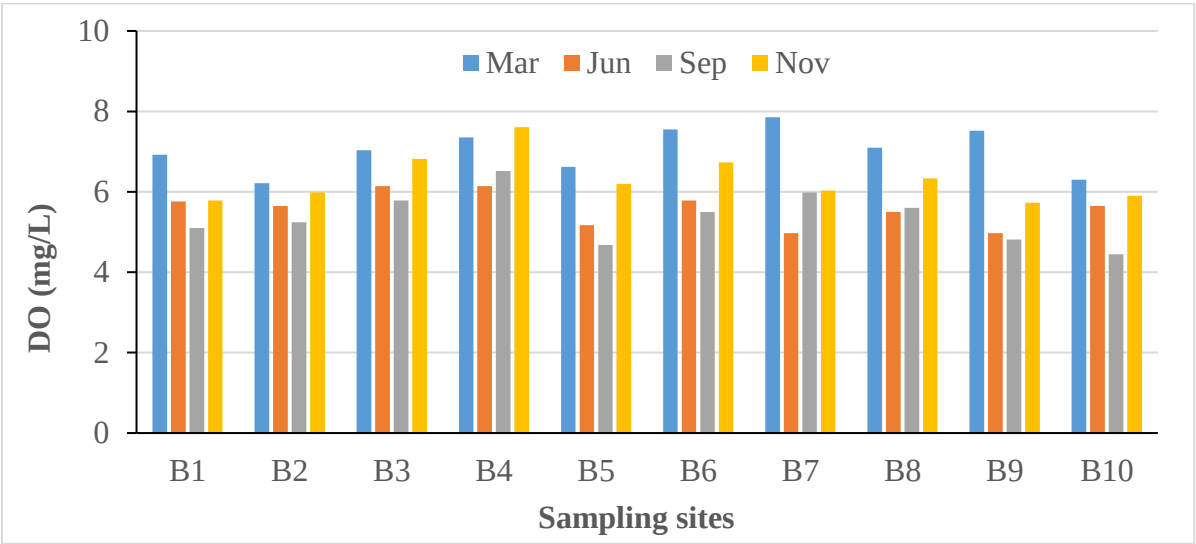

Figure 2. DO in coastal water in Tien Giang province

The chemical oxygen demand (COD) in the study area is presented in Figure 3. The results show that the average value of COD in the months of March, June, September and November is 11, 14, 12 and 12 mg/L, respectively. The COD at positions B1-B6, B10 is higher than the COD at the remaining positions. COD in November tends to be higher than COD compared to other locations.

Previous research also showed that COD has seasonal variation in which COD is higher in rainy season than in dry season [13-16]. COD in freshwater bodies usually ranges from 10 to 60 mg/L [14-16]. However, the COD value is not specified QCVN 10-MT:2015/BTNMT. COD in coastal water in Bac Lieu Province ranged from 20-282.6 mg/l [10] which is much higher than that is found in the current study. It could mean that coastal water in Bac Lieu province is more tarnished than that in Tien Giang province.

