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Evaluating Coastal Surface Water Quality in Ben Tre Province, Vietnam

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Abstract

This study was conducted to assess the quality of surface water in the coastal area of Ben Tre province in 2020. Surface water quality in the study area was evaluated based on the values of eight water quality criteria including pH, salinity, total suspended solids (TSS), dissolved oxygen (DO), ammonium ($N\text{-}NH_4^+$) concentration, total open oil, iron (Fe) and coliforms. Water quality was assessed using QCVN 10-MT:2015/BTNMT National technical regulation on marine water quality. Coastal water quality was classified using cluster analysis. The results showed that TSS, coliform, and oil and grease in coastal water exceeded the allowable limits of QCVN 10-MT:2015/BTNMT. The concentration of Fe only exceeds the allowable limit in some positions while $N\text{-}NH_4^+$ is asymptotically close to the allowable limit. DO, salinity, Fe, oil and grease in the dry season were significantly higher than those in the rainy season. Meanwhile, $N\text{-}NH_4^+$ and Coliform were higher in the rainy season than those in the dry season. TSS of March and September was higher than that of June and November. pH has little seasonal variation. CA classified coastal water quality into three clusters due to the difference in concentrations of salinity, TSS, oil and grease, and coliform. Further studies need to add monitoring indicators such as phosphorus, organic matters (chemical oxygen demand, biological oxygen demand) and heavy metals to more comprehensively assess water quality in coastal areas for appropriate management solutions. Coastal water quality needs to be protected as it plays an important role in the local economic development.

1. Introduction

Ben Tre is a coastal province of the Mekong Delta, with a natural area of 2,360 km^2. The province is made up of An Hoa islet, Bao isle, Minh island and alluvium from the 4 tributaries of the Mekong River accumulates into the citadel, including Tien River, Ba Lai River, Ham Luong River and Co Chien River [1]. With the advantage of natural conditions, the people of Ben Tre province have developed agriculture in all three ecological zones of salt, brackish and freshwater. However, the process of cultivation and aquaculture has caused residues of pesticides and antibiotics to accumulate in the water, leading to a decrease in the use value of water sources, causing negative impacts. to human health and aquatic species [1]. Along with the effects from agricultural production, domestic activities and industrial development also have a strong impact on surface water quality [1, 2]. The change of physico-chemical components in the aquatic environment will affect the biodiversity of the aquatic ecosystem [3]. Therefore, it is necessary to evaluate surface water quality indicators and identify trends in water quality change in Ben Tre province [1]. This study was conducted to assess the quality of surface water environment in coastal areas, aquaculture sites and seaports in Ben Tre province by comparing water quality indicators with the permissible

limits of QCVN 10-MT:2015/BTNMT, and water quality classification using cluster analysis. The results provide useful water quality information for coastal water environment management.

2. Materials and methods

Water samples were collected at coastal estuaries, aquaculture areas and port areas in 2020 with a frequency of 4 times/year (March, June, September and November) (Table 1). The sampling procedure was carried out according to the instructions specified in TCVN 6663-6:2018 (ISO 5667-6:2014). Surface water quality in the study area was evaluated based on the value of 8 criteria, including pH, salinity, total suspended solids (TSS), dissolved oxygen (DO), ammonium (N- NH_4^+), total open oil, iron (Fe) and coliforms. In which, the indicators of pH, DO, and salinity are measured directly in the field by hand-held devices. The remaining criteria were collected, preserved and transported for analysis according to standard sample analysis methods [4]. Details of the sample collection and analysis methods are presented in Table 2.

Table 1. Sampling sites in the study area

Sites	Longitude	Latitude	Brief description
TS1	106º42’23,6’’	10º09’38,2’’	Coastal water with aquacultural
TS2	106º37’57,6’’	09º59’38,0’’	Coastal water with aquacultural
TS3	106º36’01,1’’	09º53’24,2’’	Coastal water with aquacultural
VB1	106°38'35.6"	10° 8'17,1’’	Coastal areas
VB2	106°37'58.2"	9°57'31,1’’	Coastal areas
VB3	106°42'0.95"	10°12'49,8"	Coastal areas
VB4	106°35'13.2"	9°46'15,7"	Coastal areas
CA1	106°42'15,6’’	10°12'10,9’’	Coastal water with fish port
CA2	106°36'12,8’’	09°58'53,5’’	Coastal water with fish port
CA3	106°35'54,6’’	09°52'59,6’’	Coastal water with fish port
CA4	106°25'42,2’’	10°18'39,5’’	Coastal water with fish port

Water quality was assessed using QCVN 10-MT:2015/BTNMT National technical regulation on marine water quality [5]. Details of limit values are presented in Table 2. Cluster analysis is used to group water quality by sampling sites. The cluster analysis method was performed using Euclidean distance [6]. The result of CA is presented in form of dendogram [7]. CA was performed using copyrighted software Primer 5.2 software for Windows (PRIMER-E Ltd, Plymouth, UK).

