



ASSESSMENT OF SURFACE WATER QUALITY IN PHUNG HIEP DISTRICT, HAU GIANG PROVINCE, VIETNAM

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Abstract

The study aims to assess the current state of surface water quality in Phung Hiep district, Hau Giang province, Vietnam. Surface water quality data were collected at nine locations (PH1 - PH9) collected at a frequency of 4 times in the year 2020 (March, May, August and October), with surface water quality parameters included temperature, pH, dissolved oxygen (DO), total suspended solids (TSS), nitrite ($N-NO_2^-$), nitrate ($N-NO_3^-$), ammonium ($N-NH_4^+$), orthophosphate ($P-PO_4^{3-}$), biochemical oxygen demand (BOD), chemical oxygen demand (COD), coliform and iron (Fe). Surface water quality is assessed by comparing with national technical regulation on surface water quality (QCVN 08-MT:2015/BTNMT, column A1) and by calculating the water quality index (WQI). The results showed that TSS, $N-NO_2^-$, $N-NH_4^+$, $P-PO_4^{3-}$, BOD, COD, coliform, Fe exceeded the allowable limits of QCVN 08-MT:2015/BTNMT, column A1. DO was lower than the regulation while the water quality parameters of temperature, pH and $N-NO_3^-$ were within the allowable limits. The water indicators of DO, TSS, $N-NO_2^-$, $N-NO_3^-$, $N-NH_4^+$ in the dry season were higher than those in the rainy season while the remaining parameters such as $P-PO_4^{3-}$, BOD, COD, coliform and iron in the dry season were lower than those in the rainy season. The WQI values ranged from 24 - 85, showing that surface water quality in Phung Hiep area was poor - good; In which, PH6 location has the best water quality ($WQI = 46 - 85$); PH1 (May) and PH7 (August) had poor water quality, mainly due to organic matters, coliform and $N-NO_2^-$. Future study needs to investigate the causes of water pollution to have appropriate treatment solutions.

Keywords: Water quality; WQI; Organic matters; Microorganisms; Hau Giang.

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1. Introduction

Surface water in the Mekong delta is mainly from the upstream of the Mekong river (accounting for about 80 % of the water volume) flowing into the Mekong delta through two main rivers, the Tien River and the Hau River [1, 2]. The Mekong delta is one of the areas heavily

affected by climate change and sea - level rise [1, 2]. In which, Phung Hiep district, which is considered as one districts most likely to flood because of sea level rise. In addition, Phung Hiep district is influenced by the tides of the West Sea and the East Sea, so it is also known as the bordering area and there is no significant

tidal difference; This can cause stagnation of nutrients in the canal systems [3, 4]. Moreover, surface water often contains many dissolved gases, especially oxygen, suspended solids, organic matter, various types and microorganisms and other dissolved substances [5]. Sources of surface water pollution mainly come from concentrated residential areas, industrial activities, waterway traffic and agricultural production. Due to inadequate water management measures, surface water sources from rivers, streams, lakes, lagoons and wet rice fields are often places with high levels of pollution [6]. Therefore, the assessment of water quality in river systems is necessary. Typically, the area has a special location such as Phung Hiep district, Hau Giang province.

Several methods have been used to classify surface water quality. In particular, the WQI water quality index is commonly used in many countries to assess and classify surface water quality. This index has the advantage of being simple, easy to understand, highly generalizable and can be used for the purpose of classifying water quality as well as assessing water quality changes in space and time [7]. In addition, national technical regulation on surface water quality is also very useful in evaluating specific problem relating to the water quality for a particular water body [8]. This study aims to assess the quality of surface water environment in Phung Hiep district, Hau Giang province for domestic water supply using both national technical regulation on surface water quality and water quality index.

