Identifying Key Variables Influencing Surface Water Quality in Coastal Provinces of Soc Trang and Bac Lieu, Vietnam

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Article information	Abstract
	The study was carried out to assess the quality, main influencing indicators and sources of impact on surface water quality of coastal provinces such as Soc Trang and Bac Lieu. Water quality data were collected at 19 sampling locations in Soc Trang province and eight sampling locations in Bac Lieu province in 2019 including parameters of temperature, pH, electrical conductivity (EC), turbidity (Turb), total suspended solids (TSS), dissolved oxygen (DO), chemical oxygen demand (COD), biological oxygen demand (BOD), ammonium ($N\text{-}NH_4^+$), nitrite ($N\text{-}NO_2^-$), nitrate ($N\text{-}NO_3^-$), soluble phosphorus ($P\text{-}PO_4^{3-}$), total Fe (Fe), total nitrogen (TN), total phosphorus (TP), sulfate (SO_4^{2-}), chloride (Cl^-), coliforms, total organic matter (TOC), alkalinity (Alk) and salinity (Sal). Principal component analysis (PCA) was used to identify the main factors affecting surface water quality in the study area. In Soc Trang, the results showed that the water quality shows signs of pollution by suspended solids, organic matters, nutrients and microorganisms in the central areas of the city, urban areas, inland areas and salinity. in coastal areas. The PCA results indicated that the parameters that need to be selected for monitoring included EC, TSS, COD, Cl^-, total Fe, SO_4^{2-} and BOD, $N\text{-}NH_4^+$, $P\text{-}PO_4^{3-}$. In Bac Lieu, the results showed that the water quality is not suitable for domestic purposes. The parameters of TSS, COD, BOD, $N\text{-}NO_2^-$, $N\text{-}NH_4^+$ and Cl^- all did not meet the permitted standards of QCVN 08:2015/BTNMT (column A2). The PCA results showed the criteria that need to be considered for monitoring such as pH, salinity, COD, BOD, TSS, total Fe, Cl^-, DO, $N\text{-}NO_3^-$, alkalinity and coliforms. The current results provide scientific information for monitoring water quality in the coastal provinces of the Mekong Delta.

1. Introduction

Water is a key component of the living environment, capable of determining the success of strategies, master plans and plans for socio-economic development, and ensuring national defense and security. In recent years, the negative changes of climate along with the continuous development of the economy have created a lot of pressure on this rare and important natural resource. The risk

of water shortage, especially fresh and clean water, is a great danger to human life as well as all life on earth. With the negative developments from the climate and the continuous development of the socio-economic, many resources are at risk of loss or disappearance. The challenge is to effectively manage and maintain the current state of the environment, keeping these much-needed resources.

In order to effectively manage and protect the water environment, the monitoring of water quality assessment criteria is essential. These monitoring indicators will provide important information on water quality through which we can know the current state of water quality in the study area. Currently, in our country, there are many analytical techniques such as multivariate analysis such as cluster analysis, discriminant analysis, principal component analysis, which can help us to extract important information thereby reducing errors. Sampling point, sampling frequency or unnecessary sampling criteria avoids costs and improves monitoring efficiency.

Multivariate analysis method is also used to identify pollutant sources, evaluate the effectiveness of the monitoring network including location, frequency and monitoring criteria [1-4]. Among the methods, CA and PCA have been widely used, capable of detecting similarities between samples and/or environmental parameters [4-6]. From the above studies, the multivariate statistical method can be used to evaluate the surface water environment monitoring network. Soc Trang and Bac Lieu are two provinces in the Mekong Delta located in the lower part of the Hau River, adjacent to the East Sea, with a coastline of more than 72 km. Having a diverse and interlaced system of rivers and canals creates many advantages for economic development in agriculture, industry and services [8-9]. However, due to its location adjacent to the sea, surface water is often contaminated with seasonal saline alum. In recent years, water flow in the upper Hau River has decreased, combined with increasing saltwater intrusion, prolonged drought, causing water shortage, difficulties for exploitation and use, and damage. for production of people in some localities in the province [8-9].

This study was conducted using monitoring data from main rivers and canals in Soc Trang and Bac Lieu provinces to identify environmental pollution issues that need to be addressed and resolved and contribute to the improvement of the system. Monitoring the quality of surface water environment in the coastal provinces of the Mekong Delta.