Table 2. Analytical methods and limits of coastal water quality

Parameters	Unit	Analytical methods	Limits
pH	-	pH meter	6.5-8.5
DO	mg/L	DO meter	≥5
Salinity	‰	Salinity meter	-
TSS	mg/L	SMEWW 2450D:2017	50
N-NH_4^+	mg/L	SMEWW 4500 NH_3 B&F:2017	0.1
Oil&Grease	mg/L	SMEWW 5520.B:2012	0.5
Fe	mg/L	SMEWW 3111B:2017	1
Coliform	MPN/100mL	TCVN 6187-2:1996	1000

3. Results and discussion

3.1 Evaluating coastal water quality

The pH at the study sites is in the range of 7.1-7.8 (Figure 1). The pH between the months of sampling was in the range of 7.2-7.6. The pH in fisheries, coastal areas, and port areas is in the range of 7.2-7.6, 7.3-7.6, and 7.2-7.6, respectively. The pH in the study area has little variation between locations and between sampling periods. This pH value is within the allowable limit of

QCVN 10-MT:2015/BTNMT. The results of monitoring pH value in surface water in salt water area of Bac Lieu province ranged from 6.98 to 9.2 [8]. pH in freshwater areas is usually in the neutral range [3,10-11]. The pH in the study area is suitable for the growth of aquatic organisms [5, 12].

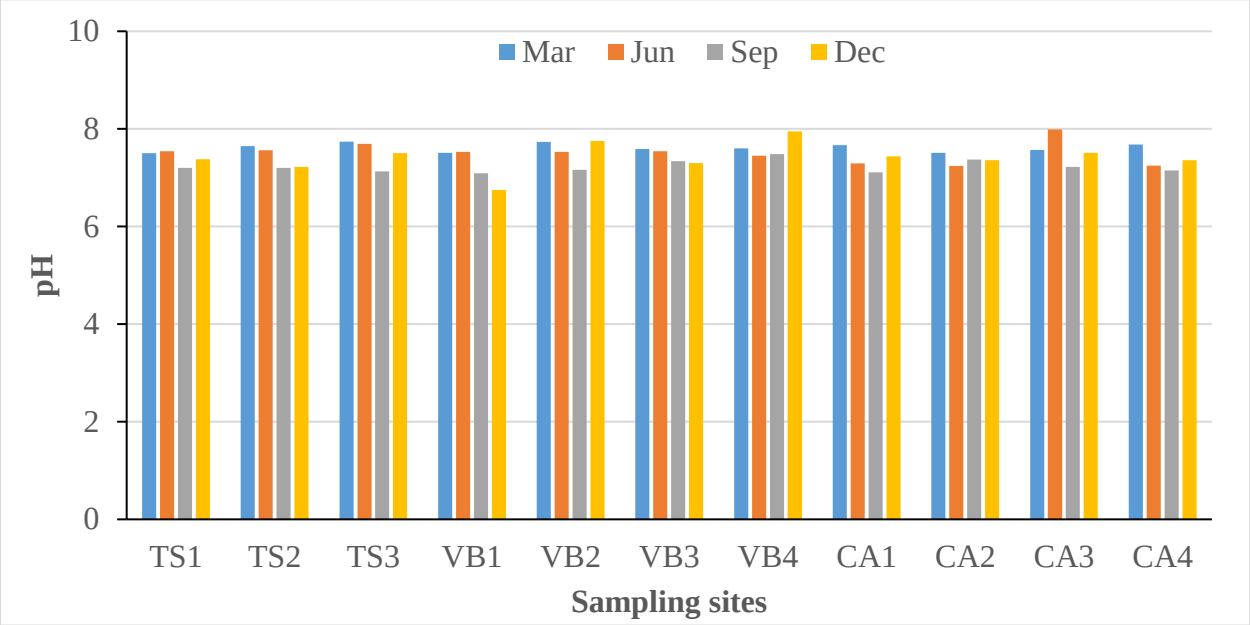

Figure 1. pH in coastal water in Ben Tre province

Dissolved oxygen (DO) concentrations by locations and sampling periods ranged from 5.4-7.5 and 6.5-6.9 mg/L, respectively (Figure 2). DO at positions TS, VB, CA are 5.9-6.5, 6.3-7.1, 5.6-6.9 mg/L, respectively. DO in the dry season tends to be higher than in the rainy season, which may be due to an increase in the concentration of organic matter, suspended solids, and a decrease in photosynthesis in the rainy season. DO in the study area are within the allowable limit of QCVN 10-MT:2015/BTNMT. Previous research showed that DO in seawater in Bac Lieu area is also quite high 4-6.8 mg/l [10].

