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Seasonal and Tidal Influence on Surface Water Quality – A Case Study in the Hau River Segment, Vietnamese Mekong Delta Province

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ABSTRACT

The study aimed to evaluate the influence of seasons and tides on surface water quality of Hau River in Hau Giang province, Vietnam. The water quality data were collected at six locations at low tide and high tide. The monitoring parameters included pH, dissolved oxygen (DO), biochemical oxygen demand (BOD), chemical oxygen demand (COD), total suspended solids (TSS), ammonium (NH_4^+-N), nitrate (NO_3^--N), orthophosphate (PO_4^{3-}-P), total phosphorus (TP), total nitrogen (TN), iron (Fe) and Coliform. One-way analysis of variance (One-way ANOVA), cluster analysis (CA) and discriminant analysis (DA) were applied to determine the influence of tides and seasons on water quality. The surface water quality was compared with the national technical regulation on surface water quality in column A1 (QCVN 08-MT:2015/BTNMT). The results showed that surface water in the study area had organic pollution and high eutrophication potential. The BOD, COD, TN, TP, Fe and coliform parameters in low tide tended to be higher than those in high tide. Five parameters, including TSS, TP, TN, PO_4^{3-}-P and coliform had a significant difference between the wet season and the dry season by DA analysis. Cluster analysis classified the water quality into three clusters, mainly by the BOD, COD, TSS, PO_4^{3-}-P and Fe parameters. The study provides important information on the water quality of the Hau River in the Hau Giang province for water uses and monitoring.

Keywords: surface water quality, Hau Giang, season, discriminant analysis, tides.

INTRODUCTION

Hau Giang is a province in the Mekong Delta region with an interlaced system of rivers and canals with a total length of about 2,300 km. The density of rivers and canals in the province is quite large with the Hau riverside area in Chau Thanh district up to 2 km. Due to the geographical conditions of the region, the hydrological regime of the Hau Giang province is largely influenced by the tidal regime of the Hau River (East Sea tide) and Cai Lon River (West Sea tide). The Hau River is also one of the water sources that play an important role in the development of agro-forestry and aquaculture in the province. In the process of economic development and urbanization, the Hau River has to face many challenges, such as changes in flow and deterioration of water quality, because it is a direct recipient of waste from socio-economic activities associated with the Hau Giang province, especially the waste sources from the areas with dense population and intensive farming in agricultural production (Tuan et al., 2015; Nguyen Thi Kim Lien et al., 2016). Hydrological characteristics and tidal regime also have a significant impact on river water quality (Purnaini et al., 2018). According to Thai et al. (2014), the Hau River is strongly influenced by the tides of the East Sea with irregular semi-diurnal regime, the high tide lasts about 6 hours and the low tide lasts about 7 hours. The difference in discharge and flow rate between high tide and low tide leads to a difference in river water quality between the two tidal streams. During low tide, the discharge and flow rate in the river are poor, so the pollutant concentration increases and vice versa (Kamarudzaman et al., 2019, Cereja et al., 2022, Kar et al., 2022). In addition, the tidal regime also affects the movement of pollutants and the dispersion of pollutants from different discharge points (Kar et al., 2022). Fatema et al. (2015) suggested that tidal activity has changed the temperature, salinity, pH, dissolved oxygen, nitrogen and phosphate in the river water environment.

Tide is an important factor to consider when collecting surface water quality samples (Fortune and Mauraud, 2015). However, there is relatively little research on the role of tides and their effects on water quality. This study was conducted to find out the influence of tides and seasons on water quality of the Hau River, the Hau Giang province based on multivariate statistical tools including cluster analysis (CA) and discriminant analysis (DA). The study results provide useful scientific information for water uses and monitoring.

METHODOLOGY

Water sampling and analysis

Water samples were collected at six locations, including four locations on the Hau river – the section from Mai Dam to Cai Con dam (HR1, HR2, HR3 and HR4) and two locations from upstream of the Mai Dam river (HR5) and HR6) (Figure 1) with a frequency of 12 times/year.

Surface water quality parameters, including pH, dissolved oxygen (DO), biochemical oxygen demand (BOD), chemical oxygen demand (COD), total suspended solids (TSS), ammonium (NH_4^+-N), nitrate (NO_3^--N), orthophosphate (PO_4^{3-}-P), total phosphorus (TP), total nitrogen (TN), iron (Fe) and Coliform were used to assess the water quality and as input in multivariate statistical analysis. The water samples collected and preserved surface water samples comply with the current Vietnamese standards (TCVN 6663-1:2011; TCVN 6663-3:2008; TCVN 5994:1995; TCVN 6663-6:2008; TCVN 6663-3): 2008-ISO 5667-3:2003). The parameters of pH, temperature, DO, and turbidity were measured in the field, while the remaining parameters were analyzed in the laboratory by using standard methods (APHA, 2012). The criteria, units, analytical methods and allowable limits of surface water quality parameters are presented in Table 1.

