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Assessment of Surface Water Quality Duyen Hai District, Tra Vinh Province, Vietnam

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Abstract

The study was carried out to assess surface water quality in Duyen Hai district, Tra Vinh province at 7 monitoring locations from NM1 to NM7 with the parameters studied inclue including pH, total suspended solids (TSS), dissolved oxygen (DO), biological oxygen demand (BOD), chemical oxygen demand (COD), ammonium ($N\text{-}NH_4^+$), nitrate ($N\text{-}NO_3^-$), phosphate ($P\text{-}PO_4^{3-}$), iron (Fe) and coliform to assess surface water quality in the years2020 and 2021. Surface water quality is assessed through comparison with the national technical regulation on surface water quality column A1 (QCVN 08-MT:2015/BTNMT). The study has applied statistical methods including cluster analysis and principal component analysis to group monitoring locations with similarity in the concentrations of parameters and determine the influencing parameters on surface water quality. The study results showed that the water quality in the study area appeared polluted in both years. Compared with column A1, all water quality parameters exceeded the allowable limits of QCVN 08-MT:2015/BTNMT (except pH parameter).Cluster analysis (CA) analysis has grouped from 7 monitoring sites into 3 monitoring groups, reducing 54% of monitoring costs for future monitoring programs. The results of the principal component analysis (PCA) analysis in the years 2020 and 2021 showed that there were 81.3% and 93.3% of surface water quality changes explained by three PCs and four PCs, respectively. All parameters used in the study should be further monitored in the upcoming monitoring program. Causes of pollution in the study area could originate from natural factors, acid sulfate soil, decomposition of plant residues in water, waste from agricultural and livestock production, farming, aquaculture and saltwater intrusion.

1. Introduction

Surface water is an extremely important resource, contributing greatly to human production and daily activities. In the Mekong Delta region, due to the process of urbanization, population growth and economic development activities, there is significant polluting of surface water and this has the potential to lead to water scarcity in the Mekong Delta in the near future [1]. In particular, the flow

of the Mekong River is being affected by hydroelectric dams and other uses from countries in the Mekong River Basin leading to significant challenges in terms of water quality as well as water discharge from the Mekong Delta in the future [2]. In particular, along with the process of climate change and saltwater intrusion, the provinces bordering the sea will face many challenges and a high risk of water scarcity. Tra Vinh is a coastal province in the Mekong Delta region, with a dense system of rivers and typical sand dunes in the locality, so the terrain of Tra Vinh province is complicatedly divided, leading to different hydrological regimes differences between some places in the province [3]. Water supply for production and daily life is mainly based on water from Hau and Co Chien rivers and groundwater. More than 90% of natural land is saline, with a depth of about 30km [4]. Saltwater intrusion is becoming more and more serious, accompanied by prolonged drought, the dry season is longer than the rainy season, and the amount of water flowing from the Mekong River to Tra Vinh has decreased sharply, causing great impacts on Tra Vinh province, especially the districts along the coast, notably Duyen Hai town [3]. This study aims to assess surface water quality in coastal areas, namely Duyen Hai town, Tra Vinh province and the results could be used as a scientific basis to support future monitoring surface water quality

2. Materials & Methodology

2.1. Study area

The study on surface water quality monitoring at 7 locations (symbols from NM1 to NM7) of canals and rivers with the same basin in Duyen Hai town, Tra Vinh province. The sampling locations for surface water quality monitoring are described and summarized in Table 1. Surface water quality monitoring data are provided by Duyen Hai District Department of Natural Resources and Environment in 2020 and 2021. Quality Surface water is assessed through 11 monitoring criteria including pH, total suspended solids (TSS), dissolved oxygen (DO), biological oxygen demand (BOD), chemical oxygen demand (COD), ammonium ($N\text{-}NH_4^+$), nitrate ($N\text{-}NO_3^-$), phosphate ($P\text{-}PO_4^{3-}$), iron (Fe) and coliform. All surface water quality monitoring samples in the study area were collected, preserved and analyzed according to standard methods [5] as shown in Table 2

Table 1. Monitoring location of surface water quality in Duyen Hai

Code	Brief information	Coordinates (VN2000)	
		X	Y
NM1	Dan Thanh - Chi Chi channel (Dan Thanh commune)	611076	1060615
NM2	Con Tau Bridge (Dan Thanh - Truong Long Hoa)	614205	1063431
NM3	Kenh Xang Bridge (Long Toan - Dan Thanh)	609588	1063215
NM4	Giang River section of Hiep Thanh market (Hiep Thanh commune)	614489	1078397
NM5	Cong Long Huu (Ward 2)	610491	1070975
NM6	Long Toan River, the embankment of Duyen Hai market	608640	1065249
NM7	Ba Dong River (Truong Long Hoa commune)	616057	1070085