2. Methodology

2.1 Water sampling and analysis
The study was conducted in two provinces of Soc Trang and Bac Lieu, Vietnam. Locations of water quality monitoring data collection is shown in Figure 1. Surface water samples were collected according to the guidelines of TCVN 6663-6:2018 water quality – sampling at the time of April, May, October and November. Water samples were collected according to the guidelines of TCVN 6663-6:2018 (ISO 5667-6:2014) - Sampling guide for rivers and streams. Water samples were collected midstream (this depends on the width of the channel) with a depth of 30 cm below the surface water. At each site, three increments were mixed and pooled samples were collected. The sample collection device consists of a 2-liter plastic bottle with a screw cap and must be filled with water at least 3 times at the sampling site before sampling. As for the coliforms index, samples were collected using specialized instruments (glass vials) that were sterilized at 175°C for about 2 hours. Monitoring water quality indicators in Soc Trang including temperature, pH, electrical conductivity (EC), turbidity, total suspended solids (TSS), dissolved oxygen (DO), chemical oxygen demand (COD), biological oxygen demand (BOD), ammonium ($N-NH_4^+$), nitrite ($N-NO_2^-$), nitrate ($N-NO_3^-$), orthophosphate ($P-PO_4^{3-}$), total Fe (Fe), total nitrogen (TN), total phosphorus (TP), SO_4^{2-}, chloride (Cl^-), coliforms, total organic carbon (TOC) and includes pH, salinity, total suspended solids (TSS),

dissolved oxygen content (DO), demand chemical oxygen (COD), biological oxygen demand (BOD), ammonium ($N-NH_4^+$), nitrite ($N-NO_2^-$), nitrate ($N-NO_3^-$), alkalinity, total Fe, chloride (Cl^-) ,coliforms of Bac Lieu province.
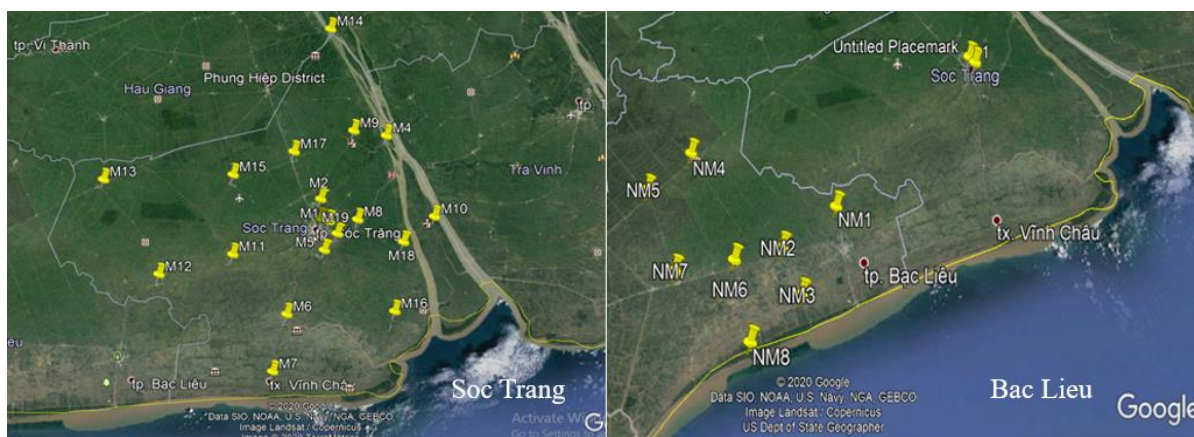

Figure 1. Study sites map in Soc Trang and Bac Lieu

The parameters of pH, temperature, and DO were measured in the field using Hanna HI 8224 hand-held meters (Romania) and Milwwaukee SM 600 (Rumania) according to the provisions of TCVN 6942:2011 (ISO 10523:2008) and TCVN 7325: 2016 (ISO 5814:2012), the remaining criteria were collected, preserved, transported and analyzed at the laboratory of the Center for Natural Resources and Environment Monitoring of Soc Trang and Bac Lieu provinces by standard methods [10]. The criteria, analytical methods, and limit values are presented in Table 1.