Data analysis

The surface water quality data were averaged prior to statistical analysis. One-way analysis of variance (One-Way ANOVA) was used to compare the significant difference between mean values of water quality parameters between low and high tide, between dry and wet seasons (Ahrari et al., 2015). Cluster Analysis (CA) was used to

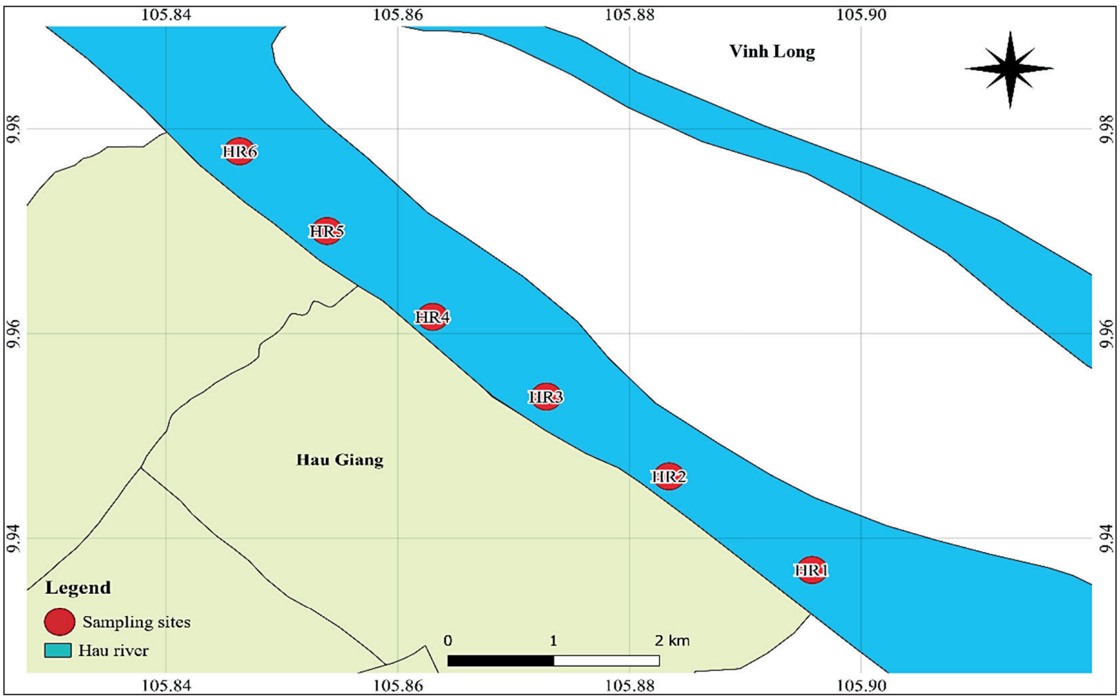

Figure 1. Sampling locations on the Hau river in the Hau Giang province

Table 1. Analytical methods of surface water quality parameters

Parameters	Meaning	Unit	Analytical methods	QCVN, A1
pH	pH	-	TCVN 6492:2011	6-8.5
DO	Dissolved oxygen	mg/l	TCVN 7325:2004	≥ 6
BOD	Biological oxygen demand	mg/l	TCVN 6001-1:2008	4
COD	Chemical oxygen demand	mg/l	TCVN 6491:1999	10
TSS	Total suspended solids	mg/l	TCVN 6625:2000	20
NH_4^+-N	Ammonium	mg/l	TCVN 6179:1996	0.3
Fe	Iron	mg/l	TCVN 6177:1996	0.5
NO_3^--N	Nitrate	mg/l	TCVN 6180:1996	2
PO_4^{3-}-P	Phosphate	mg/l	TCVN 6494-1:2011	0.1
TP	Total phosphorus	mg/l	TCVN 6202:2008	-
TN	Total nitrogen	mg/l	TCVN 6638:2000	-
Coliform	Coliform	MPN/100 ml	TCVN 6187-2:1996	2500

cluster water quality at the sampling sites according to the Ward method (Arora et al., 2015) using the Euclidean distance (Ngoc et al., 2017). CA analysis was performed using the license software Primer V5.2 for Windows (PRIMER-E Ltd, Plymouth, UK). Discriminant Analysis (DA) is a data analysis technique when the dependent variable is categorical and the independent variable is quantitative. DA analysis is only meaningful when the number of clusters and subjects in each cluster is known in advance (Liu et al., 2021). Therefore, DA analysis is often used to confirm the clusters identified by CA analysis. ANOVA and DA analyses were both processed using the IBM SPSS Statistics 20 for Windows statistical software (IBM Corp., Armonk, NY, USA).

RESULTS AND DISCUSSION

Tidal influence on surface water quality in the Hau River

The results of analysis of the influence of tides on surface water quality of the Hau River in the Hau Giang province are shown in Figure 2. The pH values at six sampling locations between the two tidal currents are relatively equal, ranging from 6.81±0.21 to 6.86±0.20 at low tide and 6.89±0.15 to 7.18±0.89 at high tide (Figure 2A). In general, the pH value is still within the allowable limit of the Vietnamese standard QCVN 08-MT:2015/BTNMT column A1 (6-8.5). Figure 2B shows that, in both tidal currents, the lowest TSS concentration at HR1 position reached 45.58±24.75 mg/L at low tide and 37.17±29.58 mg/L at high tide, meanwhile, the TSS concentration was highest at high tide recorded at position HR4 with values of 51.00±28.17 mg/L and 50.25±31.86 mg/L, respectively. TSS at all sampling points exceeded the allowable limit of QCVN 08-MT:2015/BTNMT column A1 (20mg/L) by 2.51-2.6 times. The average TSS concentration at low tide tended to be higher than that in high tide. This may be due to the influence of water transport activities (Viet & Vy, 2020).