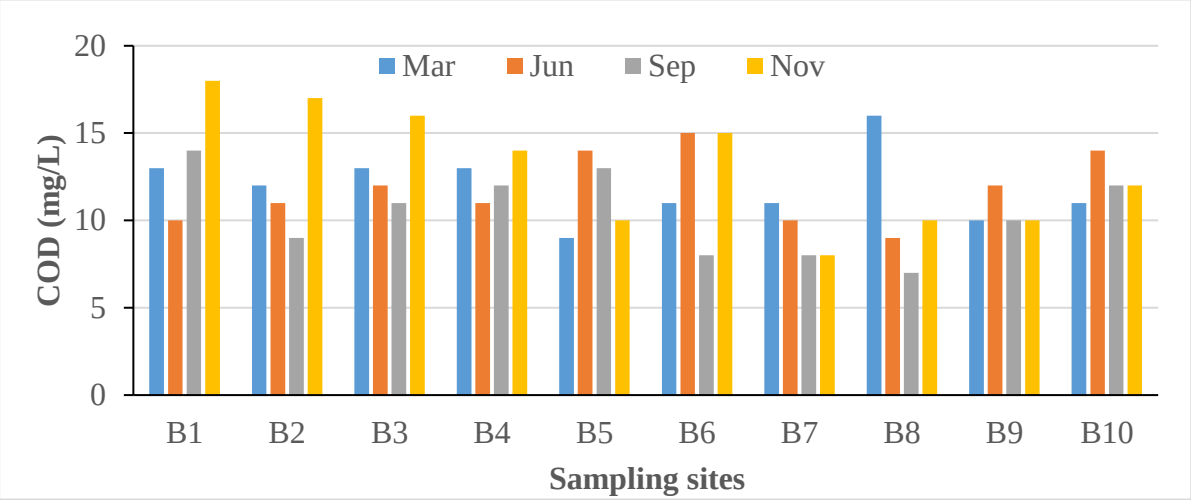

Figure 3. COD in coastal water in Tien Giang province

Total suspended solids (TSS) concentration at the sites ranged from 43.8-88.3 mg/L (Figure 4). TSS concentrations in March, June, September and November were in the range of 67-238, respectively; 33-63; 26-61; 23-41 mg/L. TSS in March was significantly higher than the rest of the month, possibly due to the presence of phytoplankton and suspended matter from the canals in the field. TSS values at sampling locations exceeded the allowable limit of QCVN 10-MT:2015/BTNMT by 1-1.7 times while TSS between months exceeded the allowable limit from 1.12 to 1.9 times. The mean of TSS concentration in the coastal water in Bac Lieu province ranges from 33-830 mg/l [10] which is much higher than that is found in the current study. Mean values of TSS in freshwater canals tend to be lower and range from 10 to 90 mg/L [13-15].

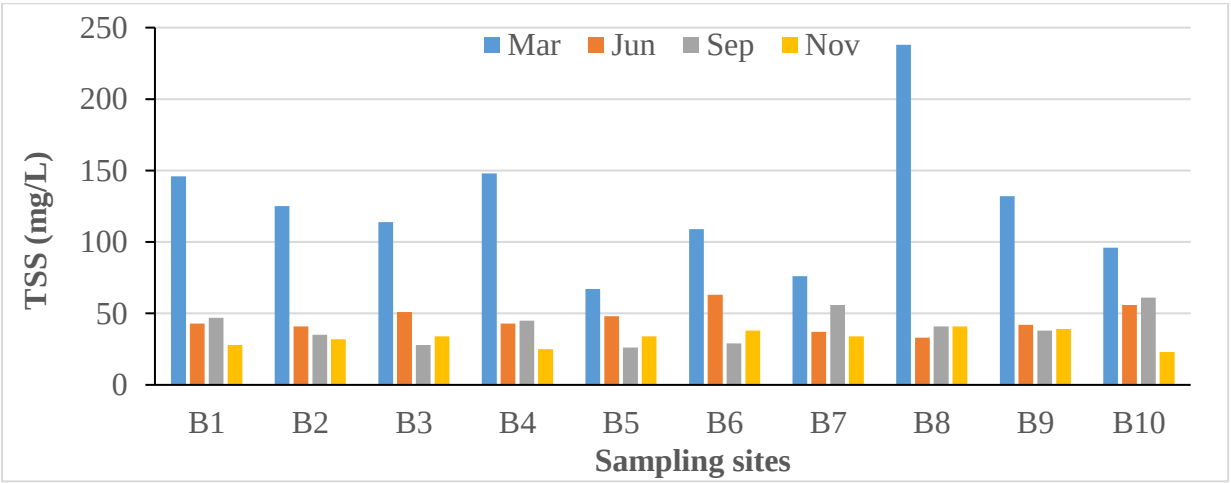

Figure 4. TSS in coastal water in Tien Giang province

The measurement results of ammonium (N-NH_4^+) are presented in Figure 5. N-NH_4^+ concentrations in the months of March, June, September and November are in the range of 0.06-0.16; 0.07-0.16; 0.06-0.16; 0.08-0.17 mg/L, respectively. The concentration of N-NH_4^+ according to the study sites fluctuated in the range of 0.07-0.14 mg/L. N-NH_4^+ concentration exceeds the allowable limit of QCVN 10-MT:2015/BTNMT according to sampling location from 1-1.4 times and seasonally from 1-1.6 times. N-NH_4^+ in the rainy season tends to be higher than that in the dry season. Thus, it can be seen that coastal surface water has been contaminated with nutrients, and there is a risk of eutrophication. The concentration of N-NH_4^+ in the coastal water of Bac Lieu was 0.099-1.79 mg/L, in which N-NH_4^+ in the dry season tended to be higher than that in the dry season [10]. The study indicates that coastal water is prone to be tarnished with N-NH_4^+ and this potentially causes water eutrophication [17].