Table 1. Parameters, analytical methods, and permissible limits

No.	Parameters	Unit	Analytical methods	QCVN, A2
1	Temperature	^0C	SMEWW 2550B:2012	
2	pH	-	TCVN 6492:2011	6-8.5
3	Electrical conductivity (EC)	µS/cm	SMEWW 2510B:2012	
4	Total suspended solid (TSS)	mg/L	SMEWW 2540D:2012	30
5	Turbidity	NTU	HACH 2100N	
6	Dissolved oxygen (DO)	mg/L	TCVN 7325:2004	≥ 5
7	Biological oxygen demand (BOD)	mg/L	SMEWW 5210B:2012	6
8	Chemical oxygen demand (COD)	mg/L	SMEWW 5220C:2012	15
9	Nitrate ($N-NO_3^-$)	mg/L	SMEWW 4500-NO_3^--E:2012	5
10	Nitrite ($N-NO_2^-$)	mg/L	SMEWW 4500-NO_2^--E:2012	0.05
11	Ammonium ($N-NH_4^+$)	mg/L	SMEWW 4500-NH_3.B&F:2012	
12	Orthophosphate ($P-PO_4^{3-}$)	mg/L	SMEWW 4500-P-E:2012	0.2
13	Total nitrogen (TN)	mg/L	TCVN 6638:2000	
14	Total phosphorus (TP)	mg/L	SMEWW 4500-P-B&E:2012	
15	Sulfate (SO_4^{2-})	mg/L	SMEWW 4500-SO_4^{2-}E:2012	
16	Total iron (Fe)	mg/L	TCVN 6177:1996	1.0
17	Chlorua (Cl^-)	mg/L	TCVN 6494-1:2011	350
18	Coliforms	MPN/100mL	TCVN 6187-2:1996	5000

2.2 Data analysis

The study used the method of principal factor analysis (Principal Component Analysis, PCA) to extract important information from the initial data set [11-12]. The pivot method used in PCA is Varimax, each initial data variable will be classified into a principal component (PC) and each PC will represent a small group of initial variables [11-12]. The result of PCA is to reduce the initial data variables that do not make a significant contribution to the variability of the data. The

correlation between PCs and the initial data variables is shown through the weighting correlation coefficient (loading) [11-12]. The absolute value of the coefficient of correlation coefficient greater than 0.75 means that the correlation between the main component and the water quality parameter from 0.75-0.5 is moderate and 0.5-0.3 is weak. twelfth]. The water environment parameters after analysis will be compared with QCVN 08-MT:2015/BTNMT, column A2 [13]. Details of the limit values are presented in Table 1.

3. Results and discussion

3.1 Surface water quality in Soc Trang province
The results of analysis of water temperature in Soc Trang province in 2019 showed that the temperature did not fluctuate between sampling locations. The temperature ranges from 28.6 ± 1.2 to 29.7 ± 1.5^oC. The water temperature at the points is still suitable for aquatic life, in the appropriate range from 25 to 32^oC [14]. The pH value in Soc Trang province at the sampling locations ranged from 6.56 to 8.13, with the average value from 7 ± 0.3 to 7.5 ± 0.3; However, most of the sampling locations, the pH concentration is within the allowable limit of QCVN 08-MT:2015/BTNMT. The average EC value at the study sites has a lot of variation and the difference is quite high from 29.7 ± 6.1 to 966.3 ± 704.4 mS/m. The highest EC value was 966.3 ± 704.4 mS/m at location M6 (Co Co Market Canal).

Turbidity at the sites ranged from 18.8 to 964.9 NTU with an average of 43.5 ± 29.7 to 207.7 ± 258.7 NTU. The highest turbidity value was 207.7 ± 258.7 NTU at location M6 (Co Co canal) and the lowest was 43.5 ± 29.7 NTU at location M14 (Hau river at Cai Con). The average total suspended solids (TSS) at the sampling sites ranged from about 34.1 ± 22.4 to 249.9 ± 273.9 mg/L. Suspended solids at the monitoring locations are above the allowable threshold when compared with QCVN 08-MT:2015/BTNMT in column A2 from 1 to 8 times. The average dissolved oxygen content between the sites varied quite a lot. The DO content ranged from 2.0 to 6.51 mg/L, on average from 2.5 ± 0.4 to 4.0 ± 1.2 mg/L. This average value does not meet the value according to QCVN 08-MT:2015/BTNMT, column A2 [13]. From there, it can be seen that the DO content in 2019 in Soc Trang province has signs of organic pollution but has not significantly affected aquatic organisms. BOD values ranged from 1.47 to 16.6 mg/L with mean values from 3.0 ± 1.7 to 9.6 ± 3.4 mg/L. The COD content ranged from 5.13–73.6 mg/L with the mean value from 13.4 ± 5.4 to 37.8 ± 9.1 mg/L. BOD and COD at the sampling locations are above the allowable limit QCVN 08-MT:2015/BTNMT column A2 [13] except M4 and M14.