2. Research methodology

2.1. Water sampling and analysis

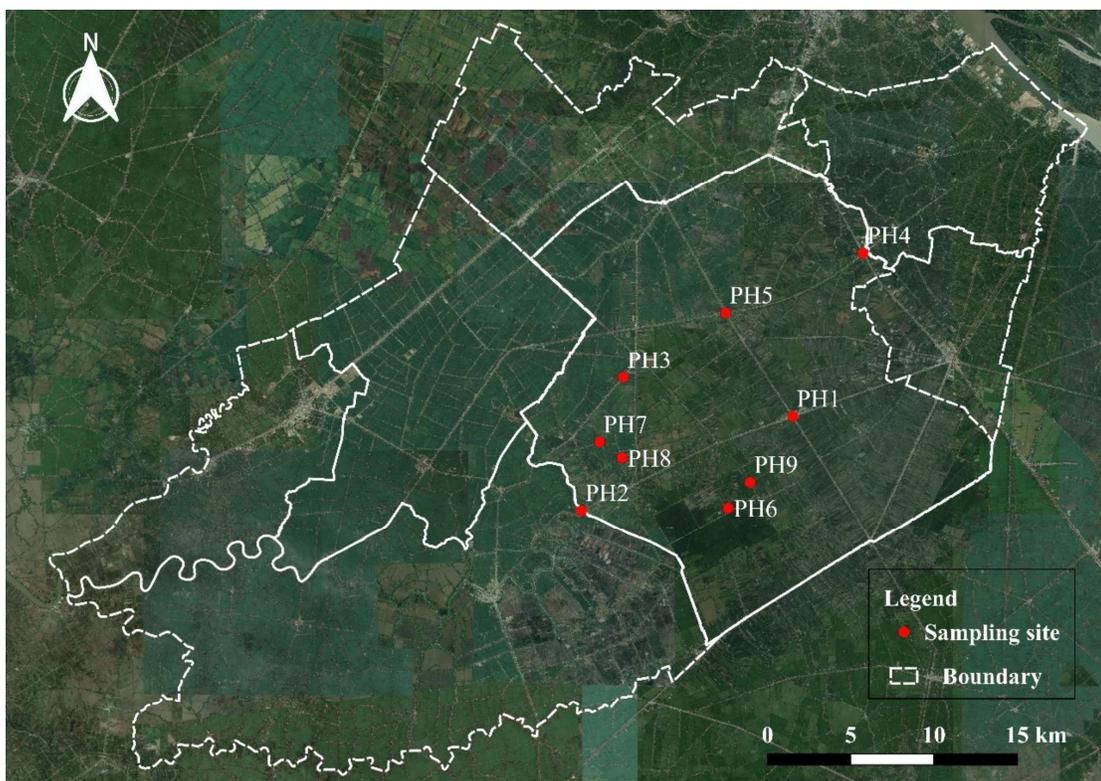


Figure 1: Map of sampling sites

Surface water quality data was collected from the Department of Environment and Natural Resources, Hau Giang province. Nine water sampling locations (PH1 - PH9) were collected with the frequency of four times in the year 2020 (March, May, August and October) (Figure 1). These sampling locations were collected on canals in Phung Hiep district, namely Lai Hieu canal (PH1 and PH2), Hau Giang 3 canal (PH6 and PH9), Xeo Mon canal (PH7), Nang Mau canal (PH4 and PH5), Thuy Loi canal (PH8). These locations were directly influenced by activities such as markets, agriculture and living activities.

There are 12 parameters analyzed, including temperature (°C), pH, dissolved oxygen (DO), total suspended solids

(TSS), nitrate (N-NO₃⁻), nitrite (N-NO₂⁻), ammonium (N-NH₄⁺), orthophosphate (P-PO₄³⁻), biological oxygen demand (BOD), biological oxygen demand (COD), iron (Fe) and coliform. The parameters of water quality such as temperature, pH, DO were measured in the field while the remaining parameters were analyzed at the laboratory in compliance with Vietnam's standards and technical regulations on instructions for sampling, preserving and analyzing samples in the laboratory. The method of sampling, preserving and analyzing surface water samples was carried out in accordance with TCVN 6663-6:2018 on water quality - Sampling Part 6: Guidance on sampling of rivers and streams. The sample analysis methods [9] were shown in Table 1.

Table 1. Water quality analysis

No.	Parameters	Unit	Analytical methods	QCVN 08-MT, A1
1	pH	-	pH meter	6 - 8.5
2	Temperature	°C		-
3	DO	mg/L	DO meter	>6
4	TSS	mg/L	TCVN 6625:2000	20
5	COD	mg/L	SMEWW 5220C:2012	10
6	BOD	mg/L	TCVN 6001-1:2008	4
7	N-NO ₂ ⁻	mg/L	Spectrophotometer	0.05
8	N-NO ₃ ⁻	mg/L	Spectrophotometer	2
9	N-NH ₄ ⁺	mg/L	TCVN 4563:1988	0.3
10	P-PO ₄ ³⁻	mg/L	TCVN 6202:2008	0.1
11	Fe	mg/L	TCVN 6177:1996	0.5
12	Coliform	MPN/ 100mL	TCVN 6187-2:1996	2500

2.2. Data processing

The data on surface water quality were presented in the form of TB ± SD. The difference in mean values of the analytical parameters between the locations of water samples was tested by using the analysis of variance (Analysis of Variance or ANOVA) IBM SPSS Statistics for Windows version 16.0 software (IBM Corp., Armonk, NY, USA) at 5 % significance level. The results of

analysis of surface water quality criteria are compared with the national technical regulation on surface water quality QCVN 08-MT:2015/BTNMT. The WQI index is calculated according to the guidance in Decision No. 1460/QD-TCMT on the promulgation of the technical guidelines for the calculation and publication of the Vietnam Water Quality Index (VN_WQI) [7]. The Water Quality Index (WQI) is a composite index that is calculated

from defined water quality parameters through a mathematical formula. WQI is a quantitative description of water quality and is expressed on a scale. WQI parameters are calculated according to the formula:

$$WQI = \frac{WQI_{pH}}{100} \times \left[\frac{1}{k} \sum_{i=1}^k WQI_{Iv} \times \frac{1}{l} \sum_{i=1}^l WQI_{Iv} \right]^{1/2}$$