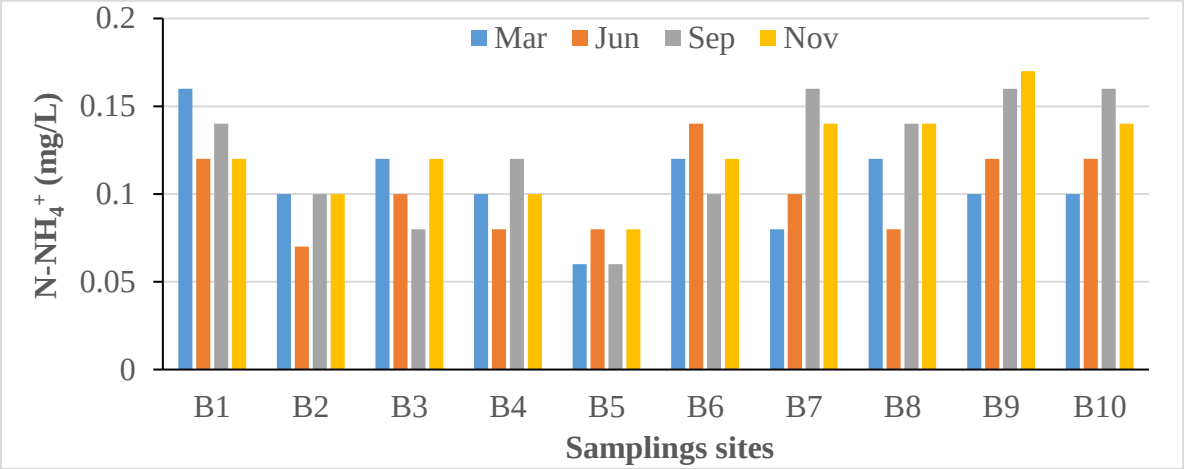

Figure 5. N-NH_4^+ in coastal water in Tien Giang province

The sulfide (S^{2-}) concentration detected only in March was in the range of 0.8-1.6 mg/L. Sulfide was not detected in June, 9, and 11, except for site B10 (S^{2-} was detected in June and September at concentrations of 0.40 and 0.15 mg/L, respectively). This shows that sulfide has a very large seasonal variation.

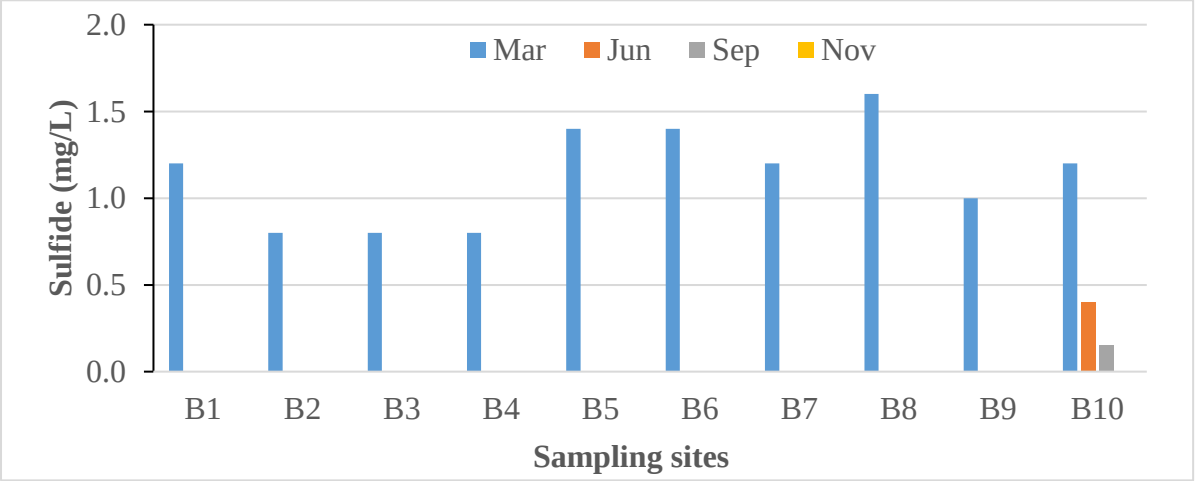

Figure 6. Sulfide in coastal water in Tien Giang province

The results of measurement of chloride (Cl^-) concentration at the study area are presented in Figure 7. Cl^- concentrations at the sampling sites ranged from 6,447 to 12,752 mg/L. Cl^- in the months of