2.2. Data analysis

The study has used Microsoft Excel software to synthesize, process and analyze the collected monitoring data. The analysed results results of each monitoring indicator will be compared with the allowable limit of the National Technical Regulation on surface water quality (QCVN 08-MT:2015/BTNMT) [6]. Multivariate statistical method is also applied to the study, namely cluster

analysis (CA) and principal component analysis (PCA) for the 7 monitoring locations through the value of 11 quality evaluation parameters of surface water in the two years 2020 and 2021. Cluster analysis (CA) is a method of grouping objects into clusters based on the similarities and differences of the analyzed objects, thereby reducing the number of points in analysis and service. for the comparison of water quality indicators in space or time [7]. The study applied CA analysis to group and compare locations with similar water quality. For PCA analysis, this method is often used to extract important information from the original data set. The eigenvalue in PCA is an important value when looking at results, the coefficient represents how much or how little it contributes to explaining the variability of variables [8]. The absolute value of the important correlation coefficients (loading) shows the correlation between the main components and water quality indicators, the closer the loading coefficient is to 1, the higher the degree of tightness (>0.75 is a strong correlation; 0.5 – 0.75 is a moderate correlation; 0.3 – 0.5 is a weak correlation) [9]. This study uses PCA to identify the main pollutant indicators, forecast the fluctuation and pollution of water quality in the study area. CA and PCA analysis was performed on Primer 5 Windows software (PRIMER-E Ltd, Plymouth, UK).

3.0 Results and Discussion

3.1. Surface water quality in Duyen Hai

The evolution of pH parameters in the study area is shown in Figure 1a, showing that the pH value in 2020 ranges from 7.01 to 7.53 (average is 7.23) and in 2021 it is 6.12 – 7.12 (average pH is 6.75). The pH value in Bac Lieu ranges from 7.12 to 8.38 [10], in Can Tho city it is 7 to 7.8 [11] and at the mouth of Hau river in Soc Trang province is 7 – 7.8 [11-12]. This shows that all 7 water quality monitoring locations in 2020 and 2021 have similar pH values to other basins and are within the allowable threshold (6.0 – 8.5) according to column A1 QCVN 08-MT:2015/BTNMT [6]. Although the pH values are within the allowable range, the pH value in 2021 tends to decrease lower than the same period last year. Although the study area is adjacent to the sea, mixing between river water and sea water can occur at locations near the river mouth, but the pH in the study area ranges from mildly acidic to neutral. The cause of low pH in water can come from soil improvement, alkaline soil properties in the area or decomposition of plants in the water [13-14].

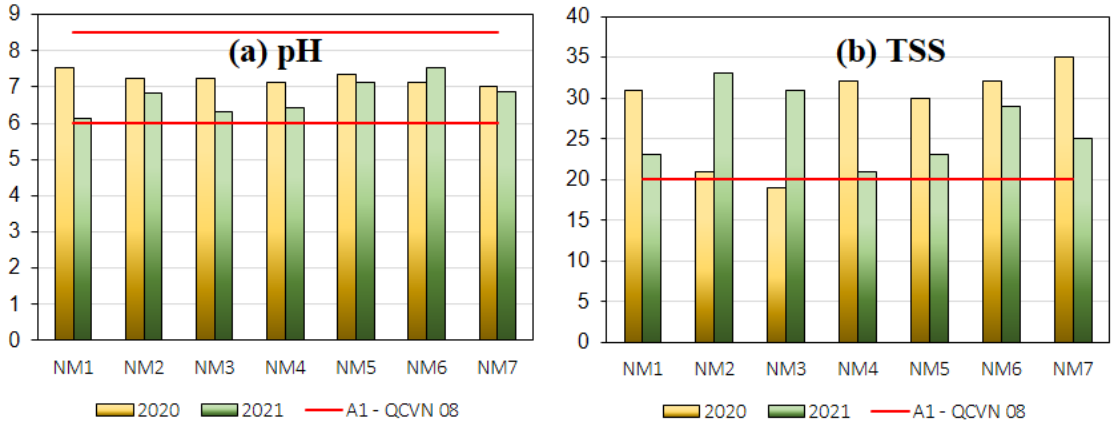

Figure 1. Evolution of (a) pH and (b) TSS in the study area

TSS parameters in the study area ranged from 19 to 35 mg/L (average 28.57 mg/L) in 2020 and ranged from 21 to 33 (average 26.43 mg/L) in 2021 (Figure 1b). There is an inverse correlation between monitoring locations for TSS content over time, locations with high TSS content in 2020 will decrease in 2021 and vice versa. TSS concentrations in other areas such as Hau river basin