The average dissolved oxygen concentration at low tide was lower than that at high tide (Figure 2C). The lowest DO concentration at high tide at position HR2 was 4.69±0.44 mg/L and the highest at HR1 was 4.79±0.42 mg/L. Meanwhile, at low tide, the DO concentration did not differ significantly between the sampling stations, ranging from 4.63±0.37 to 4.68±0.36 mg/L. The DO concentration measured at two times of low tide showed the presence of organic waste in the study area, leading to the rapid growth of microorganisms that consumed dissolved oxygen, thereby reducing DO in water (Kamarudzaman et al., 2019, Kar et al., 2022). The average biochemical oxygen demand in a year is not much different between the two tidal currents (Figure 2D). The highest BOD concentration at low tide was 8.50±2.88 mg/L at location HR6. At high tide, the highest BOD concentration reached 8.25±3.47 mg/L at HR2. Similarly, the highest COD concentrations during low tide and high tide at HR2 were 14.92±5.37 and 14.75±5.91 mg/L, respectively. The lowest COD concentration recorded at location HR3 was 13.83±5.64 mg/L at low tide and at location HR4 was 13.42±5.65 mg/L at high tide (Figure 2E). When compared with QCVN

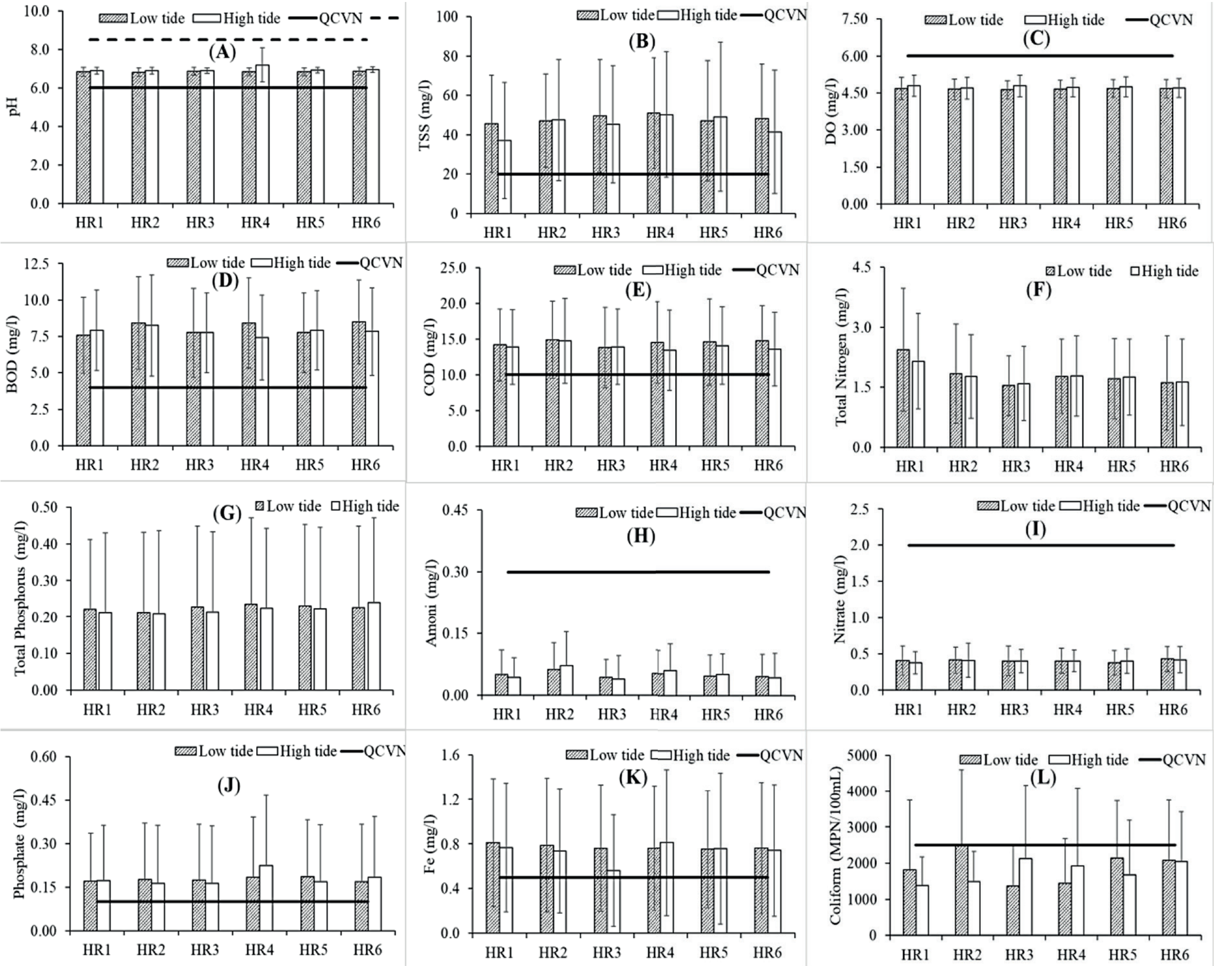

Figure 2. Changes in water quality of the Hau River affected by tides

08-MT:2015/BTNMT column A1, the BOD and COD concentrations at six sampling locations exceeded the allowable thresholds. This result is consistent with the previously discussed DO value and the study area has been contaminated with biodegradable organics by domestic activities, wastewater from industrial and agricultural activities along rivers (Fetter et al., 2017, Astari, 2019, Giao et al., 2021). In general, both BOD and COD parameters had lower concentrations at high tide than those at low tide, since the high tide increases the dissolved oxygen content and dilutes the organic matter concentration in the water (Mena-Rivera et al. 2017).