March, June, September and November are in the ranges of 13,490-16,795; 7,029-13,419; 2,293-10,926; and 2.272-10,508 mg/L, respectively. The Cl^- concentration in the dry season tends to be significantly higher than that of the Cl^- in the rainy season. Cl^- in coastal water in Bac Lieu province (1,021 - 17,087 mg/l) was in a larger range than that in the current study. In freshwaters, the concentration of Cl^- is very low ranging from 7.2-8.4 mg/L [18] and 32.8-54.2 mg/L [19] where it could be inspired by daily, urban and industrial activities.

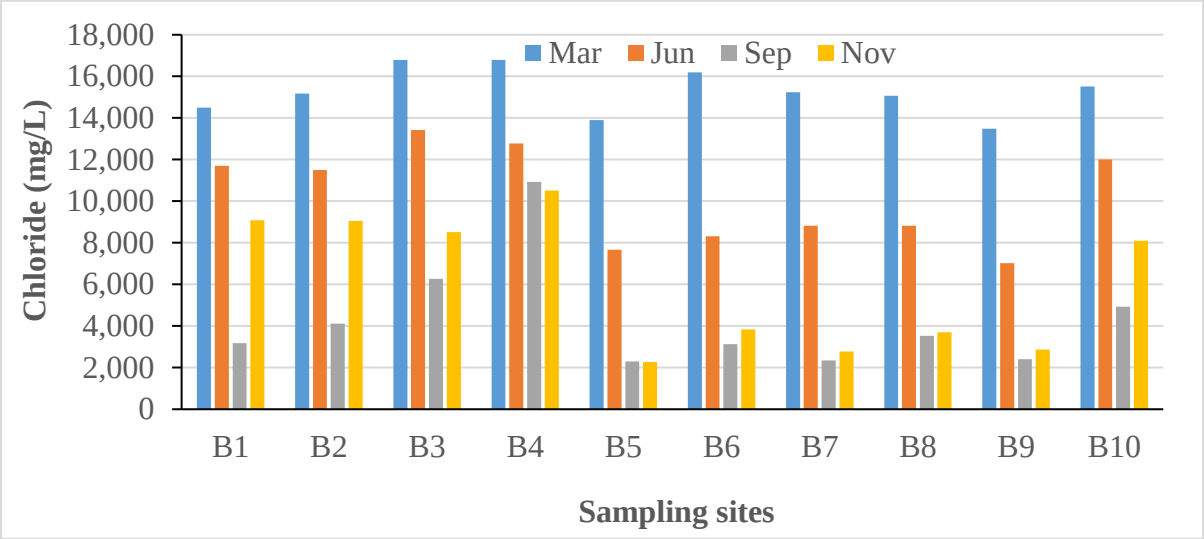

Figure 7. Chloride in coastal water in Tien Giang province

The number of coliforms in coastal seawater at the sampling sites ranged from 288-575 MPN/100 mL. Meanwhile, coliform density in March, June, September and November ranges from 240-640; 290-560; 320-640; 300-600 MPN/100 mL. The presence of coliform indicates that the coastal marine environment is contaminated with microorganisms. However, the number of coliforms at all locations according to the sample were within the allowable limits of QCVN 10-MT:2015/BTNMT. In Bac Lieu's coastal water, the mean of coliform ranged from 1,100-9,500 MPN/100ml [10]. In the freshwater bodies, coliform density is often exceeded the regulation of QCVN 08-MT:2015/BTNMT (2,500 MPN/100 mL) [13-16]. The sources of coliform contamination are from human and animal wastes, especially the fecal materials [19]. The current results showed that coliform in the current study' areas were less tarnished compared to the former studies.