ranged from 41.2 33.7 to 89.57±31.31 mg/L [15], canals of Soc province The moon ranges from 16-176 mg/L [12]. This result shows that TSS concentration in the study area tends to be lower than in other areas. At the same time, compared with Tra Vinh province in the period 2005 - 2009 when TSS fluctuated on average from 47.05 to 69.98 mg/L [3], TSS content here also tends to decrease gradually. by the time. According to [11], the downstream areas of the Mekong River often has a very large TSS content in the water and are mainly alluvial, specifically TSS has an average value of 240.6±25.9 mg/L at tributary collection points and 230.0±56.1 mg/L at estuary collection points. However, this is not consistent with the case study in Duyen Hai town, Tra Vinh province. The difference in TSS could be because of the difference in water flow and velocities in various water bodies. According to a study by Ly and Giao [16], TSS in the downstream area is usually lower than that in the upstream due to the flow rate and the amount of silt in the water column. Although there is a tendency to decrease lower than before, compared to QCVN 08-MT:2015/BTNMT column A1 [6] only position NM3 in 2020 is within the allowable threshold (20mg/L), the remaining positions during the study period all exceeded the limit. High TSS will increase water treatment costs and may affect biological life because it is a carrier of pathogens, bacteria, etc., spreading throughout the water body [11].

The results of DO parameter in Figure 2a show that the amplitude of fluctuation of DO parameter in the study area is not large and there is little difference. DO concentrations in 2020 ranged from 4.66 to 4.88 mg/L with an average of 4.61 (lowest at NM4 and highest at NM5) and ranged from 4.55 to 5.03 mg/L, an average of 4.74 mg/L (highest at NM6 and lowest at NM3). There is a slight increase in DO concentration in 2021 compared to the same period last year, but compared to the DO concentration in the period 2005 - 2009 in Tra Vinh (5.17 - 5.32 mg/L) at present is lower [3]. Besides, the monitoring positions of surface water quality for 2 years in the study area all have DO below the permissible threshold of the National Regulation on surface water quality for domestic water supply and aquatic life conservation purposes (column A1, QCVN 08-MT:2015/BTNMT). DO concentration in Soc Trang canals ranged from 1.7 to 6.17 mg/L [12], in the upstream water body of An Giang province in the period 2009 - 2016 it was 4 0.0 to 5.2 mg/L [16] shows the difference in values and fluctuations of other water bodies compared to the study area. DO concentrations below 5 mg/L in the waters of Hau Rivers would not be suitable for aquatic life in these areas [11]. Therefore, only the DO concentration at position NM6 (5.03 mg/L) is suitable for this permissible threshold.

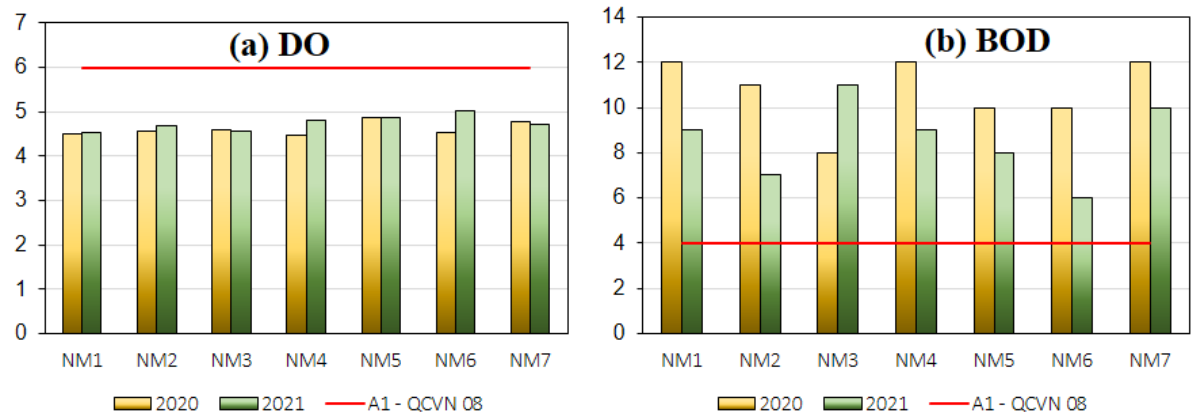

Figure 2. Evolution of (a) DO and (b) BOD in the study area

The results of Figure 2b show that the BOD evolution in the study area ranges from 8 (NM3) to 12 mg/L (NM7) in 2020, 6 (NM6) to 11 mg/L (NM3) in 2021 and average values were 10.71 mg/L, 8.57 mg/L, respectively. The BOD content in the study area tends to decrease over time, however, the NM3 position has increased in value compared to the same period last year (reaching the smallest