The TN concentration at six sampling locations did not differ much between the two times of high tide and low tide, in the range from 1.59±0.93 to 2.15±1.19 mg/L and 1.54±0.75 to 2.44±1.53 mg/L, respectively (Figure 2F). According to Palma et al. (2020), to limit the possibility of eutrophication of water sources, the concentration of TN should not exceed 1.5 mg/L. It can be seen that the concentration of TN in the study area has a high potential for eutrophication. Similarly, in Figure 2G, the TP concentration in the monitoring area fluctuates quite low between the two tidal currents, ranging from 0.21±0.22 to 0.24±0.23 mg/L. Amic et al. (2018) suggested that if the TP concentration exceeds the limit of 0.1 mg/L, eutrophication is likely to occur. It can be seen that at the sampling points on the Hau River, there is a high potential for eutrophication and at the time of low tide, it tended to be higher than that in high tide.

The concentrations of ammonium and nitrate in the Hau River are quite low and both meet the allowable limits of QCVN 08-MT:2015/BTNMT column A1 (0.3 mg/L and 2 mg/L) (Figures 2H and 2I). The highest ammonium concentration was recorded at location HR2 at 0.06±0.06 mg/L at low tide and 0.07±0.08 mg/L at high tide. Meanwhile, the HR3 positions all had the $N\text{-}NH_4^+$ values of 0.04±0.04 mg/L in both tidal currents. The nitrate content at six water quality monitoring points ranged from 0.38±0.16 to 0.43±0.17

mg/L in the two tidal currents. The highest concentration of N-NO_3^- with 0.43±0.17 mg/L at low tide and 0.42±0.18 mg/L at high tide were found at location HR6. The difference in the phosphate content between high tide and low tide is relatively low (Figure 2J). At low tide, the highest concentration of P-PO_4^{3-} was recorded at the HR5 position at 0.19±0.20 mg/L and the lowest at the HR6 position at 0.17±0.20 mg/L. The two locations HR2 and HR3 recorded the lowest P-PO_4^{3-} concentration at high tide, both at 0.16±0.20 mg/L and the highest at HR4 at 0.22±0.24 mg/L. All water quality monitoring stations had the phosphate content exceeding the standard of column A1 of QCVN 08-MT: 2015/BTNMT (0.1 mg/L). This result is also consistent with the study of Giao (2020) that the water source on the Hau River had a high level of nutrients and has the potential to cause eutrophication.

The Fe concentration during low tide was higher than that of high tide, ranging from 0.56±0.50 mg/L to 0.81±0.57 mg/L and Fe at all monitoring locations exceeded the allowable limit from 1.12 to 1.62 times when compared with QCVN 08-MT:2015/BTNMT column A1 (0.5 mg/L) (Figure 2K). Iron can be derived from wastewater from the pharmaceutical, leather and textile industries (Arefin et al., 2016). According to Wedyan et al. (2016), the higher the metal concentration in the water, the worse the surface water quality will be, affecting the water treatment capacity if river water is used as domestic water supply.

The mean coliform value had a rather large difference between high tide and low tide (Figure 2L). At position HR3, coliform at low tide was the lowest at 1372.50±1161.97 MPN/100 mL, while it was 2116.67±2045.70 MPN/100 mL at high tide. When compared with QCVN 08-MT:2015/BTNMT column A1 (2500 MPN/100 mL), only the HR2 position at low tide had coliform (2520.00±2076.54 MPN/100 mL) that exceeded the permissible limit. According to Aram et al. (2021), coliform in surface water is strongly influenced by physical factors and tidal conditions. In this study, the coliform concentration at low tide was higher than that at high tide. Safitri et al. (2021) also reported that the coliform at high tide and low tide varied from 100/100 mL to 2400/100 mL, respectively. The results of the research on the surface water quality of the Hau River in the Hau Giang province presented that the concentrations of BOD, COD, TN, TP, Fe and coliform in low tide tended to be higher than those in high tide. However, there is no statistically significant difference between sampling locations in both tidal currents. In addition, 5/12 water quality parameters at six sampling locations exceeded the allowable limit of QCVN 08-MT:2015/BTNMT column A1 including TSS, BOD, COD, PO_4^{3-}-P and Fe. From the above results, it is shown that surface water in the study area has been contaminated with organic matter and is at risk of eutrophication.