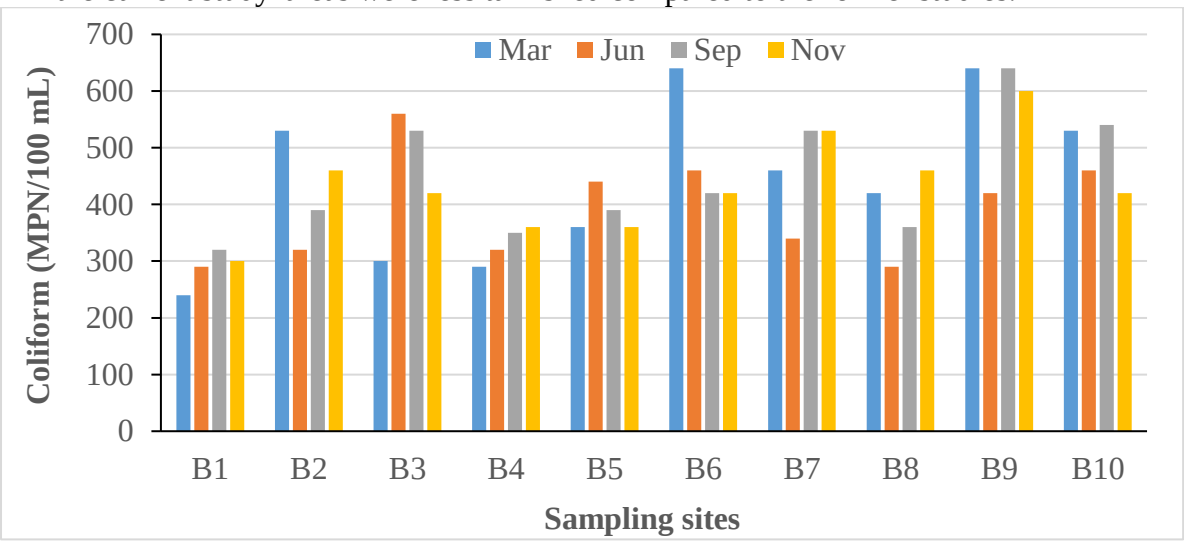

Figure 8. Coliform in coastal water in Tien Giang province

Among all surveyed heavy metals including Zn, As and Cr, only Zn was detected at some locations and some observations (Figure 9). Zn was detected at positions B1-B4, B8, B10 with concentrations ranging from 0.029-0.055 mg/L. The concentration of Zn is still within the allowable limit of QCVN 10-MT:2015/BTNMT (Zn = 0.5 mg/L). Oil and grease were not detected at the study sites.