Where: WQI_{pH} : Calculated WQI value for pH parameter; WQI_{II} : Calculated WQI value for the parameter; WQI_I : WQI calculated value for parameters: DO, BOD, COD, $N-NH_4^+$, $N-NO_2^-$, $N-NO_3^-$, $P-PO_4^{3-}$; WQI_{II} : The calculated WQI value for the coliform parameter. The WQI parameter has a value from 0 to 100. In which, a value from 91 - 100 presents very good water quality that is considered good for domestic water supply purposes; A value of WQI from 76 to 90 shows good water quality suitable for use for domestic water supply but need suitable treatment measures; WQI value between 51 - 75 shows average water quality to be used for irrigation and other equivalent purposes; WQI values from 26 to 50 shows bad water quality used for navigation and other equivalent purposes; WQI values from 10 to 25 shows poor quality so the water is heavily polluted, needing treatment measures in In the future, water with a WQI value < 10 is water of very heavy quality, contaminated water and needs to be remedied and treated [7].

3. Results and discussion

3.1. Seasonal variation of surface water quality

The temperature at the sampling points is relatively stable and ranges from 28.1 to 29.8. The average temperature in 4 months ranged from 28.8 ± 0.25

to 29.4 ± 0.46 °C and there was no statistically significant difference ($p > 0.05$) between locations (Table 2). The average temperature at the sampling points has a slight seasonal variation (Figure 2a); Which has values ranging from 28.67 ± 0.22 to 29.16 ± 0.38 °C. and the temperature in March and August difference is statistically significant ($p < 0.05$) with October. In May, there is no statistically significant difference ($p > 0.05$) with the remaining 3 months. Water temperature in the Hau river ranges from 27.1 - 32.0 [10, 11] and in the Mekong River is from 19.9 - 32.2 °C [2]. The temperature is seasonally varied [12, 13]. The temperature is in the range suitable for the growth of aquatic organisms [14].

The results showed that the pH value through 4 sampling periods at 9 locations from 6.71 to 7.42, the lowest pH at PH3 in March and the lowest at PH9 in August. The average pH of 4 months at 9 sites ranged from 6.79 ± 0.02 to 7.04 ± 0.27 , the highest at PH8 and the lowest at PH9. The average pH at PH9 was significantly different ($p < 0.05$) with PH8, while there was no difference with the remaining points (Table 2). Average pH has a slight seasonal variation, ranging from 6.84 ± 0.11 to 7.04 ± 0.19 , in August the difference was statistically significant ($p < 0.05$) with March, but not different from May and October (Figure 2b). This result is consistent with the previous studies. The results of [15] also showed that the pH value on the main and tributary rivers of the Hau River route ranges from 6.3 to 8.0 and has an average value of 7.1 ± 0.32 and Hau River in An Giang - Hau Giang ranges from 6.7 to 7.12 [11]. In general, pH has little variation in space and time and the samples are within the allowable range of QCVN 08-MT:2015/BTNMT, column A1 (6 - 8.5) [8].

Table 2. Physical properties of surface water in the study area in 2020

Sites	Temperature (°C)	pH	DO (mg/L)	TSS (mg/L)
PH1	28.8 ^a ± 0.25	6.96 ^{ab} ± 0.1	3.23 ^{ab} ± 0.78	65 ^a ± 30.99
PH2	29.4 ^a ± 0.46	6.92 ^{ab} ± 0.08	3.38 ^{ab} ± 0.1	63 ^a ± 23.83
PH3	28.7 ^a ± 0.45	6.82 ^{ab} ± 0.11	2.7 ^b ± 0.5	63 ^a ± 16.12
PH4	28.9 ^a ± 0.62	6.98 ^{ab} ± 0.11	3.75 ^a ± 0.97	80.25 ^a ± 27.72
PH5	28.7 ^a ± 0.41	7.02 ^{ab} ± 0.07	3.3 ^{ab} ± 0.77	71.5 ^a ± 41.97
PH6	28.9 ^a ± 0.33	6.97 ^{ab} ± 0.14	3.18 ^{ab} ± 0.05	46.75 ^a ± 35.78
PH7	29.1 ^a ± 0.33	6.89 ^{ab} ± 0.15	2.98 ^{ab} ± 0.263	58 ^a ± 19.2
PH8	29.1 ^a ± 0.5	6.79 ^b ± 0.02	3.2 ^{ab} ± 0.14	59.5 ^a ± 27.77
PH9	28.9 ^a ± 0.35	7.04 ^a ± 0.27	3.22 ^{ab} ± 0.1	46 ^a ± 14.17

The DO concentration in water throughout the year is quite low, ranging from 2 (PH3 in May) to 4.3 mg/L (PH4 in August). The average DO range from 2.7 ± 0.49 to 3.75 ± 0.97 mg/L (Table 2), the difference is significant statistically between the PH4 and PH3 sites ($p < 0.05$); However, there was no statistically significant difference ($p > 0.05$) with the remaining sampling sites. The average DO value has little seasonal variation, ranging from 2.72 ± 0.55 to 3.42 ± 0.44 mg/L (Figure 2c). The DO concentration through 4 sampling periods lower than QCVN 08-MT:2015/BTNMT, about 0.4 - 0.86 times. According to the survey results of [10], the DO concentration in the main and tributary rivers of the Hau River route has large fluctuations and ranges from 1.76 to 7.96 mg/L (average at 4.9 ± 1.4 mg/L); Which is higher than the value in the present study [14]. Moreover, DO should be 5 mg/L or higher to be suitable for aquatic life [16]. Therefore, low oxygen in water bodies of the study area can lead to the loss of biodiversity in water bodies.