value in 2020 but reaching the maximum value in 2021). . Although there is a tendency to decrease, the BOD content at all locations exceeds the allowable limit according to column A1 QCVN 08-MT:2015/BTNMT from 1.5 to 4 times. However, compared with other areas such as Bac Lieu (13.8 - 410 mg/L), Soc Trang (2.2 to 22.4 mg/L) the BOD content in the study area fluctuates. smaller ([12]. According to Mekong River Commission [11], high TSS and BOD is a common problem of water bodies in the Mekong Delta. Causes may stem from agricultural production activities, domestic waste, and landfills [17]. In addition, the use of water containing a large amount of BOD as domestic water supply is very easy to create hazardous compounds when reacting with chemicals during the sterilization phase, leading to health effects during use [18].

The results in Figure 3a also show that, similar to the BOD parameter, the COD content in the study area tends to decrease over time. COD values in Duyen Hai town ranged from 18 (NM3) to 29 mg/L (NM7) with an average of 24 mg/L in 2020 and ranged from 11 (NM6) to 23 mg/L (NM7), an average of 17.43 mg/L in 2021. COD content in Bac Lieu ranges from 21.3 to 602.6 mg/L [10], in Soc Trang City ranges from 4.5 – 44.9 mg/L. Both of the above studies have a much larger fluctuation amplitude and COD content than the study area. Although the COD concentration in Duyen Hai town tends to decrease, compared to the allowable limit (20mg/L) of column A1 of QCVN 08-MT:2015/BTNMT [6], all monitored locations show COD results exceeded the threshold from 1.1 to 2.9 times. Parameters BOD and COD are used to assess the level of organic pollution of water sources and play an important role in the selection of wastewater treatment technology [19]. Wastewater from industrial and service production activities and wastewater from urban areas can be the cause of high COD content in water [19]. TSS parameter results in the study area may be the cause of the similarity between BOD and COD in terms of content, fluctuation amplitude and decreasing trend over time.

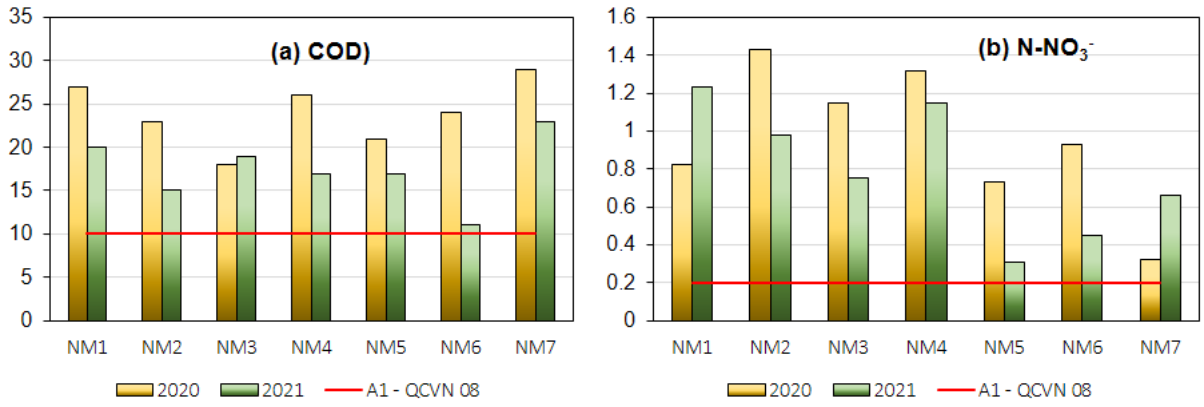

Figure 3. Evolution of (a) COD and (b) $N\text{-}NO_3^-$ parameters in the study area