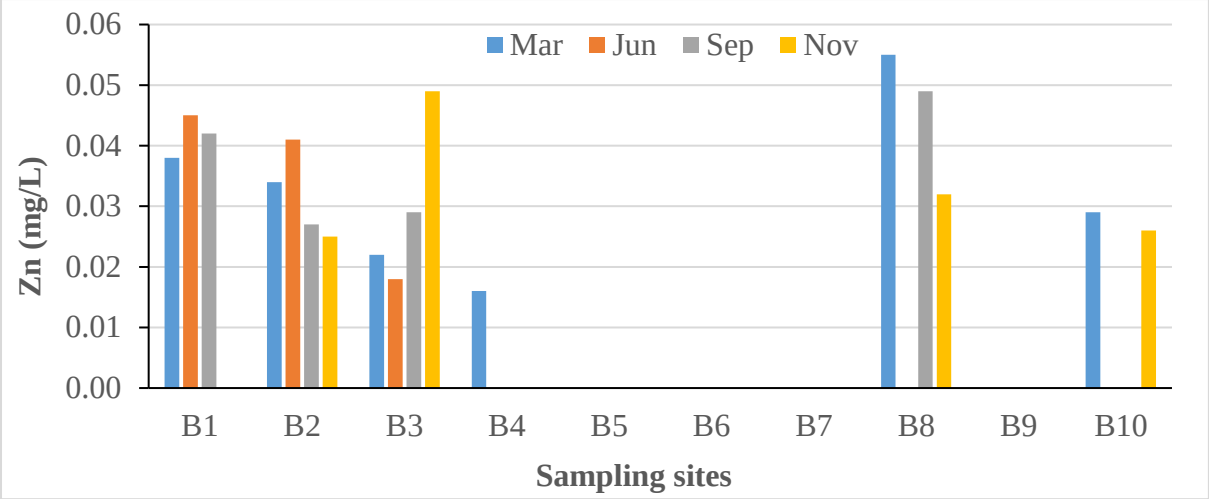

Figure 9. Zinc in coastal water in Tien Giang province

3.2 Spatial variation of coastal water quality

The classification of coastal water quality is shown in Figure 10. Water quality is classified into three clusters. Cluster 1 includes positions B1-B4, B10; cluster 2 includes only 1 position B8 while cluster 3 includes positions B5-B7, B9. The results in Table 3 show that cluster 1 is characterized by indicators of COD, TSS, N-NH_4^+, Cl^- higher than other clusters and higher than the allowable limits of QCVN 10-MT:2015/BTNMT. TSS in cluster 2 was higher than cluster 1 and cluster 3. TSS and N-NH_4^+ cluster 3 exceeded the allowable limit. It can be seen that cluster 1 is more polluted than the other clusters.

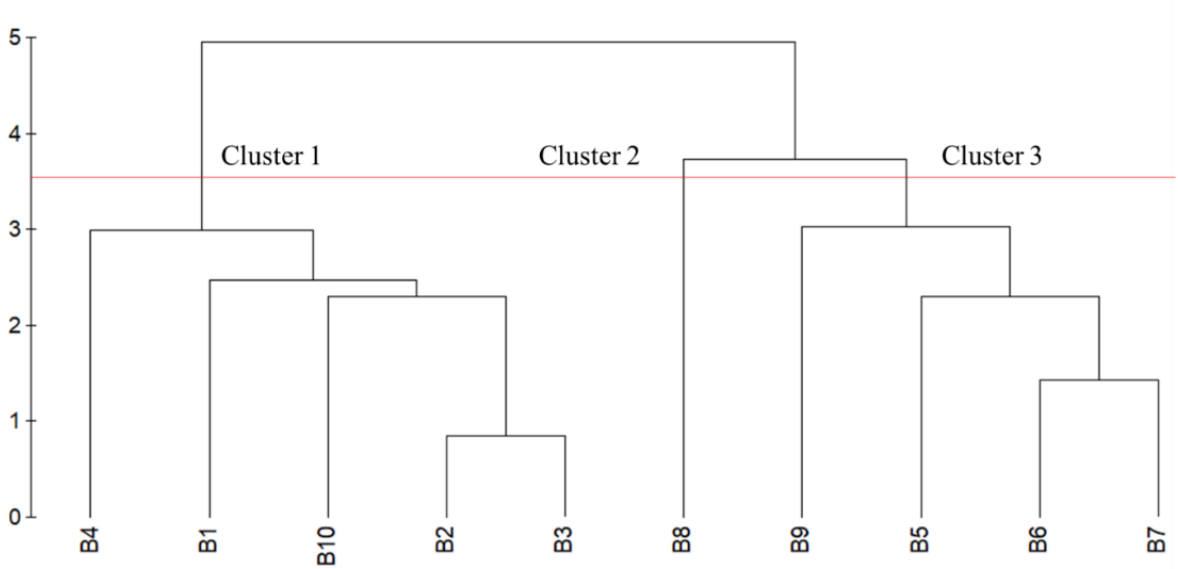

Figure 10. Clustering coastal surface water quality

Table 3. Water quality of identified clusters

Site	Cluster 1	Cluster 2	Cluster 3	Limits

pH	7.7	7.8	7.8	6.5-8.5
COD	**12.8**	10.5	10.9	-
DO	6.1	6.1	6.0	≥5
TSS	**61.1**	**88.3**	**54.3**	50
$N\text{-}NH_4^+$	**0.11**	0.10	**0.11**	0.1
S^{2-}	0.27	0.4	0.31	-
Cl^-	**10,743**	7,780	7,035	-
Coliform	397	383	478	1,000
Zn	0.02	0.03	0.00	0.5

3.3 Key water variables influencing coastal water quality

Research results show that 8 PCs can explain 100% of the variation in water quality in the study area (Table 4). PC1-PC4 is the main component explaining 73.4% of water quality variation. Meanwhile, PC5-PC8 is the sub-component explaining 26.6% of water quality in the study area. PC1 is associated with fluctuations in parameters including COD, DO, Cl^-, Coliform, and Zinc. PC2 is involved in the changes of pH, DO and Zinc. PC3 is negatively correlated with TSS, $N\text{-}NH_4^+$ and S^{2-} indicators. PC4 is involved in $N\text{-}NH_4^+$, S^{2-} and coliform. PC5 is involved in COD, TSS, $N\text{-}NH_4^+$, S^{2-} and Zn. PC5 is associated with $N\text{-}NH_4^+$, S^{2-}, Cl^- and coliform. PC7 is associated with COD, Cl^- and coliform. PC8 is related to DO, TSS, Zn. The parameters having the main influence on water quality in the study area include pH, COD, DO, TSS, $N\text{-}NH_4^+$, S^{2-}, Cl^-, coliform, and Zn. It is necessary to add indicators to assess water quality related to phosphorus.