The fluctuation of total suspended solids in 4 sampling periods at 9 points had significant variability and ranged from 13 - 130 mg/L. All positions exceed the allowed limit of QCVN 08-MT:2015/

BTNMT, except PH in August. The mean TSS concentration in surface water was quite high and fluctuated widely at the sampling sites, ranging from 46 ± 14.17 to 80.25 ± 24.72 mg/L (Table 2). The average value of TSS was the lowest at PH9 and the highest at PH4. TSS concentration has a seasonal variation from 46.89 ± 25.714 to 93.1 ± 18.41 mg/L (Figure 2d). The concentration of TSS was recorded higher than previous studies in similar water bodies such as Hau River, An Giang, Soc Trang [5, 10, 11, 17]. Besides that, Lien et al., [10] and Ut et al., [18] also showed that water quality is strongly influenced by time, in which the TSS is always higher than that of the rainy season due to the impact of rainwater runoff and erosion [5, 12]. TSS upstream tends to be higher than downstream because of the flow rate and the amount of sediment contained in the water column [11]. In addition, during the rainy season, flood water flows from upstream carrying many sediments, causing TSS values to increase. Suspended solids in water include inorganic solids and organic solids. TSS concentration affects the quality of water used for domestic use, production, hinders and consumes many chemicals in the water treatment process.

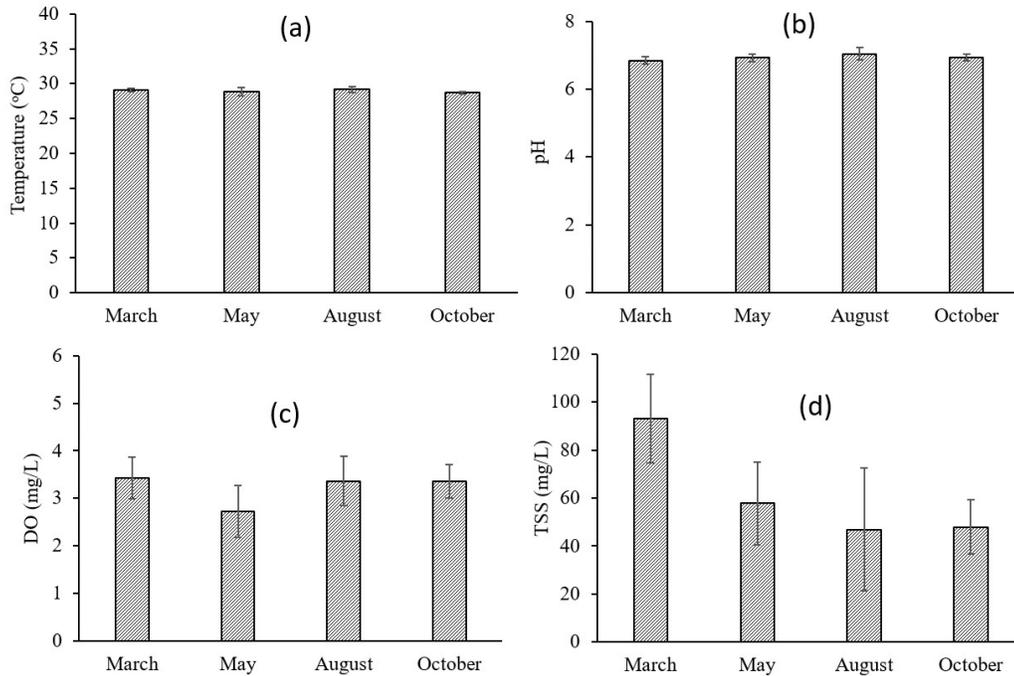


Figure 2: Temporal variation of temperature, pH, DO and TSS in surface water

The monitoring results showed that the concentration of N-NH_4^+ ranged from 0 to 0.85 mg/L. N-NH_4^+ at positions PH1, PH2, PH3, PH4, PH7, PH8 in March and positions PH7 and PH8 in May exceeded the allowable limit. N-NH_4^+ at the PH2 position (August and October) and the PH8 position in October exceeded the limit from 1.1 to 2.8 times. The average concentration of N-NH_4^+ at the sampling sites fluctuated relatively high from 0.098 ± 0.07 to 0.58 ± 0.28 mg/L (Table 3). The average concentration of N-NH_4^+ was lowest at PH6 and highest at PH8 and the difference was statistically significant ($p < 0.05$) at the sampling points. The concentration of N-NH_4^+ had slightly seasonal variation (0.15 ± 0.1 to 0.34 ± 0.19 mg/L) (Figure 3c). This study is consistent with the survey results at sites on the Hau River with an average concentration of N-NH_4^+ ranging from 0.13 to 0.25 mg/L [19]. The results of this survey are lower than that of surface water on the Tien River flowing through