Nitrate ($N\text{-}NO_3^-$) content in the study area (Figure 3b) ranges from 0.32 to 1.43 mg/L (in 2020) and 0.31 to 1.23 mg/L (in 2021). In 2021, the concentration of $N\text{-}NO_3^-$ tends to decrease slightly compared to the same period last year (the average $N\text{-}NO_3^-$ in 2020, 2021 is 0.96 mg/L and 0.79 mg/L, respectively). At all monitoring locations of surface water quality, the concentration of $N\text{-}NO_3^-$ exceeded the permissible limit (2mg/L) from 1.6 to 7.15 times compared with QCVN 08-MT: 2015/BTNMT, column A1 [6]. Previous research by [12,16], $N\text{-}NO_3^-$ concentrations in Soc Trang, My Thanh river, Hau river mouths and An Giang canals ranged from 0.05 to 0.14 mg/L, 0.02 – 0.97 mg/L, 0.31 ± 0.3 to 0.58 ± 0.64 mg/L, respectively. This shows that the concentration of $N\text{-}NO_3^-$ in the study area is much higher than in other areas of the Mekong Delta. Besides, the high $N\text{-}NO_3^-$ in water is likely to cause eutrophication, which affects aquatic life because according to [20], $N\text{-}NO_3^-$ in the range of 0.2 - 10 mg/L has eutrophication potential.

Figure 4a shows the results of P-PO_4^{3-} concentration in the study area ranging from 0.038 (NM5) to 0.26 mg/L (NM3), with an average of 0.10 mg/L in 2020 and 0.023 (NM7) – 0.088 mg/L (NM3), average 0.06 mg/L in 2021. The concentration of P-PO_4^{3-} in Duyen Hai town area tends to decrease, however, at NM3 location, it is still recorded highest P-PO_4^{3-} value during the study period. Compared with QCVN 08-MT:2015/BTNMT column A1 [6], in 2020 there are two locations (NM3 and NM4) with values exceeding the allowable limit (O.1mg/L), in 2021 all monitoring positions give results within the prescribed limits. determined. At the same time, compared with the study [10], the concentration of P-PO_4^{3-} in Bac Lieu (0.01 - 0.32 mg/L) has a higher value than the study area.

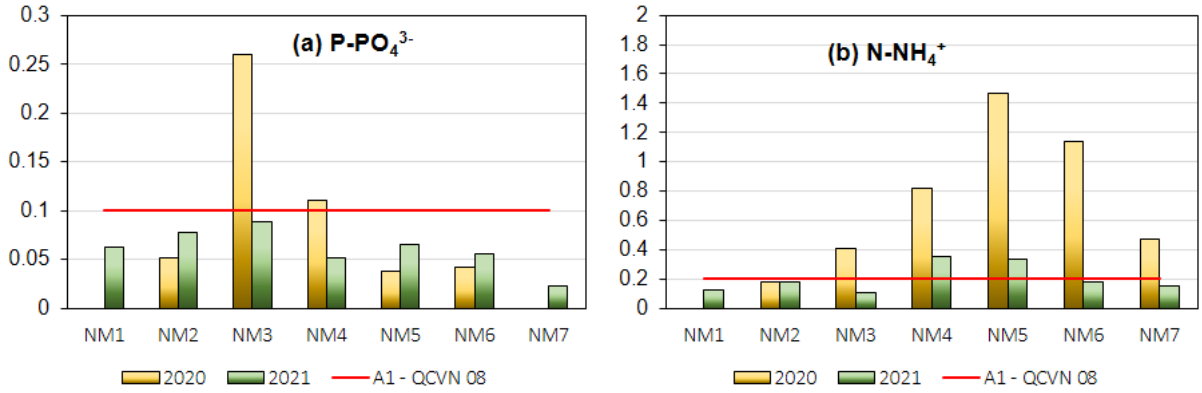

Figure 4. Evolution of parameters (a) P-PO_4^{3-} and (b) N-NH_4^+ in the study area

The research results in Figure 4b show that the concentration of N-NH_4^+ in Duyen Hai town in 2020 is very high, with a large range ranging from 0.18 to 0.82 mg/L. In which, there is position NM1 that does not detect the content of N-NH_4^+ and position NM4 has high value. In addition to positions NM1 and NM2, the remaining positions in 2020 all exceed the allowable threshold (0.3mg/L) of column A1 QCVN 08-MT:2015/BTNMT [6]. Research [20] indicates that water quality will be very dirty if the concentration of N-NH_4^+ in water is higher than 5 mg/L. From there, it can be seen that at NM4 location, the water quality is very dirty. The value and fluctuation amplitude of N-NH_4^+ in 2021 has improved markedly, the fluctuation amplitude is reduced to from 0.11 (NM3) to 0.35 mg/L (NM4) and the average is 0 ,20 mg/L. Compared with QCVN 08-MT:2015/BTMNT column A1 [6], only two positions NM4 and NM5 exceeded the allowable limit. According to [21], N-NH_4^+ with high content comes from domestic and production wastewater from households around the study area, which is discharged directly into the water source. In addition, high N-NH_4^+ reflects the leaching of excess fertilizer during agricultural cultivation [22]. The parameters N-NH_4^+, N-NO_3^- with high content in the study area easily cause eutrophication and eutrophication in the aquatic environment.