Seasonal influence on surface water quality in the Hau River

The results of seasonal water quality analysis of the Hau River in the Hau Giang province are shown in Figure 3. There are five water quality parameters with significant differences between the rainy season and the dry season at 5% including TSS, TP, TN, PO_4^{3-}-P and coliform. In general, most of the water quality monitoring parameters had higher concentrations in the rainy season. The pH value in the dry season was higher than that in the rainy season and the pH of the water samples are all below 7, indicating that the river water is acidic at this time (Figure 3A). However, the pH value at the sampling locations is still within the allowable limits of QCVN 08-MT:2015/BTNMT column A1 (6 – 8.5). Figure 3B showed that the TSS concentration in the rainy season increases partly because flood water flows from upstream carrying a large amount of silt along with erosion on both sides of the river. In addition, the increased river discharge along with the fast flow rate disturbed the bottom layer leading to an increased TSS value (Ojok et al., 2017, Giau et al., 2019). This result is consistent with many former studies reporting that the TSS values have seasonal fluctuations (Lien et al., 2016, Nghi, 2017; Giao et al., 2021). The higher BOD and COD values in the rainy season than those in the dry season may be due to the flood water from upstream and the rainwater runoff from agricultural activities that has dragged organic matter into the water source (Akaahan et al., 2016; Adegbite et al., 2018) (Figures 3D and 3E). The high concentration of organic matter created favorable conditions for the growth of microorganisms. This leads to a sharp decrease in the dissolved oxygen content in the water in the rainy season (Figure 3C). The concentrations of TN and TP were recorded in the wet season higher than those in the dry season, and the concentrations of these two parameters were high enough to cause potential eutrophication (Figures 3F and 3G). This significantly affects the