An Giang with N-NH_4^+ concentrations ranging from 0.3 to 8.3 mg/L [20]. Previous studies have shown that the content of nitrogen tended to be increased seasonally from March to June, then decreased in November [6, 12, 13]. The concentration of ammonium nitrogen in the water should not exceed 5 mg/L, if it is more than 5 mg/L, the water is in very polluted. In freshwater environments, an increase in pH to 8 increases the toxicity of ammonia in water compared to a lower pH [18, 21].

The concentration of N-NO_2^- at 9 sampling points ranged from 0.014 to 0.147 mg/L. Monitoring results in October at all locations reached the standard value of QCVN 08-MT:2015/BTNMT (0.05 mg/L); The results in August had 6/9 positions meeting the standards, except for positions PH2, PH8 and PH8 with results exceeding the standard; Monitoring results in March and May, only 2 locations PH1 and PH4 (in March)

had satisfactory results, the remaining locations exceeded the standard, the level exceeded 1.2 - 2.9 times. The average nitrite concentration in 4 months at the sampling points ranged from 0.05 ± 0.05 to 0.07 ± 0.04 mg/L (Table 3), the point with the lowest nitrite concentration at PH9 and highest at PH7 and there is no significant difference at $p > 0.05$. The concentration of N-NO_2^- in the months

of March, May, August and October was 0.07 ± 0.02 , 0.11 ± 0.03 , 0.04 ± 0.03 and 0.02 ± 0.003 mg/L (Figure 3a). N-NO_2^- concentration tended to increase from March to May and gradually decreased to October and fluctuated highest in May. The previous study also suggested that there was seasonal variation, in which nitrogen species increased from March to June, then decreased in November [6, 13].

Table 3. The average content of nutrients in surface water in 2020

Sites	N-NO_2^- (mg/L)	N-NO_3^- (mg/L)	N-NH_4^+ (mg/L)	P-PO_4^{3-} (mg/L)
PH1	$0.06^a \pm 0.06$	$0.35^{ab} \pm 0.2$	$0.2^c \pm 0.13$	$0.2^b \pm 0.04$
PH2	$0.05^a \pm 0.02$	$0.52^a \pm 0.29$	$0.33^{bc} \pm 0.06$	$0.21^b \pm 0.05$
PH3	$0.06^a \pm 0.06$	$0.2^b \pm 0.12$	$0.25^{bc} \pm 0.21$	$0.35^a \pm 0.1$
PH4	$0.06^a \pm 0.06$	$0.22^b \pm 0.07$	$0.13^c \pm 0.05$	$0.22^b \pm 0.06$
PH5	$0.06^a \pm 0.06$	$0.21^b \pm 0.11$	$0.17^c \pm 0.07$	$0.18^b \pm 0.04$
PH6	$0.06^a \pm 0.03$	$0.22^b \pm 0.07$	$0.1^c \pm 0.07$	$0.12^b \pm 0.02$
PH7	$0.07^a \pm 0.04$	$0.21^b \pm 0.08$	$0.46^{ab} \pm 0.26$	$0.18^b \pm 0.11$
PH8	$0.05^a \pm 0.02$	$0.25^b \pm 0.05$	$0.58^a \pm 0.28$	$0.18^b \pm 0.03$
PH9	$0.05^a \pm 0.05$	$0.24^b \pm 0.06$	$0.23^{bc} \pm 0.04$	$0.12^b \pm 0.011$

Monitoring results showed that nitrate ranged from 0.08 to 0.93 mg/L at all sampling locations. Nitrate through 4 samples collection was within QCVN 08-MT:2015/BTNMT. The average N-NO_3^- ranged from 0.21 ± 0.11 to 0.35 ± 0.21 mg/L, the average N-NO_3^- concentration was lowest at PH3 and PH5 and highest at PH1. The nitrate value at the PH1 site did not have a statistically significant difference with the remaining sites, while there was a significant difference between the PH2 site and PH3 - PH9 at the significance level of $p < 0.05$ (Table 3). This result is consistent with the report of the Ministry of Natural Resources and Environment, the concentration of N-NO_3^- at monitoring points on Hau and Tien Rivers is low. The nitrate concentration has slight seasonal variation, but there is no statistically significant difference ($p > 0.05$) and ranges from 0.2 ± 0.14 to

0.31 ± 0.27 mg/L (Figure 3b), N-NO_3^- concentration tends to be high in the dry season and lower in the rainy season, this survey is consistent with previous studies showing that the N-NO_3^- concentration in Co Chien river, Hau River, Tien River [5, 10, 19, 20]. In the current study, N-NO_3^- concentration remains low which does not cause eutrophication.