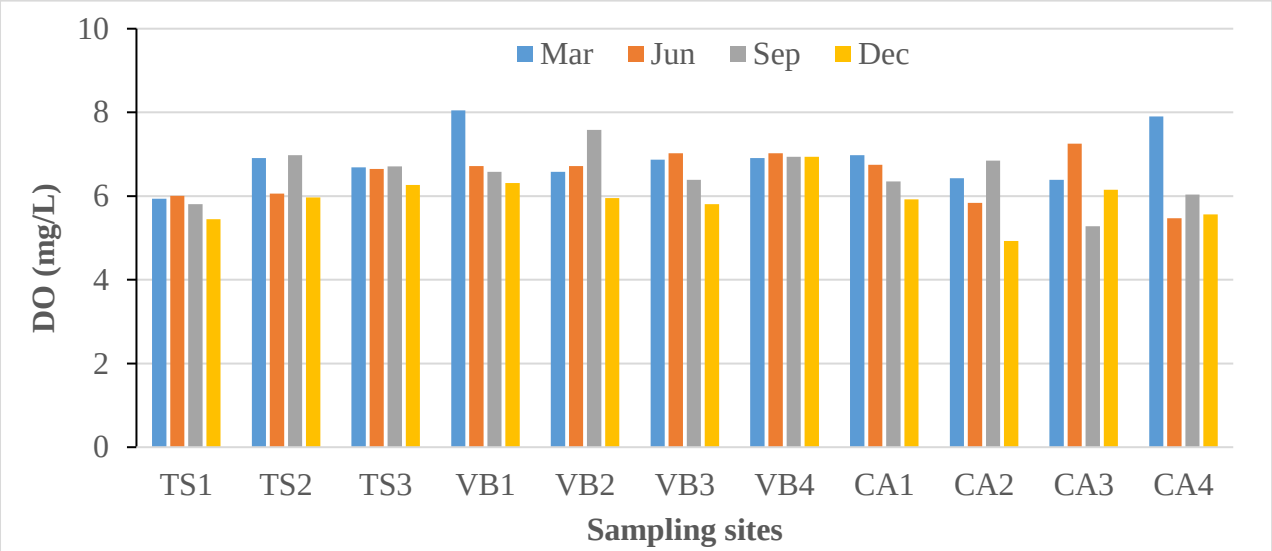

Figure 2. DO in coastal water in Ben Tre province

The salinity in the water in the study area is shown in Figure 3. The salinity at the locations and sampling periods ranged from 2.3-73.8 and 5.9-34.9‰, respectively (Figure 3). The results

show that salinity fluctuates greatly between locations and sampling periods. The salinity in the dry season was significantly higher than that in the rainy season. Salinity in coastal locations was higher than the rest.