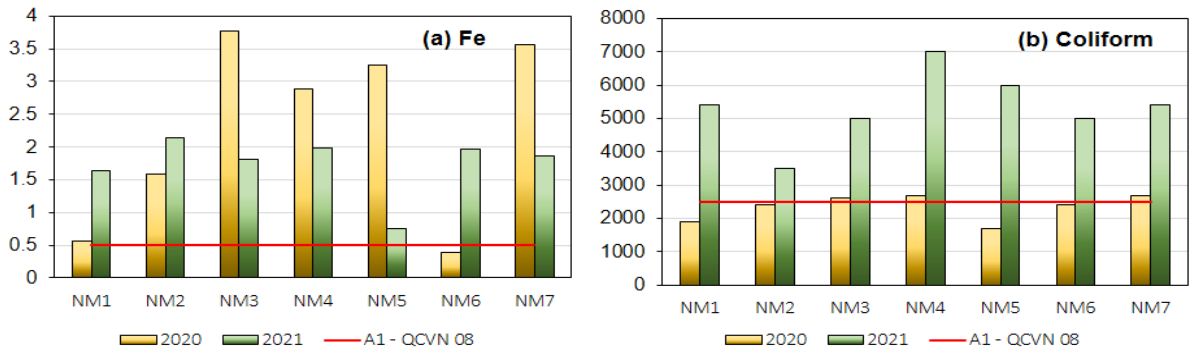

Figure 5. Evolution of parameters (a) Fe and (b) coliform in the study area

The iron (Fe) content in surface water in the study area ranges from 0.39 (NM6) to 3.78 mg/L (NM3), reaching an average of 2.29 mg/L in 2020 and ranged from 0.75 (NM5) to 2.15 mg/L (NM2), with an average of 1.74 mg/L in 2021 (Figure 5a). Fe content in water in the study area tends to decrease compared to the same period last year (2020 is higher than 2021), however compared to QCVN 08-MT:2015/BTNMT column A1 [6] in 2020 has 1 position (NM6) is within the allowable threshold (0.5mg/L), the remaining positions in both years are above the limit of the norm. Research by [12], recorded in canals of Soc Trang province, Fe content ranges from 0.3 to 3.75 mg/L, showing the similarity of Fe pollution. in water resources in the Mekong Delta. When water is contaminated with Fe, the water will be discolored, with many yellow or black brown residues and a fishy smell [23]. Iron pollution can be caused by the natural conditions of the Mekong Delta, which is alkaline soil, together with alum washing activities, agricultural and industrial production activities [12].

The results of Figure 6b show that coliforms in surface water in Duyen Hai town ranged from 1700 (NM5) to 2700 MPN/100mL (NM4, NM7) in 2020 and 3500 (NM2) – 7000 MPN/100mL (NM4) in in 2021. The average coliform in two years (2020 and 2021) in the study area was 2342.86 MPN/100mL and 5328.57 MPN/100mL, respectively. Contrary to the decreasing trend over time of other observed parameters, the coliform content increased a lot compared to the same period last year. Specifically, compared with the allowable threshold (2500MPN/100mL) for column A1 QCVN 08-MT:2015/BTNMT [6], in 2020 there are 3 positions exceeding the allowable limit (NM3, NM4 and NM7) and these positions exceed the threshold with not high values. Meanwhile, at all positions in 2021, they exceed the allowable limit from 1.4 to 2.8 times. Thereby, it shows that the current research area is receiving a large amount of human excreta (domestic waste) and animal (in livestock activities). Water sources contain many coliforms that cause diseases related to the digestive system and are susceptible to infectious diseases [24].