The average concentration of $N-NH_4^+$ ranges from 0.1 ± 0 to 2.3 ± 1.6 mg/L, reaching the highest value at position M2 (Channel 30-4) at 2.3 ± 1 ,6 mg/L. The results at 19 locations show that the Ammonia $(N-NH_4^+)$ content of the sites has 14/19 points exceeding the surface water quality standard QCVN 08-MT:2015/BTNMT column A2 [13]. The content of $N-NO_2^-$ ranges from 0 to 0.2 ± 0.2 mg/L, the $N-NO_2^-$ values of most locations are within the allowable limits of the regulation (except for the positions M1, M3, M5, M7, M10, M11, M16, M17, M19). $N-NO_2^-$ is an intermediate oxidation product of $N-NH_4^+$ and $N-NO_3^-$, which is more harmful to animals and humans than $N-NO_3^-$. $N-NO_3^-$ in the study area fluctuated in the range of 0.01 to 1.93 mg/L and there was not much difference between sites, however, there was a difference between some sites. The average values of $N-NO_3^-$ are within the allowable limits of QCVN 08-MT:2015/BTNMT column A2 [13]. The average $P-PO_4^{3-}$ ranged from 0 to 0.3 ± 0.3 mg/L. In general, the average $P-PO_4^{3-}$ value at all locations met QCVN 08 MT:2015/BTNMT column A2 [13] except for 02 positions M1, M2 which exceeded the allowed threshold. The results of the study at 19 sites showed that the average protein content at the sites ranged from 1.4 ± 0.4 to 3.7 ± 1.6 mg/L, reaching the highest average value at position M2

(channel 30-4) is 3.7±1.6 mg/L. The average phosphorus content ranges from 0.3±0.1 to 0.7±0.4 mg/L. This result is consistent with previous studies, the surface water environment in the Mekong Delta is at risk of eutrophication, affecting aquatic life and human health [15]. The total Fe content in Soc Trang province in 2019 ranged from 0.3 to 25.9 mg/L with an average ranging from 0.7±0.3 to 4.4±7.2 mg/L. Fe content in the study area mostly exceeded the allowable limit for column A2 QCVN 08-MT:2015/BTNMT, column A2 [13]. The average sulfate content at monitoring locations in Soc Trang province ranges from 26.7±13.2 to 377.8±288.5 mg/L. The average Cl^- concentration ranges from 22.8±18.5 to 2,832.4±2.055.5 mg/L, there are 3/19 monitoring locations exceeding the standard QCVN 08-MT:2015/BTNMT column A2 [13]. The average coliforms density of the sites in the study area ranged from 5,690±5,249.1 to 127,936±227,526.3 MPN/100mL. Coliform at most locations exceeded the surface water quality standard QCVN 08 MT: 2015/BTNMT column A2 [13]. The mean TOC at the study sites fluctuated a lot and the difference was quite high from 3.7±1.9 to 13.2±4.0 mg/L.

3.2 Surface water quality in Bac Lieu province
The monitoring results of pH value in surface water of Bac Lieu province in 2019 ranged from 6.46 to 8.53 with the average value from 7.2±0.5 to 7.7±0.2. The pH values of all positions are within the allowable limits according to QCVN 08-MT:2015/BTNMT column A2 [13]. The salinity value of Bac Lieu in 2019 has a large difference, ranging from 0 to 32‰ with an average of 0.9±2.2 to 22.0±6.0‰. The highest average salinity value is 22.0±6.0 ‰ at NM6 (Xom Lung canal) located in saline area. DO in surface water of Bac Lieu province in 2019 fluctuated between 4.0 and 7.0 mg/L with the average value from 5.3±0.6 to 5.9±1.0 mg/L. DO values of all positions are within the allowable limit according to QCVN 08-MT:2015/BTNMT column A2 [13]. The evaluation results show that the BOD value ranges from 22.3±12.4 to 68.6±49.8 mg/L Similar to BOD, the COD value ranges from 32.9±18.2 to 101 ±73.3 mg/L, exceeding the allowable limit of 08-MT:2015/BTNMT, column A2 [13].