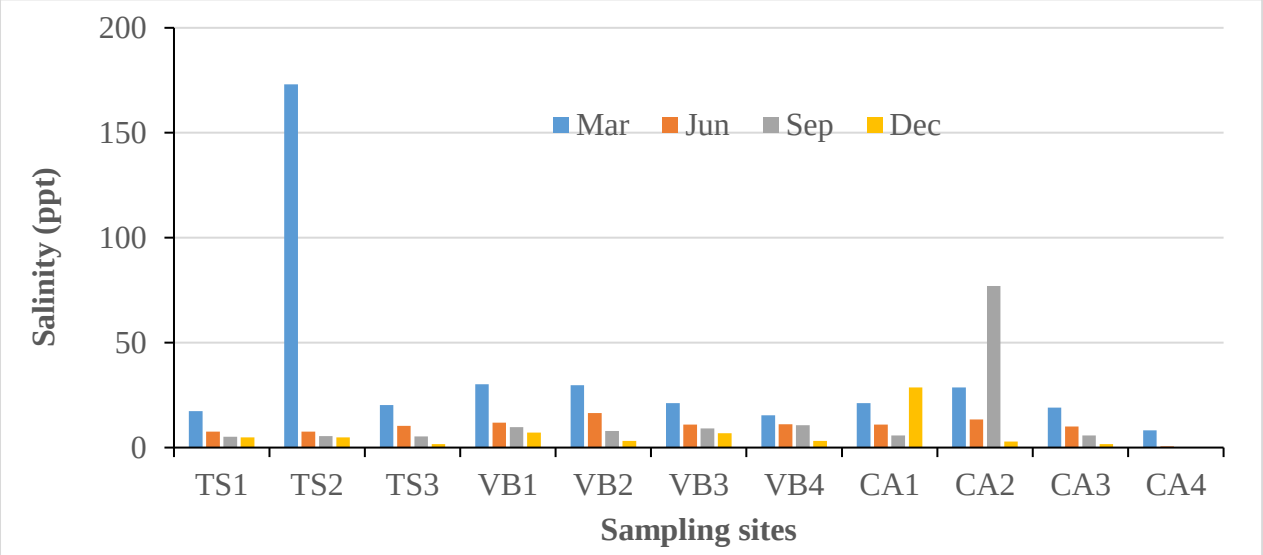

Figure 3. Salinity in coastal water in Ben Tre province

Total suspended solids (TSS) at the sampling sites ranged from 21-107 mg/L (mean 60.3 mg/L). TSS through 4 sampling sessions ranged from 34.8-72.0 mg/L. The results show that TSS fluctuates greatly in space and time (Figure 4). TSS in March and September tended to be higher than other months. The positions TS1, TS2, VB2, CA4 were higher than the remaining positions. The mean values of TSS at TS, VB, and CA were 59.3-103.5, 21.0-70.1, 30.1-67.0 mg/L, respectively. TSS was highest in TS area. Most of the locations in the study area exceed the allowable limit of QCVN 10-MT:2015/BTNMT (TSS = 50 mg/L). TSS often exceeds permissible standards in all water bodies of the Mekong Delta [2]. Previous studies have also shown that TSS has seasonal fluctuations [13-14].

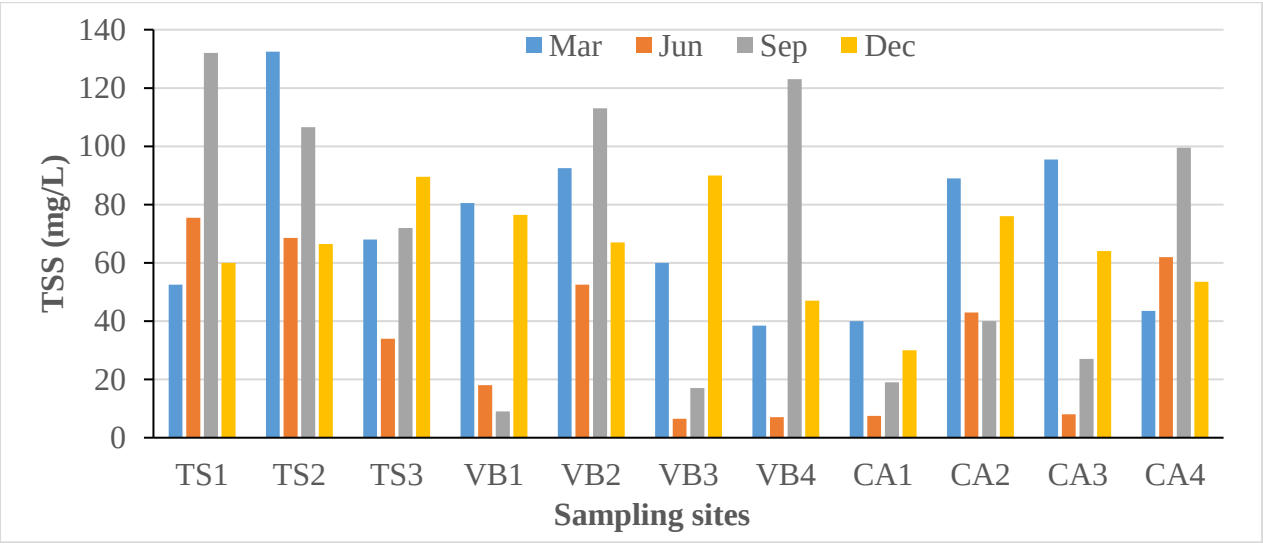

Figure 4. TSS in coastal water in Ben Tre province

The ammonium ($N\text{-}NH_4^+$) concentration in the water at the study area is shown in Figure 5. $N\text{-}NH_4^+$ at the sampling sites ranged from 0.06-0.11 mg/L while between the sampling sites was