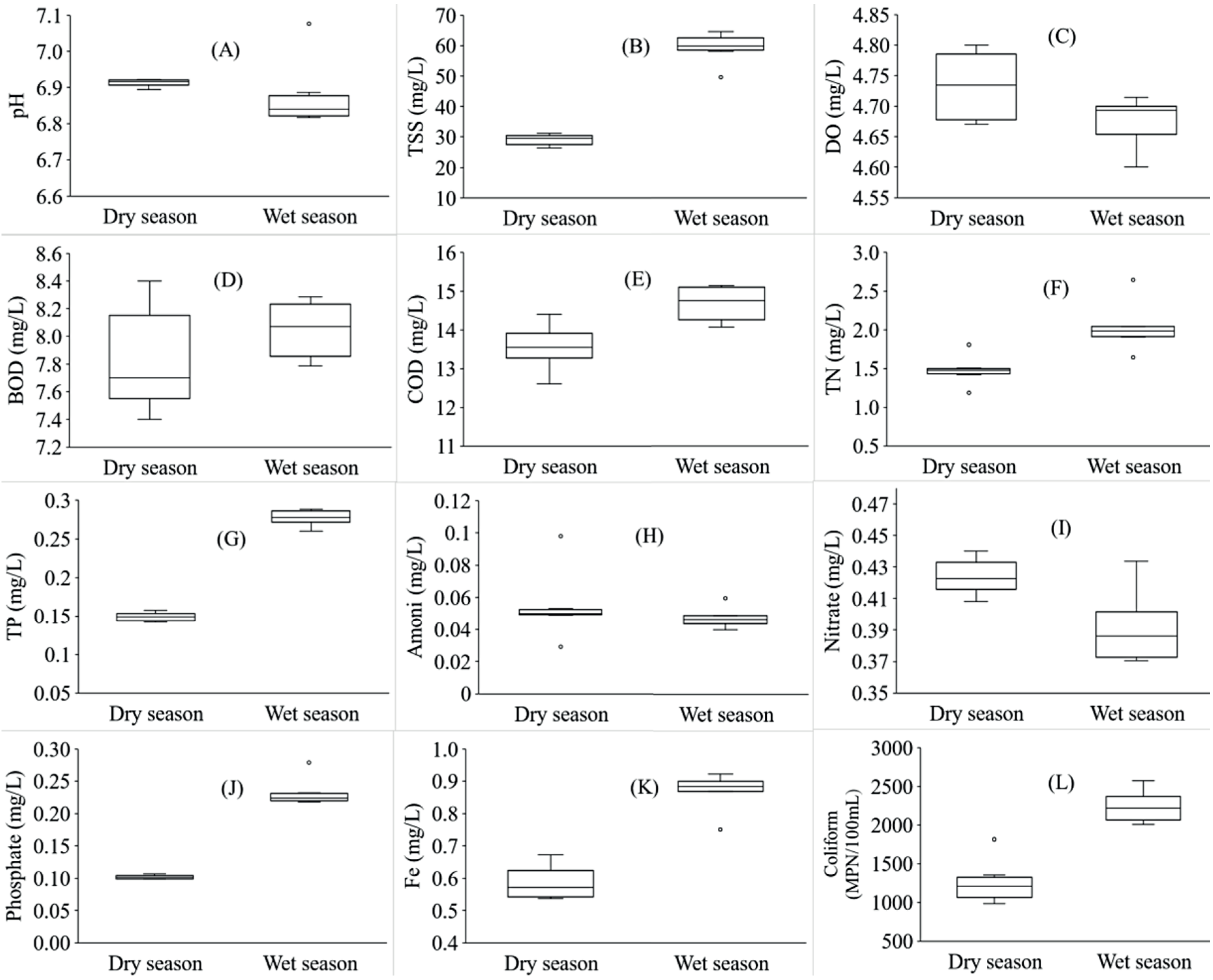

Figure 3. Seasonal variation of surface quality in the Hau River

growth and development of aquatic life in Hau river. It can be explained that the rainwater runoff from agricultural activities has contributed a large amount of TN and TP to river water (Deng et al., 2018). Similarly, the P-PO_4^{3-} value was higher in the rainy season (Figure 3J). Many previous studies also showed seasonal variation in phosphate values (Woldeab et al., 2018, Truc et al., 2019); however, the P-PO_4^{3-} concentrations in the dry season were higher those in the dry season. It can be seen that the water quality of the Hau River is influenced by a part of water from upstream and the activities of people living near the study area. The concentrations of ammonium, nitrate and Fe in the wet and dry seasons were not statistically significant ($p>0.05$) and the dry season tended to be higher than that in the rainy season (Figures 3H and 3I). According to Giao et al. (2021), water flow in the river in the dry season is low, so the ability to dilute wastewater from domestic, industrial and agricultural activities into rivers is lower than that in the rainy season. The high coliform content in the rainy season showed that the water quality can only be used for domestic water supply purposes, but appropriate treatment technology must be applied. Divya & Solomon (2016) suggested that the presence of coliform in water originates from human and animal waste.

Identifying the water quality parameters influenced by season

In order to identify the surface water quality parameters causing the seasonal difference, discriminant analysis was applied to find the most important parameters affecting the seasonal variation in water quality (Table 2). Wilk's Lambda value is 0.371 and the significance level of p=000<0.05 indicated that this is a good result in DA analysis. From the results of the DA analysis, it was shown that TSS, COD, PO_4^{3-}-P, TP, TN and coliform contributed significantly to the change in water quality between the two seasons. TSS and PO_4^{3-}–P, were the most important parameters affecting the

Table 2. Discriminant analysis for surface water variables

DFs	TSS	PO_4^{3-}-P	Coliform	TP	TN	COD	NO_3^--N	Fe
1	0.462	0.273	0.246	0.240	0.203	0.081	-0.07	-0.058
DO	NH_4^+-N	pH	BOD	Eigenvalue	% of variance	Cum %	Wilks' Lambda	Sig.
-0.058	-0.05	-0.04	0.029	1.698	100	100	0.371	0.000

seasonal change of the Hau River water quality. DA analysis can support a significant reduction in the size of the monitoring dataset and requires only a few key parameters responsible for spatial and temporal changes in the surface water quality (Giao et al., 2021). Therefore, the water quality monitoring system of the Hau River in the Hau Giang province should focus on surface water quality parameters including TSS, COD, PO_4^{3-}-P, TP, TN and coliform so that changes of surface water quality can be accurately assessed. In addition, this can help reducing monitoring costs of surface water quality in the study area.

Spatial variations of surface water quality in the Hau River

The results of analysis of water quality clusters at six sampling locations on the Hau River are shown in Figure 4. On the basis of 12 water quality parameters, the sampling sites were divided into 3 distinct clusters including cluster I (position HR1 and HR4), cluster II (position HR3) and cluster III (position HR2, HR5 and HR6). It can be seen that cluster I was mainly affected by the wastewater from industrial and agricultural activities, so it has high PO_4^{3-}-P and

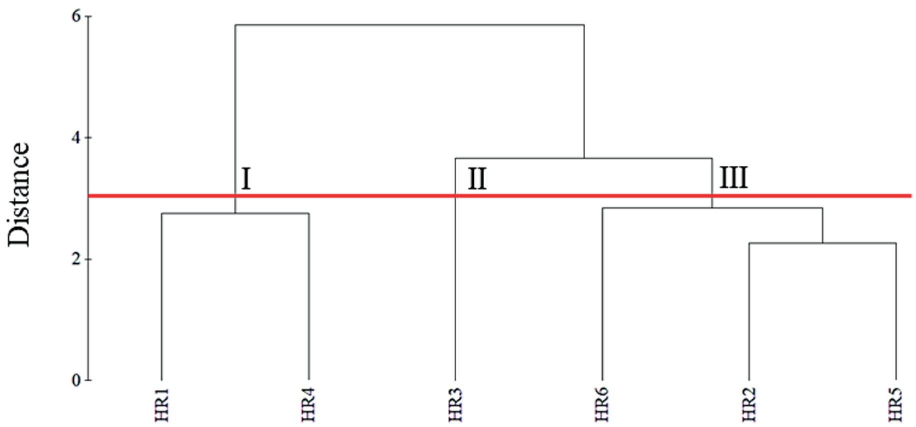

Figure 4. Clustering surface water quality in the Hau River

Table 3. Surface water quality in the identified clusters

Parameter	Unit	Cluster 1	Cluster 2	Cluster 3	QCVN, A1
pH	-	6.93	6.87	6.88	6-8.5
DO	mg/l	4.71	4.70	4.69	≥ 6
TSS	mg/l	46.00	47.46	46.75	20
BOD	mg/l	7.83	7.75	8.11	4
COD	mg/l	14.00	13.88	14.44	10
TP	mg/l	0.22	0.22	0.22	-
TN	mg/l	2.04	1.57	1.72	-
N-NH_4^+	mg/l	0.05	0.04	0.05	0.3
N-NO_3^-	mg/l	0.40	0.40	0.41	2
P-PO_4^{3-}	mg/l	0.19	0.17	0.17	0.1
Fe	mg/l	0.79	0.66	0.76	0.5
Coliform	MPN/100 ml	1637.71	1744.58	1990.14	2500