The average total suspended solids (TSS) at the sampling sites ranged from 63.1±55.0 to 550.4±550.6 mg/L. Suspended solids at monitoring locations are all above the allowable threshold when compared with QCVN 08-MT: 2015/BTNMT in column A2 [13]. This is consistent with high COD and BOD results, with high TSS likely due to the presence of organic and inorganic components in the water. The $N-NO_2^-$ content ranged from 0.16±0.18 to 0.28±0.3 mg/L. Nitrite at all survey sites exceeded the threshold in surface water quality standards QCVN 08-MT:2015/BTNMT, column A2 [13]. The nitrate content in water in Bac Lieu ranges from 0.97±1.07 to 2.14±1.95 mg/L and does not exceed the allowable threshold of QCVN 08-MT: 2015/BTNMT on surface water quality (column A2). The $N-NH_4^+$ value ranged from 0.66±0.71 to 1.55±0.86 mg/L, exceeding the limit of QCVN 08-MT:2015/BTNMT (0.3 mg/L, column A2). Alkalinity in the study area ranged from 95.4±33.4 to 123±18 mg/L $CaCO_3^-$. Currently, there are no standards for alkalinity in surface water. Total Fe content ranged from 0.31±0.2 to 1.08±1.15 mg/L. Fe in the total study area mostly reached the allowable limit for column A2 QCVN 08-MT:2015/BTNMT except NM7. The average Cl^- value at all locations ranges from 609.9±924.8 to 12,423±3.731 mg/L. The value of Cl^- exceeds the permissible threshold of the standard 35 times. The density of coliforms appearing in surface water in Bac Lieu ranged from 2,000±1,067 to 4,200±2,796 MPN/100mL. When compared with the standard, at all positions, the coliforms value is still within the allowable threshold of QCVN 08-MT:2015/BTNMT, column A2 [13].

3.3 Key variables influencing surface water quality in Soc Trang province

Table 2 presents the results of analysis of main components, sources of pollution and indicators of the impact of pollution sources in 2019. Results of analysis of main components PC1, PC2, PC3 and PC4 are all have eigenvalues greater than 1, respectively 6.9; 6.6; 1.56 and 1.38 and account for the cumulative 273.3 % of the variance. Therefore, PC1, PC2, PC3 and PC4 are the main factors or 4 sources of water pollution, explaining 86.6% of the total data.

Table 2. Results of PCA analysis based on water quality parameters in Soc Trang

Parameters	PC1	PC2	PC3	PC4
Temp	-0,041	-0,248	**-0,469**	-0,141
pH	-0,218	-0,195	0,196	**-0,345**
EC	**-0.337**	-0,148	-0,033	-0,041
Turb.	-0,284	-0,191	0,153	0,197
TSS	**-0,312**	-0,191	0,152	0,087
DO	0,134	-0,297	**0,345**	-0,064
BOD	-0,109	**0,344**	-0.001	-0,005
COD	**-0,350**	0,103	-0,114	0,003
Cl⁻	**-0,339**	-0,145	-0,030	-0,030
$N-NH_4^+$	-0,102	**0,342**	0,200	0,116
$N-NO_2^-$	-0,088	0,194	-0,125	**-0,499**
$N-NO_3^-$	0,022	-0,286	**0,438**	-0,151
$P-PO_4^{3-}$	-0,038	**0,331**	0,277	0,130
Fe	**-0,305**	-0,102	0,010	0,255
TN	-0,267	0,221	0,143	0,040
TP	-0,160	0,285	0,288	-0,012
SO_4^{2-}	**-0,338**	-0,145	-0,072	-0,067
Coliforms	-0,028	0,132	0,149	**-0,659**
TOC	-0,258	0,208	**-0,326**	-0,034
Eigenvalues	6,90	6,60	1,56	1,38
Var. (%)	36,3	34,7	8,2	7,3
C.Var. (%)	36,3	71,1	79,3	86,6