within the range of 0.02-0.18 (mean 0.08 mg/L). $N\text{-}NH_4^+$ in TS, VB, CA areas are in the range of 0.04-0.13, 0.05-0.09, 0.06-0.16 mg/L, respectively. $N\text{-}NH_4^+$ in September tended to be higher than other months. The positions with high $N\text{-}NH_4^+$ exceeding the allowable limit of QCVN 10-MT:2015/BTNMT include TS1, TS2, VB1, CA2, CA3. The $N\text{-}NH_4^+$ value in the saltwater area of Bac Lieu province ranged from 0.099 to 1.79 mg/l [8]. Previous studies have shown that $N\text{-}NH_4^+$ fluctuates with the seasons in which the rainy season was usually higher than the dry season [13-15]. The results show that inland canals had higher concentrations of $N\text{-}NH_4^+$ than in coastal areas.

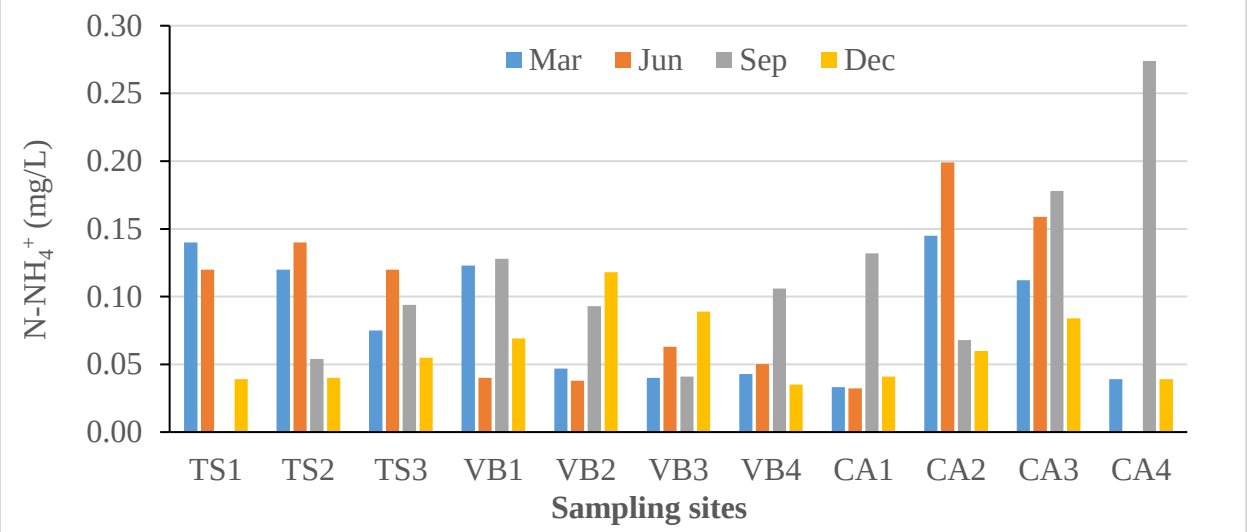

Figure 5. $N\text{-}NH_4^+$ in coastal water in Ben Tre province

Concentrations of iron (Fe) in coastal waters of Ben Tre province are presented in Figure 6. Fe concentrations at sampling sites and across sampling periods ranged from 0.2-1.5 and 0.3-1.3 mg/L, respectively. Fe concentration in June was significantly higher than the other months. Fe concentrations at sites VB1, VB2, CA1 in March and June were significantly higher than those of other sites, and exceeded the allowable limit of QCVN 10-MT:2015/BTNMT (Fe = 1 mg/L). The results show that Fe concentration fluctuates greatly in space and time. Fe in surface water in saline area of Bac Lieu province is about 0.11-4.84 mg/l [8]. The origin of Fe can be from natural (acid sulfate soil) and human activities (wastewater from production processes) [13].