Fe concentration by 1.9 times and 1.58 times higher than the standards, respectively (Table 3). In addition, this cluster had the highest concentration of TN and exceeded the limit of 1.5 mg/L (by 1.36 times higher). Therefore, the positions HR1 and HR4 had high possibility of potential eutrophication. Cluster II had only position HR3 with very high TSS and 2.37 times higher than the standard. It can be seen that in addition to being affected by rainwater overflow, waterway transport, the HR3 location is also affected by flow speed and alluvium because it is located upstream (Giao, 2020). Cluster III had the lowest DO, leading to higher BOD and COD in this cluster than the rest of the sampling sites (2.02 times and 1.44 times higher, respectively). This cluster is mainly affected by domestic wastewater and industrial activities in the study area.

CONCLUSIONS

It was found that the water quality of the Hau River in the Hau Giang province has been organically polluted and has a potential high risk of eutrophication. Statistical analysis shows that there is no difference in water quality between high tide and low tide, but it can be seen that the concentrations of such parameters as BOD, COD, TN, TP, Fe and coliform in low tide tended to higher than those in the high tide. TSS, TP, TN, PO_4^{3-}-P and coliform had significant differences between the rainy season and the dry season. Four parameters of pH, DO, NH_4^+-N and NO_3^--N in the dry season were higher than those in the rainy season, while the remaining parameters had higher concentrations in the rainy season. There were 5/12 water quality parameters exceeding the allowable limits of QCVN 08-MT:2015/BTNMT, column A1. The parameters that cause the change in water quality between the dry season and the rainy season included TSS, COD, PO_4^{3-}-P, TP, TN and coliform. It was shown that the surface water quality monitoring program in the Hau Giang province should focus on TSS, COD, PO_4^{3-}-P, TP, TN and coliform, thus reducing the monitoring costs. The results of cluster analysis showed that water quality is classified into three clusters, mainly by BOD, COD, TSS, phosphate and Fe. The findings provide useful scientific information on the current status of water quality in the Hau River in the Hau Giang province for future water quality monitoring strategy.

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REFERENCES

1. Adegbite, S.A., Adeleke, A.E., Sangoremi, A., Oladele, E.O. 2018. Seasonal variations of Physicochemical characteristics of Brewery Industry effluent and receiving water of Ikpoba-Oha rivers, Benin City, Nigeria. Journal of Applied Sciences and Environmental Management, 22(6). 857–860.
2. Ahrari, F., Eslami, N., Rajabi, O., Ghazvini, K., Barati, S. 2015. The antimicrobial sensitivity of Streptococcus mutans and Streptococcus sangius to colloidal solutions of different nanoparticles applied.
3. Akaahan, T. J. A. and Azua, E. T. (2016). Assessment of seasonal variation of oxygen demands as pollution indicators of river Benue, Nigeria. European Journal of Earth and Environment, 3(3).
4. Amic, A., Tadic, L. 2018. Analysis of basic physical-chemical parameters, nutrients and heavy metals content in surface water of small catchment area of Karasica and Vusica rivers in Croatia. Environments, 5(20).
5. Aram, S.A., Saalidong, B.M., Osei Lartey, P. 2021. Comparative assessment of the relationship between coliform bacteria and water geochemistry in surface and ground water systems. PLoS ONE, 16(9), e0257715.
6. Arefin, M.T., Rahman, M.M., Wahid-U-Zzaman, M., Kim, J. 2016. Heavy Metal Contamination in Surface Water Used for Irrigation: Functional Assessment of the Turag River in Bangladesh. Journal of Applied Biological Chemistry, 59(1), 83–90.
7. Arora, N., Arora, A.S., Sharma, S., Reddy, A.S. 2015. Use of cluster analysis – a data mining tool for improved water quality monitoring of River Satluj. International Journal of Advanced Networking Applications, 63–68.
8. Astari, A.F.T. 2019. Analisis Daya Tampung Beban Pencemar Sungai Code Menggunakan Software Qual2k. Undergraduate thesis. Universitas Islam Indonesia. Yogyakarta, Indonesia.
9. Cereja, R., Brotas, V., Nunes, S., Rodrigues, M., Cruz, J.P.C., Brito, C. 2022. Tidal influence on water quality indicators in a temperature mesotidal estuary (Tagus estuary, Portugal). Ecological Indicators, 108715.
10. Deng, A., Ye, C., Liu, W. 2018. Spatial and seasonal patterns of nutrients and heavy metals in twenty-seven rivers draining into the South China Sea. Water, 10(50).