Component 1 (PC1) explains 36.3% of the total variation of the obtained water quality data, which is weakly correlated with the EC (- 0.337); TSS (-0.312); COD (-0,350); Cl⁻ (-0.339); Fe (-0.305); SO_4^{2-} (-0.338). Thus, the important parameters in PC1 are explained for the water quality in the area influenced by solids, biodegradable organic matter and ions. COD is a good indicator for the environment contaminated with organic matter [16-17], this represents the source of pollution caused by human activities such as residential - urban, service and tourism, industrial production, agriculture industry [18]. PC1 the weak contribution (-0.305) to explaining the fluctuation of iron content in the surface water environment of Soc Trang province in 2019 is a representative source for the natural conditions of the acidic soil.

Component 2 (PC2) explains 34.7% of the total variation of the obtained water quality data, PC2 is affected by positive coefficients that are weakly correlated with the indicators of BOD (0.344); $N-NH_4^+$ (0.342); $P-PO_4^{3-}$ (0.331). Thus, the indicator at PC2 explains that the water quality in the study area is influenced by organic matter and nutrients. $P-PO_4^{3-}$ is commonly found in fertilizers, detergents, and in the decomposition of waste, animal and plant residues [18-19]. Component 3 (PC3) explains 8.2% of the total variation of the obtained water quality data, which is weakly correlated with the temperature parameters (-0.469); DO (0.345); $N-NO_3^-$ (0.438) and TOC (-0.326). And component 4 (PC4) explains 7.3% of the total variation in surface water quality in the study area, at an average correlation with the coliforms (-0.659) affected by humans and animals through fecal excretion into the environment and is not well managed [20-21] and is weakly correlated with pH (-0.345), $N-NO_2^-$ (-0.499). Through the analysis results, the parameters affecting water quality

in Soc Trang are located in PC1 and PC2 which are EC, TSS, SO_4^{2-}, $N-NH_4^+$, BOD, Cl^-, total Fe, $P-PO_4^{3-}$ and COD. In which, BOD, $N-NH_4^+$ and COD are important parameters affecting water quality in Soc Trang because they are parameters with high correlation coefficients in all analyzed parameters. Therefore, it can be seen that the water quality in the studied water body is affected by many different pollution sources, the sources of these pollutants are mainly from wastewater from agricultural, fishery and industrial activities. activities of people around the stream, partly due to surface erosion and runoff. Thus, when assessing water quality in Soc Trang province, besides physical parameters (temperature), it is necessary to pay attention to other monitoring parameters such as EC, TSS, COD, Cl^-, total Fe, SO_4^{2-} and BOD, $N-NH_4^+$, $P-PO_4^{3-}$.

3.4 Key variables influencing surface water quality in Bac Lieu province
The analysis results of the monitoring indicators of Bac Lieu province show that the components PC1, PC2, PC3 and PC4 (accounting for 93.8% of the total variance) are the four sources of pollutants in the water environment because they are all sources of pollutants in the water environment. has eigenvalue greater than 1 with values of 7.37, 2.26; 1.47 and 1.09, respectively (Table 3). With the total value of variation of the obtained water quality data accounting for 56.7% of component 1 (PC1) related to the pH variables (-0.355); salinity (-0.353); COD (-0.347), BOD (-0.347), TSS (-0.312), Fe (0.323) and Cl^- (-0.348). The weak correlation indicators in PC1 explain that surface water quality in Bac Lieu province is heavily influenced by suspended solids, organic substances, and salt ions in the water. BOD and COD are good indicators for organic pollution environment [16-17] representing pollution sources caused by human activities such as residential-urban, service and tourism, industrial production, agriculture, and industry [18]. pH can represent weather factors (e.g., the amount of light reaching water bodies), hydrological regimes (water depth, volume, currents), and the buffering capacity of water under conditions. alkaline water environment of the province. In addition, this place is a soil contaminated with alum and saline because it has a weak contribution (0.312) to explain the fluctuation of iron content in surface water environment of Bac Lieu province in 2019. Component 2 (PC2) explains 17.4% of the total variation of the obtained water quality data, which is weakly correlated with the DO parameters (-0.407); $N-NO_3^-$ (0.470); alkalinity (0.347) and average correlation with $N-NO_2^-$ (0.555). This shows that the source of pollution to the water quality is due to the nitrate, nitrite and alkalinity levels. The source of pollution can be from agricultural activities, when in the rainy season, it will wash away fertilizer residues and material on the soil surface into water bodies. On the other hand, due to the presence of many organic substances in the water, the dissolved oxygen demand decreases sharply, which indicates that the water in the environment lacks oxygen and this can be toxic to aquatic life.