3.2. Water quality clustering

The results of CA cluster analysis in Figure 13 show that, from the 7 initial surface water quality monitoring sites, they were classified into 3 groups. Group N1 includes 3 monitoring locations, NM4, NM3 and NM7, respectively, 3 monitoring locations have similar values of monitoring parameters, so a representative monitoring location can be selected. In addition to the pH parameter, the remaining monitoring parameters of group N1 all exceeded the allowable limit of column A1, QCVN 08-MT:2015/BTNMT. Groups N2 and N3 both have 2 positions in each group, NM2 and NM5 belong to group N2, NM1 and NM6 belong to group N3. Depending on the characteristics of the study area, it is necessary to select an appropriate representative monitoring location. Groups N2 and N3 have similarities in pollutant parameters, pH and $P\text{-}PO_4^{3-}$ are within the allowable limits,

the remaining parameters of both groups are above the allowable threshold. There are no sites that need to be independently monitored in the future monitoring program. Through CA analysis results, from 7 initial monitoring locations reduced to 3 important monitoring locations and helped reduce 54% of the implementation cost for the monitoring program.

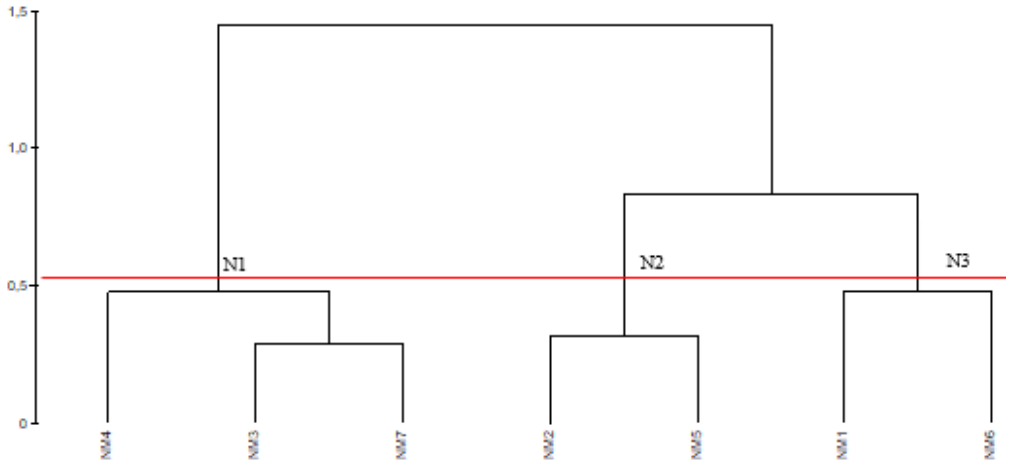

Figure 6. Clustering surface water quality in the study area

Table 2. Characteristics of surface water quality in 3 groups in the study area

Parameters	N1	N2	N3	QCVN 08, A1
pH	6,83	7,13	7,08	6-8,5
TSS	27,17	26,75	28,75	20
BOD	10,33	9,00	9,25	4
COD	22,00	19,00	20,50	10
DO	4,66	4,75	4,64	6
Fe	2,65	1,93	1,14	0,5
N-NH_4^+	1,61	0,54	0,36	0,3
N-NO_3^-	0,89	0,86	0,86	0,2
P-PO_4^{3-}	0,09	0,06	0,04	0,1
Coliform	4233,33	3400,00	3675,00	2500,0

3.3. Key parameters influencing surface water quality in the study area

The PCA analysis results of 2020 (Table 3) show that there are 3 main factors that explain 81.3% of the variation in surface water quality in the study area. The main factors are PC1, PC2 and PC3 respectively, with eigenvalue coefficients of 3.84, 2.98 and 2.16, respectively. PC1 contributed 34.6 PC2 contributed 27.1 and PC3 contributed 19.6% to the volatility of the metric. At PC1, the observed parameters were only explained at a weakly correlated level, including TSS (-0.467), BOD (-0.443), COD (-0.492), N-NO_3^- (0.312) and P-PO_4^{3-} (0.418). The causes affecting the fluctuations in the study area come from natural factors, suspended matter in the water, rainwater spread and agricultural and aquaculture production activities. The PC2 source recorded pH (0.434), N-NH_4^+ (-0.333) as a weak correlation and coliform (-0.544) as a medium correlation. The arising sources can originate from factors of natural conditions, human activities, decomposition of plant residues, saltwater intrusion and excretory waste. In the PC3 source, DO (-0.618) was explained at medium correlation, N-NO_3^- (0.470) and Fe (-0.488) were explained at weak correlation. PC3 is affected by

weather factors, natural conditions, decomposition of dead plants in the water and alum washing activities and agricultural production.