11. Divya, A.H., Solomon, P.A. 2016. Effects of some water quality parameters especially total coliform and fecal coliform in surface water of Chalakudy river. Procedia Technology, 631–638.
12. Nghi, D.T. 2017. Changes in water quality in some coastal water bodies in Vietnam. Journal of Marine Science and Technology, 18(2), 222–229.
13. Truc D.T., Phat P.H., Nam N.D.G., Toan P.V., Tri V.P.D. 2019. Surface water quality of Tien River flowing through Tan Chau area, An Giang province. Journal of Science Can Tho University, 53–60.
14. Fatema, K. (2015). Effects of tidal events on the water quality in the Merbok Estuary, Kedah, Malaysia. Journal of Environmental Science and Natural Resources, 8(2).
15. Fetter, G., Lorenz, S., Stoll, S. 2017. Effects of ship-induced waves on aquatic ecosystems. Science of the Total Environment, 926–939.
16. Giao, N.T. 2020. Evaluating current water quality monitoring system on Hau River, Mekong delta, Vietnam using multivariate statistical techniques. Applied Environmental Research, 42(1), 14–25.
17. Giao, N.T., Nhien, H.T.H. 2021. Evaluating water quality variation in the Vietnamese Mekong Delta area using cluster and discriminant analysis. Applied Environmental Research, 43(1), 14–27.
18. Kamarudzaman, A.N., Nor Asri, N.A., Ab Jalil, M.F. and Abd Aziz, R. 2019. A study of water quality for Sungai Kedah during high and low tides. Journal of Engineering Research and Education, 11, 25–24.
19. Kar, S., Ghosh, I., Chowdhury, P., Ghosh, A., Aitch, P., Bhandari, G., et al. 2022. A model-based prediction and analysis of seasonal and tidal influence on pollutants distribution from city outfalls of river Ganges in West Bengal, India and its mapping using GIS tool. PLOS Water, 1(2), e0000008.
20. Viet, L.B., Vy, H.T. 2020. Current status of surface water quality of Tien River, section flowing through Cao Lanh city, Dong Thap province. Industry and Trade Journal - Scientific research results and technology application, 19.
21. Liu, J., Zhang, D., Tang, Q., Xu, H., Huang, S., Shang, D., et al. 2021. Water quality assessment and source identification of the Shuangji River (China) using multivariate statistical methods. PLoS ONE, 16(1), e0245525.
22. Mena-Rivera, L., Salgado-Silva, V., Benavides-Benavides, C., Coto-Campos, J.M., Swinscoe, T.H.A. 2017. Spatial and seasonal surface water quality assessment in a tropical urban catchment: Burio River, Costa Rica. Water, 9(8), 558.
23. Giao, N.T., Hang, P.T., Ni, D.V., Mi, L.T.D., Tuyen, L.T.B. 2021. Evaluation of surface water quality in Ke Sach district, Soc Trang province using multivariate analysis method. Journal of Science of Natural Resources and Environment, 68–79.
24. Lien, N.T.K., Huy, L.Q., Oanh, D.T.H., Phu, T.Q., Ut, V.N. 2016. Water quality in main and tributary rivers of Hau river route. Science Journal of Can Tho University, 43, 68–79.
25. Ojok, W., Wasswa, J., 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.
26. Palma, P., Fialho, S., Lima, A., Mourinha, C., Penha, A., Novais, M. H., Rosado, A., Morais, M., Potes, M., Costa, M.J., et al. 2020. Land-Cover Patterns and Hydrogeomorphology of Tributaries: Are These Important Stressors for the Water Quality of Reservoirs in the Mediterranean Region. Water, 12, 2665.
27. Ngoc, P.N.H., Thuy, H.T.T., Au, N.H. 2017. Application of cluster analysis and numerical analysis to assess salinity of pleistocene aquifers in Tan Thanh district, Ba Ria - Vung Tau province. Science Journal of Can Tho University. Number of topics: Environment and Climate Change, 2, 129–136.
28. Purnaini, R., Purwono, S., Purwono, S. 2018. Tidal influence on water quality of Kapuas Kecil River downstream. E3S Web of Conferences, 31, 04006.
29. Safitri, A., Arisanty, D., Saputra, A.N., Nasruddin 2021. Content of fecal coliform bacteria as an indicator of water quality in the Sungai Jingah, Banjarmasin City. Atlantic Press. Advances in Social Science. Education and Humanities Research, 25, 414–416.
30. Thai, T.H., Tuyen, H.M., Dung, L.H., Tien, N.X., Anh, T.D. 2014. Flow evolution in the Mekong Delta. Hydrometeorological Journal, 7, 19–23.
31. Tuan, L.A., Thuy, H.T. 2015. Water resource variation in the Hau River mouth. Journal of Fisheries Science and Technology.
32. Giau, V.T.N., Tuyen, P.T.B., Trung, N.H. 2019. Evaluation of changes in surface water quality of Can Tho River in period 2010–2014 by calculation method of water quality index (WQI). Scientific Journal of Can Tho University, 2, 105–113.
33. Wedyan, M., Harahsheh, A.A., Muhaidat, R., Bsoul, E., Qnais, E. 2016. Cd and Fe Concentrations of the Surface Water of a Stream in Jordan. Polish Journal of Environmental Studies, 25(6), 2617–2521.
34. Woldeab, B., Beyene, A., Ambelu, A., Buffam, I., Mereta, S.T. 2018. Seasonal and spatial variation of reservoir water quality in the southwest of Ethiopia. Environmental Monitoring and Assessment, 190, 163.