Table 4. The results of principal component analysis

Site	PC1	PC2	PC3	PC4	PC5	PC6	PC7	PC8
pH	0.068	**-0.649**	-0.203	-0.195	-0.132	0.035	0.155	0.124
COD	0.435	0.224	0.075	-0.007	**-0.616**	-0.076	**0.601**	-0.074
DO	0.341	**-0.557**	0.005	0.116	0.127	0.078	0.097	0.381
TSS	0.171	-0.014	**-0.655**	0.017	0.351	0.123	0.259	**-0.568**
N-NH4	-0.116	-0.008	**-0.545**	0.493	-0.369	-0.462	-0.257	0.171
S2-	-0.293	0.071	-0.380	**-0.559**	-0.401	0.407	-0.136	0.167
Cl-	**0.524**	-0.027	0.055	0.198	-0.247	0.443	**-0.593**	-0.249
Coliform	-0.423	-0.052	0.049	**0.593**	-0.096	**0.595**	0.311	0.036
Zn	0.329	0.457	-0.279	0.043	0.310	0.208	0.069	**0.626**
E.val.	2.79	2.03	1.79	0.99	0.75	0.33	0.21	0.12
%Var.	31.0	22.5	19.9	11.0	8.3	3.6	2.3	1.3
C.%Var.	31.0	53.5	73.4	84.4	92.7	96.3	98.6	100.0

4. Conclusion

Research results show that the pH at the study sites is in the range of 7.34-7.92, ranging from neutral to slightly alkaline. The DO in the coastal area is between 4.5 and 7.9. DO in dry season months tends to be higher than DO in rainy season months. DO lower than the allowable limit value at some locations shows signs of slight organic pollution in the study area. The COD ranges from 7 to 18 mg/L, indicating that there is a slight organic pollution in the coastal water environment, especially at locations from B1-B6, B10. COD in November tends to be higher than COD compared to other months. TSS at sampling locations exceeded the allowable limit of QCVN 10-MT:2015/BTNMT by 1-1.7 times while TSS between months exceeded the allowable limit by 1.12 to 1.9 times. TSS in March was higher compared to other months. $N\text{-}NH_4^+$ concentration exceeds the allowable limit of QCVN 10-MT:2015/BTNMT according to sampling location from 1-1.4 times and seasonally

from 1-1.6 times. $N\text{-}NH_4^+$ in the rainy season tends to be higher than in the dry season. The sulfide (S^{2-}) concentration detected only in March was in the range of 0.8-1.6 mg/L. The Cl^- concentration at the sampling sites ranged from 6,447 to 12,752 mg/L and had seasonal fluctuations in which the dry season tended to be higher than the rainy season. The number of coliforms in coastal seawater at the sampling sites ranged from 288-575 MPN/100 mL, still within the allowable range. Zn was detected at positions B1-B4, B8, B10 with concentrations ranging from 0.029-0.055 mg/L. The concentration of Zn is still within the allowable limit of QCVN 10-MT:2015/BTNMT. As, Cr oil and grease were not detected at the study sites. Water quality is classified into three clusters due to the difference of indicators COD, TSS, $N\text{-}NH_4^+$, Cl^-. Cluster 1 is the cluster with more polluted locations than the other clusters. PC1-PC4 is the main component explaining 73.4% of water quality variation. Meanwhile, PC5-PC8 is the sub-component explaining 26.6% of water quality in the study area. The parameters having the main influence on water quality in the study area include pH, COD, DO, TSS, $N\text{-}NH_4^+$, S^{2-}, Cl^-, coliform, and Zn. Overall results show that coastal seawater in Tien Giang province is slightly polluted with organic matters and $N\text{-}NH_4^+$. Future study should focus on investigating concrete polluting sources to propose appropriate measure for sustainable coastal water quality management.

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