Table 3. Key parameters affecting surface water quality in 2020

Parameters	PC1	PC2	PC3	PC4
pH	0,121	**0,434**	0,179	0,116
TSS	**-0,467**	0,004	-0,064	0,186
DO	-0,049	0,166	**-0,618**	0,221
BOD	**-0,443**	-0,005	0,217	0,169
COD	**-0,492**	-0,064	0,117	-0,109
NH_4^+	-0,083	**-0,333**	0,229	0,727
NO_3^-	**0,312**	-0,124	**0,470**	0,213
PO_4^{3-}	**0,418**	-0,296	-0,039	0,008
Fe	0,113	-0,275	**-0,488**	0,363
Coliform	-0,012	**-0,544**	0,027	-0,286
Eigenvalue	3,84	2,98	2,16	0,95
%Variation	34,6	27,1	19,6	8,7
Cum.%Variation	34,6	61,7	81,3	90,0

The results of PCA analysis in 2021 show that there are 4 main factors (one more factor than in 2020) explaining 93.3% of the variation in surface water quality in Duyen Hai town. The main factors include PC1 to PC4 with eigenvalue coefficients of 4.61, 3.09, 1.37 and 1.19, respectively. In which, PC1 contributed 41.9%, PC2 contributed 28.1%, PC3 and PC4 respectively 12.4% and 10.9% to the fluctuation of surface water quality monitoring data. The factor PC1 explains for 6 parameters with weak correlation, including pH (0.434), DO (0.434), BOD (-0.361), COD (-0.319), N-NO_3^- (-0.345). The source may come from natural factors, runoff, decomposition of suspended matter in water, production activities and saline intrusion. At PC2, parameters TSS (0.542), coliform (-0.523) were explained in medium correlation and N-NH_4^+ (-0.342), Fe (0.300) were in weak correlation. The cause of the change at the source of PC2 may be from natural factors, suspended matter in water, alum washing activities and agricultural and livestock production. PC3 explains at a weak correlation for the COD parameter (0.352) and the average correlation for the parameters N-NO_3^- (-0.503), Fe (-0.529). Natural factors, the decomposition of plant residues, and agricultural practices may be the causes of the change. The PC4 source has N-NH_4^+ (0.343), Fe (-0.388) which is explained at a weak correlation and P-PO_4^{3-} (0.745) parameter at an average correlation. Source of PC4 is affected by natural factors, waste from agricultural production activities.

Table 4. Key parameters affecting surface water quality in 2021

Parameters	PC1	PC2	PC3	PC4
pH	**0,434**	0,117	0,083	-0,247
TSS	-0,003	**0,542**	0,139	-0,013
DO	**0,434**	-0,063	-0,216	-0,114
BOD	**-0,361**	-0,210	0,299	-0,060

COD	**-0,319**	-0,268	**0,352**	-0,284
N-NH_4^+	0,230	**-0,342**	-0,288	**0,343**
N-NO_3^-	**-0,345**	0,000	**-0,503**	0,099
P-PO_4^{3-}	-0,083	0,299	0,105	**0,745**
Fe	-0,161	**0,300**	**-0,529**	**-0,388**
Coliform	0,017	**-0,523**	-0,189	0,094
Eigenvalue	4,61	3,09	1,37	1,19
%Variation	41,9	28,1	12,4	10,9
Cum.%Variation	41,9	70,0	82,5	93,3

4. Conclusion

Surface water source in Duyen Hai town is currently polluted during the study period. The monitoring parameters of surface water quality appear polluted in both 2020 and 2021 when they all exceed the permissible limits compared to QCVN 08-MT:2015/BTNMT, column A1. However, the concentration of surface water quality monitoring parameters in the current study area tends to be low in 2021 compared to 2020. Some monitoring sites appeared abnormally high values such as the content of P-PO_4^{3-} (0.26 mg/L) and Fe (3.78 mg/L) at NM3, N-NH_4^+ (0.82 mg/L) and coliform (7000 MPN/100mL) at NM4. CA analysis grouped 7 monitoring sites into 3 clusters based on monitoring parameters, thereby reducing 54% of implementation costs for future monitoring programs. The PCA analysis in 2020 has 3 main factors explaining 81.3% and in 2021 with 4 factors explaining 93.3% explaining the variation of water quality in the study area. All monitoring parameters in the study need to be further monitored in the future monitoring program. Surface water quality in the study area may be affected by natural factors, runoff, decomposition of plant residues in the water, wastewater from agricultural, livestock, aquaculture, and saltwater intrusion.

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