Table 3. Results of PCA analysis based on water quality parameters in Bac Lieu

Parameter	PC1	PC2	PC3	PC4
pH	**-0,355**	0,067	-0,079	0,172
Sal	**-0,353**	-0,141	0,086	-0,128
DO	0,194	**-0,407**	0,057	**0,517**
COD	**-0,347**	-0,095	0,238	0,052
BOD	**-0,347**	-0,092	0,240	0,052
TSS	**-0,312**	-0,049	0,079	0,073
$N-NO_2^-$	-0,016	**0,555**	0,004	**-0,448**
$N-NO_3^-$	-0,026	**0,470**	-0,202	**0,605**
$N-NH_4^+$	0,260	-0,063	**0,549**	-0,128
Alk.	-0,282	**0,347**	0,006	0,162
Fe	**0,323**	0,139	0,163	0,055
Cl^-	**-0,348**	-0,171	0,069	-0,121
Coliforms	0,011	0,297	**0,699**	0,221
Eigenvalues	7,37	2,26	1,47	1,09
Var. (%)	56,7	17,4	11,3	8,4
C.Var. (%)	56,7	74,1	85,4	93,8

Total variance accounted for 11.3% of component 3 (PC3) including ammonium and coliforms criteria. It can be seen that, although the total variance is not high, PC3 with the existence of coliforms has contributed to the pollution of water quality in Bac Lieu province. The origin of coliforms is from livestock waste, human and animal feces, which can cause cholera and affect human health. Besides, this factor contributes quite high (0.699), so it is necessary to pay attention to effective management of water resources in the province. Similar to the results just analyzed for Soc Trang province, coliform is the parameter likely to contribute to water pollution. The remaining component PC4 has a total variance of 8.4%, respectively, with the contribution of DO (0.517); $N-NO_2^-$ (-0.448); $N-NO_3^-$ (0.605).

The sources can be from the use of fertilizers in agricultural production, the decomposition of organic residues, and natural factors influencing those two processes [18]. This result is similar to the PC2 just presented, so it is necessary to pay attention to these parameters as well as the source of pollution to have effective management solutions in the near future. Through analysis results, the study selected important parameters that cause fluctuations to water quality including pH, salinity, COD, BOD, TSS, total Fe, Cl^-, DO, $N-NO_3^-$, alkalinity and coliforms.

4. Conclusion

The water quality in the study area, through analysis and evaluation, shows that the water quality in both Soc Trang and Bac Lieu is not suitable for domestic purposes. The parameters of TSS, COD, BOD and DO all do not meet the allowed standards of the regulation (column A2). In addition, in Soc Trang province, some places are at risk of eutrophication due to high concentrations of TN and TP. Water quality in the study area is polluted due to agricultural and domestic activities. The PCA results show that the indicators affecting water quality in Soc Trang are BOD, $N-NH_4^+$ and COD because the indicator has a high correlation coefficient among all the analyzed indicators. Therefore, it can be seen that the water quality in the studied water body is affected by many different pollution sources, the sources of these pollutants are mainly from wastewater from agricultural, fishery and industrial activities. activities of people around the stream, partly due to surface erosion and runoff. Similarly, in Bac Lieu province, PCA results showed that indicators with high correlation coefficients included nitrite, nitrate, DO, TSS, total Fe, alkalinity and coliforms. These parameters were determined to have pollution origins from geographical conditions and human activities such as intensive agricultural production, acid soil washing, which are the causes of iron generation in surface water. In addition, it is possible that from agricultural activities, when in the rainy season, it will wash away fertilizer residues and material on the soil surface into water bodies.

References
[1] Chounlamany, V., Tanchuling, M.A., & Inoue, T. (2017). Spatial and temporal variation of water quality of a segment of Marikina River using multivariate statistical methods. *Water Science and Technology* 66.6: 1510-1522.
[2] Mama, A., Bodo, W., Ghepdeu, G., Ajonina, G. and Ndam, J. (2021). Understanding Seasonal and Spatial Variation of Water Quality Parameters in Mangrove Estuary of the Nyong River Using Multivariate Analysis (Cameroon Southern Atlantic Coast). *Open Journal of Marine Science*, 11, 103-128. doi: 10.4236/ojms.2021.113008.