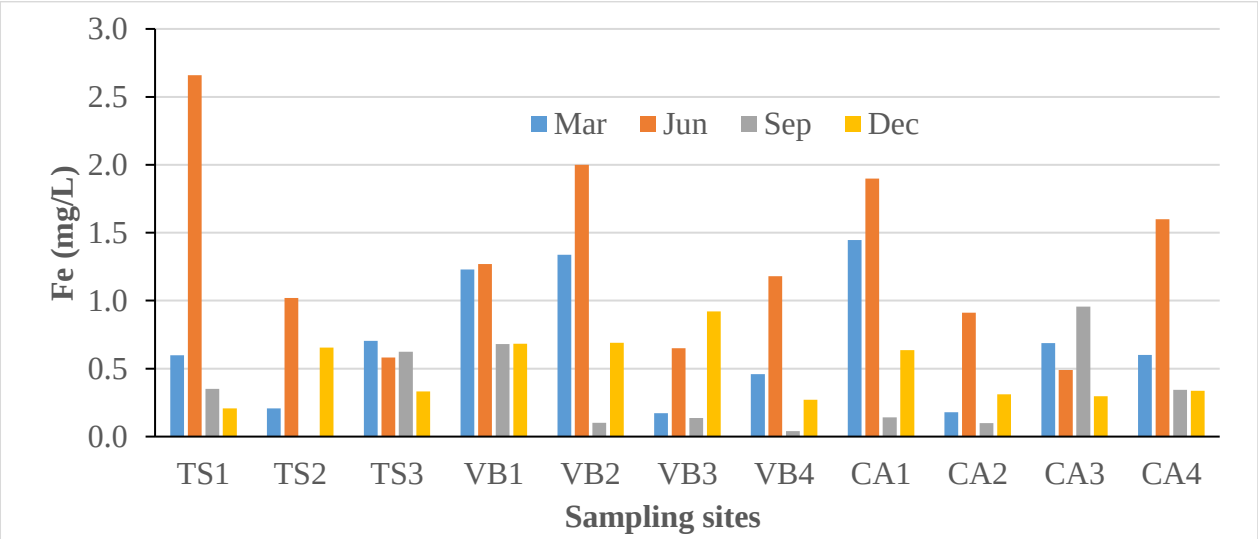

Figure 6. Fe in coastal water in Ben Tre province

The concentration of coliforms at the study area is shown in Figure 7. Coliforms at the study sites ranged from 593-4725 MPN/100 mL while coliforms at the survey sites ranged from 1602-2159 MPN/100 mL. The peak value of coliform in the dry season (4300-7500 MPN/100 mL) was significantly higher than in the rainy season (3500-3600 MPN/100 mL). Coliform in TS, VB, CA areas were 1646, 2509, 1648 MPN/100 mL, respectively. The mean coliform value between months 3, 6, 9, 11 at TS, VB, CA sites was 1935, 1543, 2171, 2088 MPN/100 mL, respectively. The results show that the VB area had a higher coliform density than TS and CA. In these areas, the coliform population in September and December was higher than in the rest of the months. The number of coliforms in the rainy season was higher than in the dry season, possibly because rainwater overflows wash away many materials containing microorganisms. The study results showed that the coliform population in the study area exceeded the allowable limit of QCVN 10-MT:2015/BTNMT (1000 MPN/100 mL). In Bac Lieu's coastal water, the mean of coliform ranged from 1,100-9,500 MPN/100ml [8]. In the freshwater bodies, coliform density is often exceeded the regulation of QCVN 08-MT:2015/BTNMT (2,500 MPN/100 mL) [2-3,10-11, 14-15].