The average concentration of P-PO_4^{3-} at the sampling points ranged from 0.12 ± 0.015 to 0.35 ± 0.1 mg/L (Table 3). The point with the lowest P-PO_4^{3-} concentration at PH6, P-PO_4^{3-} the highest at PH3 and had a statistically significant difference ($p < 0.05$) with the remaining positions. The concentration of P-PO_4^{3-} ranged from 0.18 ± 0.1 to 0.24 ± 0.08 mg/L, with no seasonal variation and (Figure 3d). This result is consistent with the study at points on the main river and tributary, ranging from 0.007

to 0.51 mg/L, with an average of 0.1 ± 0.07 mg/L [10]. $P-PO_4^{3-}$ is a nutrient for algae growth. Normally, phosphorus dissolved in natural surface water exists from 0.005 to 0.02 mg/L and greater than 0.02 mg/L, considered nutritious [21]. Sources of $P-PO_4^{3-}$ release into

the environment are human feces, cattle manure and wastewater from some phosphate fertilizer industries, food industry and in water flowing from fields [22]. The concentration of $P-PO_4^{3-}$ at the studied sites is not capable of causing eutrophication.

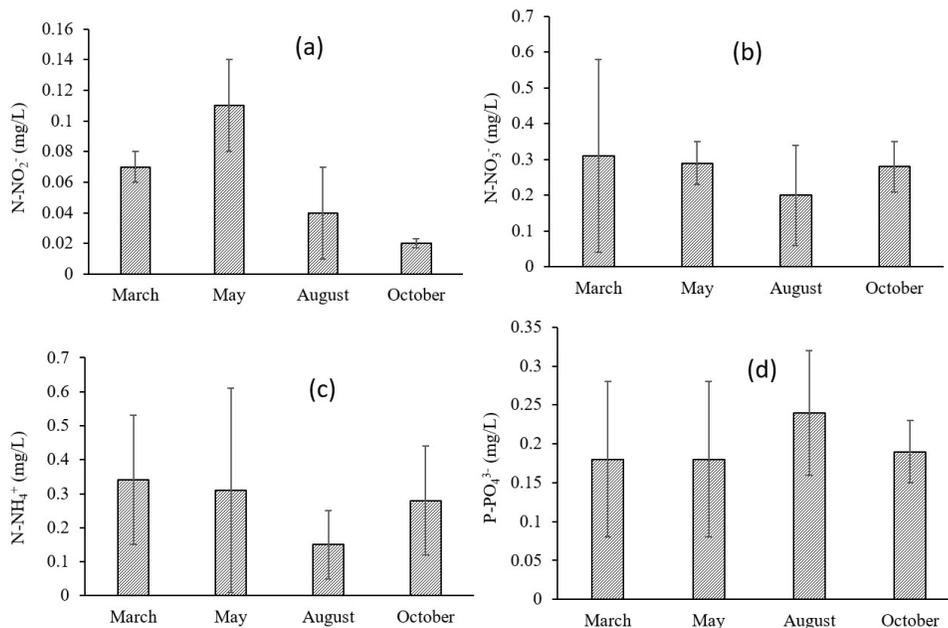


Figure 3: Temporal variation of nutrients in surface water in the study area

BOD through monitoring sessions ranged from 7 to 16 mg/L, exceeding the allowable standard from 1.2 to 2.7 mg/L. The average BOD concentration at the sampling points ranged from 11.25 ± 2.87 to 13 ± 3.56 mg/L, the point with the lowest BOD value at PH1 and PH7 and the highest at PH2. BOD at sampling points did not have a statistically significant difference ($p > 0.05$) (Table 4). The average BOD over the months ranged from 12.11 ± 1.83 to 14.56 ± 1.13 mg/L and these values have a statistically significant difference ($p < 0.05$). The mean BOD was lowest in May and highest in August (Figure 4a). Previous research showed that BOD in the rainy season is higher than in the dry season [5]. The comparison with some other studies

shows that the BOD concentration in the study area was higher than that of Hau River, while lower than other tributaries such as Can Tho river, Hau Giang canals. The cause of this situation may be because the monitoring position is affected by living activities and urban development of residential areas.

COD in the sampling sessions ranged from 9 to 28 mg/L, exceeding the standard from 1.1 to 1.9 times. The average COD parameters at the sampling locations ranged from 18.5 ± 4.93 to 21.25 ± 7.13 mg/L. COD was lowest at PH7 and PH9 sites and highest at PH5 sites. There was no statistically significant difference in COD at sampling locations ($p > 0.05$) (Table 4). The average COD concentration over the months fluctuated from 11.56 ± 1.88 to

25.22 ± 1.85 mg/L (Figure 4b). According to a study by the Ministry of Fisheries (2004) shows that COD < 5 mg/L, the environment is poor in nutrients, 20 - 30 mg/L is rich in nutrients and > 30 mg/L is a polluted environment. The results of the present study show COD concentration at a nutrient - rich level. Besides, COD was recorded higher than in water bodies such

as Can Tho river [10], Hau Giang canals [11], Hau River [19]. The concentration of COD parameters tended to increase in the rainy season. Both BOD and COD were used as indicators of organic waste concentration in water [23, 24]. From the above analysis, as can be seen that the area has been contaminated with organic matter and nutrients.