[3] Ojok, W., Wasswa, J., and Ntambi, E. (2017). Assessment of Seasonal Variation in Water Quality in River Rwizi Using Multivariate Statistical Techniques, Mbarara Municipality, Uganda. *Journal of Water Resource and Protection*, 9, 83-97. doi: 10.4236/jwarp.2017.91007.

[4] LI, Y., XU, L., and LI, S. (2009). Water Quality Analysis of the Songhua River Basin Using Multivariate Techniques. Journal of Water Resource and Protection, 1(2), 2009, 110-121.

[5] Oketola, A., Adekolurejo, S., and Osibanjo, O. (2013). Water Quality Assessment of River Ogun Using Multivariate Statistical Techniques. Journal of Environmental Protection, 4(5), 466-479.

[6] Salah, E.A.M., Turki, A.M., Othman, E.M.A. (2006). Assessment of water quality of Euphrates River using cluster analysis. *Journal of Environmental Protection*, 1021, 3: 1629–1633.

[7] Shrestha, S. & Kazama, F. (2007). Assessment of surface water quality using multivariate statistical techniques: a case study of the Fujiriver basin. *Japan Environmental Modelling & Software*, 22:464-75.

[8] People committee of Soc Trang Province. (2019). Environmental status report.

[9] People committee of Bac Lieu Province. (2019). Environmental status report.

[10] American Public Health Association. (1998). Standard Methods for the Examination of Water and Wastewater, 20th edition, Washington DC, USA.

[11] Feher, I.C., Zaharie, M & Oprean, I. (2016). Spatial and seasonal variation of organic pollutants in surface water using multivariate statistical techniques. *Water Science & Technology* 74, 1726-1735.

[12] Chounlamany, V., Tanchuling, M.A., and Inoue, T. (2017). Spatial and temporal variation of water quality of a segment of Marikina River using multivariate statistical methods. *Water Science and Technology*, 66(6), 1510-1522.

[13] Ministry of Environment and Natural Resources (MONRE). (2015). QCVN 08-MT: 2015/BTNMT National technical regulation on surface water quality.

[14] Boyd, C.E. (1998). Water quality for pond Aquaculture. Department of Fisheries and Allied Aquacultures. *Auburn University*, Alabama 36849 USA, 37 pp.

[15] Ongley, E.D. (2009). Chapter 12: Water Quality of the Lower Mekong River. In: Campbell, I.C. (ed.): The Mekong: Biophysical Environment of an International River Basin. Academic Press, 4951 Connaught Ave., Montreal, QC, Canada H4V 1X4: 297-320. ISBN 978-0-12-374026-7.

[16] Galal-Gorchev, H., Ozolins, G., Bonnefoy, X. (1993). Revision of the WHO guidelines for drinking water quality. Annalidell'IstitutoSuperiore di Sanità, 29, 335-45.

[17] Kazi, T.G., Arain, M.B., Jamali, M.K., Jalbani, N., Afridi, H.I., Sarfraz, R.A., Shah, A.Q. (2009). Assessment of water quality of polluted reservoir using multivariate statistical techniques: A case study. *Ecotoxicology and Environmental Safety*, 72(20), 301-9.

[18] Zeinalzadeh, K., and Rezaei, E. (2017). Determining spatial and temporal changes of surface water quali-ty using principal component analysis. *Journal of Hydrology: Regional Studies*, 13, 1-10.

[19] Barakat, A., Baghdadi, M.E., Rais, J., Aghezzaf, B., Slassi, M. (2016). Assessment of spatial and seasonal water quality variation of Oum Er Rbia River (Morocco) using multivariate statistical techniques. *International Soil and Water Conservation Research,* 4(4), 284-292.

[20] Bolstad, P.V., Swank, W.T. (1997). Cumulative impacts of land-use on water quality in a southern Appalachian watershed. *Journal of the American Water Resources Association,* 33(3), 519-33.

[21] UNICEF Handbook on Water Quality. (2008). United Nations Children's Fund (UNICEF), New York.