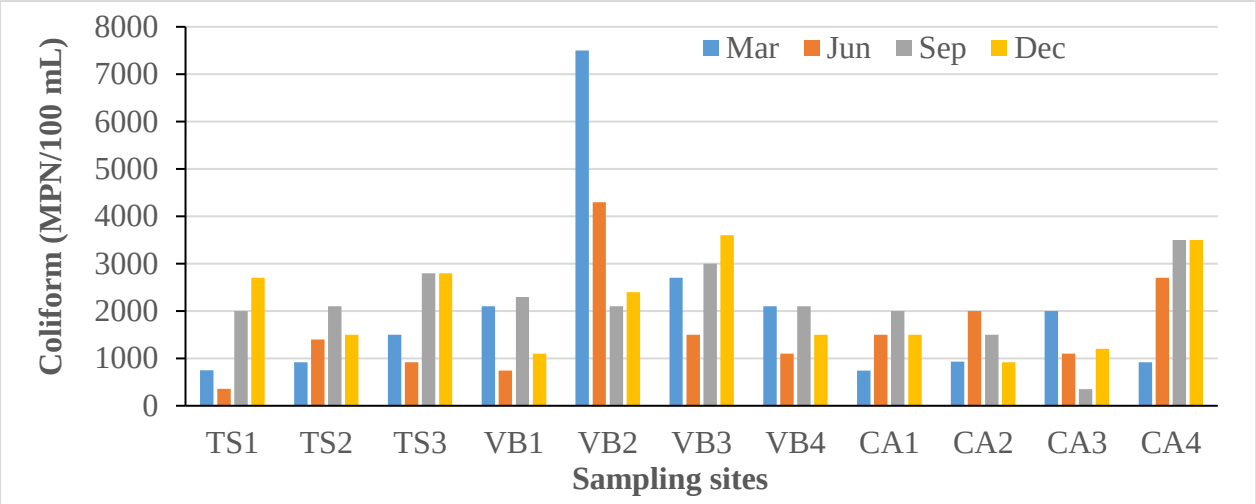

Figure 7. Coliform in coastal water in Ben Tre province

The oil and grease concentration at the study sites ranged from 1.4-27.9 mg/L while the oil and grease concentration between sampling months ranged from 2.2-18.2 mg/L. The mean value for the entire study area was 8.6 mg/L. The oil and grease concentration in the dry season months was significantly higher than in the rainy season months. Oil and grease concentration in TS, VB, CA areas were 11.4, 6.0 and 9.1 mg/L, respectively. The research results showed that the oil and grease in the TS area was significantly higher than in the remaining months. Oil and grease at 3, 6, 9, 11 at TS, VB, CA positions were 18.1, 9.5, 2.4 and 5.3 mg/L, respectively, showing that oil and grease in the dry season was significantly higher than that in the wet season. Oil and grease are derived from human activities in the study area. The results showed that the oil and grease in the study area exceeded the allowable limit of QCVN 10-MT: 2015/BTNMT (0.5 mg/L). Oil and grease were not detected in the coastal water of Tien Giang and southern part of Vietnam [2,16].

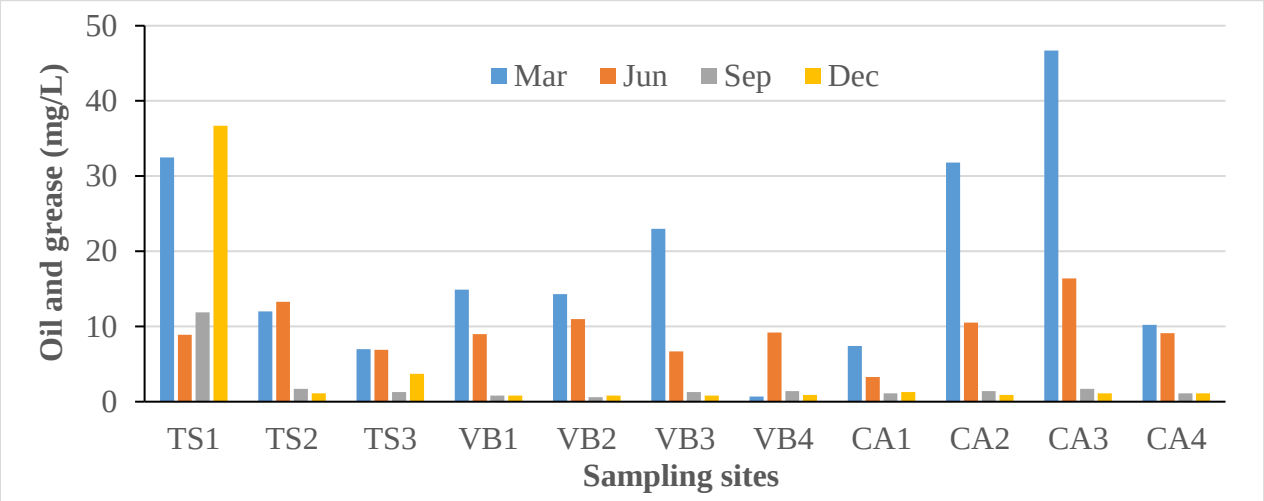

Figure 8. Oil and grease in coastal water in Ben Tre province

3.2 Clustering water quality in coastal area

Surface water quality in the coastal area of Ben Tre province is classified into 3 groups (Figure 9). Group 1 includes positions VB2, VB3, CA4. The parameters TSS, oil and grease, coliform exceeded the allowable limit (Table 3). Group 2 includes positions VB1, VB4, TS3, CA1 and the oil and grease and coliform parameters exceeding the allowable limit. Oil and grease and coliform were lower than group 1. Group 3 included TS1, TS2, CA3 and CA4 positions. The parameters TSS, oil and grease and coliform exceeded the allowable limit. Salinity, TSS, oil and grease, coliform exceed permissible limits. In which, salinity, TSS, oil and grease were significantly higher than group 1 and group 2. It can be seen that surface water quality in the study area is hindered by TSS, oil and grease, and coliforms. Suspended solids are derived from organic matter, plankton, river bank erosion. Sources of oil and grease are mainly anthropogenic. Oil and grease typically needs to be contained from entering the environment. Fecal coliforms are the group of the total coliforms that are considered to be present specifically in the gut and feces of warm-blooded animals [2,17]. Coliform growth may also be affected by phosphorus, nitrates, dissolved oxygen (DO), chemical oxygen demand (COD), temperature, or organic carbon [18].