Table 4. The average content of organic matters, microorganisms and iron in surface water in 2020

Site	BOD (mg/L)	COD (mg/L)	Coliform (MPN/100mL)	Fe (mg/L)
PH1	11.25 ^a ± 3.3	20 ^a ± 6.14	20837.5 ^a ± 11226.3	2.1 ^a ± 0.77
PH2	13 ^a ± 3.56	22 ^a ± 6.05	8487.5 ^b ± 1625	1.88 ^{ab} ± 0.68
PH3	12.25 ^a ± 3.59	20.75 ^a ± 7.37	13975 ^{ab} ± 11079.5	1.95 ^{ab} ± 0.84
PH4	12 ^a ± 3.37	19.75 ^a ± 7.5	9200 ^b ± 2492.99	1.43 ^{ab} ± 0.38
PH5	12.75 ^a ± 3.2	21.25 ^a ± 7.14	9662.5 ^b ± 3829.57	1.88 ^{ab} ± 0.88
PH6	12 ^a ± 2.94	20.25 ^a ± 5.74	6825 ^b ± 2983.71	1.05 ^b ± 0.24
PH7	11.25 ^a ± 25.87	18.5 ^a ± 4.93	15487.5 ^{ab} ± 10569.8	1.43 ^{ab} ± 0.54
PH8	11.75 ^a ± 2.06	19.75 ^a ± 4.99	8450 ^b ± 1178.98	1.44 ^{ab} ± 0.41
PH9	11.5 ^a ± 3.41	18.5 ^a ± 7.77	9412.5 ^b ± 5084.35	1 ^b ± 0.37

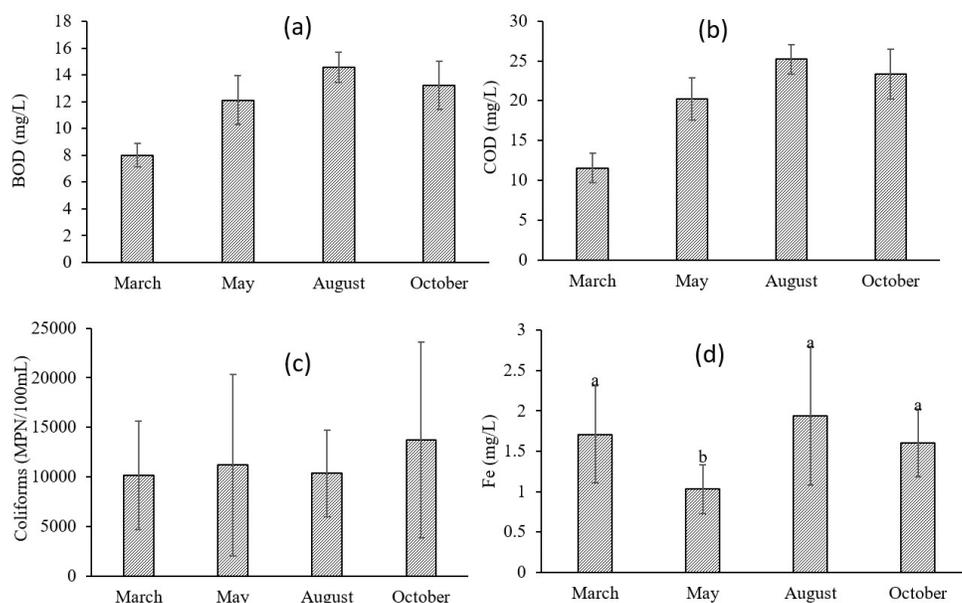


Figure 4: Temporal variation of BOD, COD, coliform and Fe in surface water

Coliform ranged from 3300 to 35000 MPN/100 mL, exceeding the standards of QCVN 08-MT:2015/BTNMT by 1.1 - 7.0 times. The average coliform at the sampling points ranged from 6825 ± 2983.7 to 20837.5 ± 11226.26 MPN/100

mL (Table 4), the site with the lowest coliform density at PH6 and the highest at PH1. Mean seasonal coliform ranged from 10172.22 ± 5445.99 to 13722.22 ± 9862.24 MPN/100 mL (Figure 4c). Coliforms in the Can Tho river ranged from 3,448 to 27,327

MPN/mL, which was higher than that of the current study [Lien]. According to the previous study reported that the density of coliform in the rainy season in the Hau river surface water was higher than the dry season [11]. Coliforms are a group of bacteria commonly found in the human digestive system. The presence of coliform indicates that the water source has shown signs of organic contamination because the coliform group is present in the intestinal tract of warm - blooded animals.

Fe at the sampling locations through 4 sampling sessions ranged from 0.5 to 3.2 mg/L (Table 4). Most of the monitoring positions had Fe concentrations exceeding QCVN 08-MT:2015/BTNMT by 1.1 to 3.2 times. The average Fe at the sampling points

ranged from 1 ± 0.37 to 2.1 ± 0.77 mg/L (Table 4), with the lowest concentration at PH1 and the highest at PH9. The average Fe in the months of sampling ranged from 1.02 ± 0.29 to 1.94 ± 0.86 mg/L (Figure 4d). This study is consistent with previous research on Hau River with Fe value from 1.2 to 1.51 mg/L [19]. The reason for the high Fe concentration at the sampling points is due to the soil characteristics of Phung Hiep district, which is a low - lying area in the soil containing potential acid sulfate soil [11]. In Soc Trang, the iron content in surface water is from 0.30 - 3.75 mg/L [17]. This is consistent with the geographical condition that the Mekong river delta is an alkaline soil and farming and alum washing activities have made the water contaminated with iron.

3.2. Evaluating surface water quality using WQI

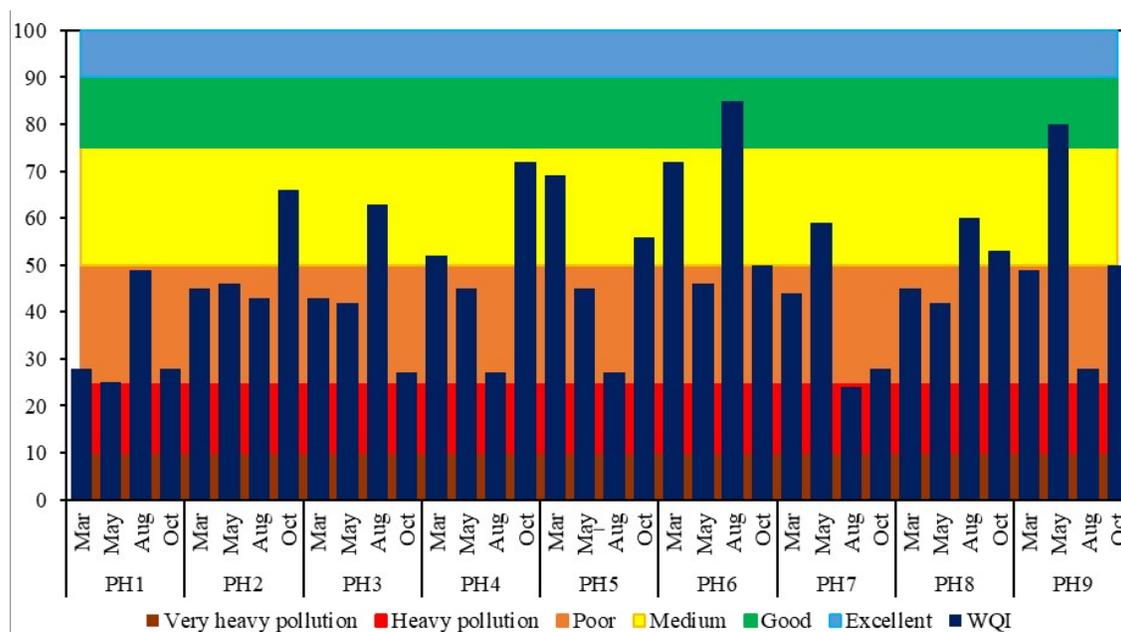


Figure 5: Evaluating surface water quality using water quality index

WQI calculation results ranged from 25 - 85; The lowest WQI value in the study area was recorded at PH7 (August) and the highest at PH6 (August). Specifically, the values ranged from 28 - 72 (March), 25 - 80 (May), 24 - 85 (August), 27 - 72

(October), respectively. This value has the greatest variability in August and the lowest in March. In general, the water quality at the monitoring points through the sampling periods was mostly poor and medium quality. The two locations PH6

(in August) and PH9 (in May) had good WQI values suitable for domestic water supply purposes but require appropriate treatment. This can be explained by the location PH6 and PH9 are located near the area of Lung Ngoc Hoang nature reserve, so it is less affected by other industrial activities. Sampling locations at PH1 (May) and PH7 (August) had poor water quality, heavily polluted water, need treatment measures, mainly caused by high concentrations of coliform and N-NO_2^- .

4. Conclusion

The surface water quality in water bodies in Phung Hiep district, Hau Giang province was studied. The results showed that surface water was polluted by organic matters (low DO, BOD, COD, TSS high), nutrients (N-NO_2^- , N-NH_4^+ , P-PO_4^{3-} high), microorganism (coliforms) and heavy metal (Fe). The water quality parameters of temperature, pH and N-NO_3^- were within the allowable limits. It has been found that the water indicators of DO, TSS, N-NO_2^- , N-NO_3^- , N-NH_4^+ in the dry season were higher than those in the rainy season. The water parameters such as P-PO_4^{3-} , BOD, COD, coliform and iron in the dry season were lower than those in the rainy season. The calculated WQI values (24 - 85) revealed that surface water quality in Phung Hiep area was heavily polluted mainly due to organic matters, N-NO_2^- and coliform; in which, PH6 location has the best water quality ($\text{WQI} = 46 - 85$). Future study needs to investigate the causes of water pollution in order to have appropriate treatment solutions.

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