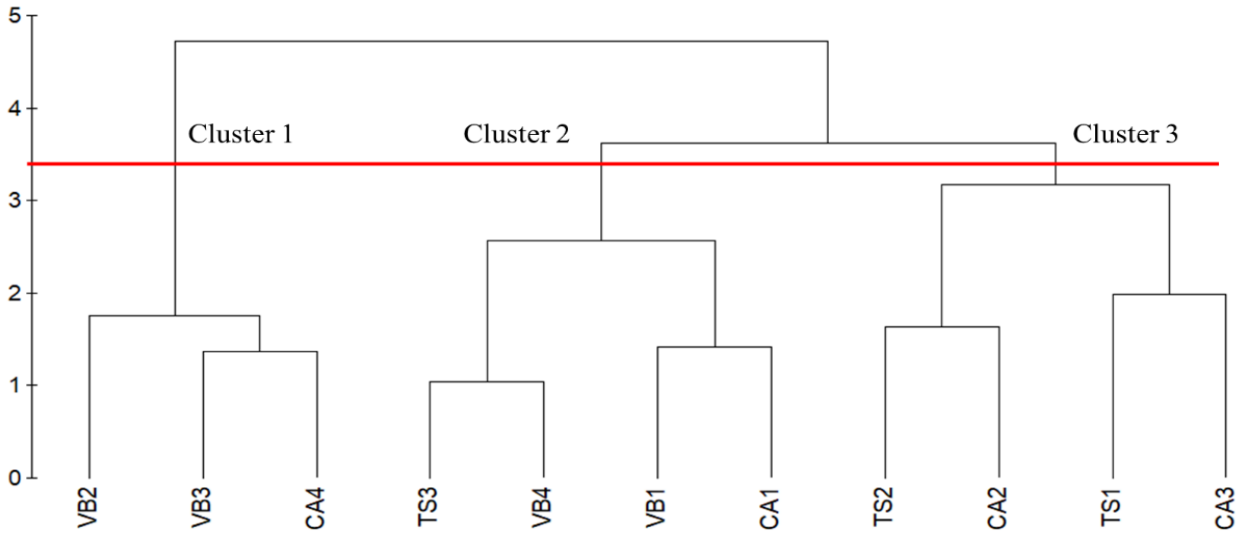

Figure 9. Clustering coastal water in Ben Tre province

Table 3. Water quality in the identified clusters

Variables	Cluster 1	Cluster 2	Cluster 3	Limits
pH	7.4	7.4	7.4	6.5-8.5
DO	6.5	6.7	6.1	≥5
Sal	9.5	12.7	24.0	-
TSS	63.1	47.5	71.0	50
N-NH4	0.1	0.1	0.1	0.1
Oil and grease	6.7	4.4	14.3	0.5
Fe	0.7	0.8	0.6	1
Coliform	3143.3	1675.0	1358.1	1000

4. Conclusion

The research results show that the surface water quality in the coastal area has TSS, coliform, and oil and grease criteria exceeding the allowable limit of QCVN 10-MT:2015/BTNMT. Most surface water indicators were seasonal fluctuations. DO, salinity, Fe, oil and grease in the dry season were significantly higher than those in the rainy season. Meanwhile, $N\text{-}NH_4^+$ and Coliform were higher in the rainy season than that in the dry season. TSS of March and September was higher than that of June and November. pH has little seasonal variation. Surface water quality in the coastal area of Ben Tre province was classified into three clusters due to the difference between the parameters of salinity, TSS, oil and grease, coliform exceeding the allowable limits. Coliform in cluster 1 was significantly higher than that in cluster 2 and 3. Meanwhile, salinity, TSS, oil and grease were significantly higher than that in the cluster 1 and 2. It can be seen that surface water quality in the area The study was hindered by TSS, oil and grease, and coliform criteria. These indicators need to be continuously monitored and a solution for good water quality management is needed.

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