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Assessing Surface Water Quality in Phong Dien District, Can Tho City, Vietnam

Nguyen Thanh Giao[1] and Le Thi Diem Mi[1]

[1]College of Environment and Natural Resources, Can Tho University, Vietnam

Corresponding author email: ntgiao@ctu.edu.vn

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Abstract

The study aimed to assess the variation of surface water quality in the water bodies in Phong Dien district, Can Tho city, Vietnam. Data were collected in 2019 at 5 locations in the district, namely My Khanh (MK), Phong Dien (PD), Giai Xuan (GX), Truong Long (TL) and Vam Sang market (VS). The samples were collected in the dry and rainy seasons, each collection period was performed at low and high tide. Surface water quality was evaluated using 12 water quality parameters belonging to the group of physical, biological and chemical parameters including pH, temperature, dissolved oxygen (DO), biochemical oxygen demand (BOD), chemical oxygen demand (COD), total suspended solids (TSS), ammonium (NH_4^+-N), nitrite (NO_2^--N), nitrate (NO_3^--N), orthophosphate (PO_4^{3-}-P), iron (Fe), coliform. Water quality was compared with the national technical regulation on surface water quality QCVN 08-MT: 2015/BTNMT (column A1). The results showed that the study area had organic pollution (high BOD and COD), microorganisms. Nutrient parameters were still within the allowable limits of QCVN 08-MT: 2015/BTNMT. The concentration of nutrients and organic matter in the dry season at low tide was higher than that in the rainy season in high tide. Coliform were only detected at low time sampling period. The source of organic and microbiological pollution was mainly from domestic and animal husbandry wastes discharged directly into the water environment by the households. The results revealed that surface water quality in the water bodies in Phong Dien district, Can Tho city was no longer suitable for domestic needs. The environmental managers need urgent solutions, for example solid waste and wastewater collection and treatment systems, to solve the problem of surface water pollution.

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1. Introduction

Water resources are the main components of the living environment, a particularly important factor in ensuring the successful implementation of socio-economic development strategy, planning ensuring national defense and security. However, the process of unreasonable and unsustainable exploitation and use of water resources has caused water resource degradation, especially challenges to surface water quality due to the process of receiving wastewater from other economic activities. Along with the rapid process of industrialization and modernization of the country, the process of continuous urbanization and population growth leads to increasing human demand for water. The amount of untreated wastewater before being discharged into the environment is increasing, making

water quality in these water bodies severely impaired, even many water bodies from the function of providing irrigation water have become storage of wastewater discharge from human activities. Phong Dien district is also in the period of economic restructuring, along with a system of rivers, canals, convenient for goods exchange by waterways and aquaculture, the economic structure of the district develops according to the direction: Trade, service, high-quality tourism-agriculture-industry, and handicraft. This is a strong point that is considered to be the advantage of the district to exploit the type of garden tourism, ecotourism associated with visiting historical-cultural relics and spiritual tourism. Up to now, there are 24 enterprises operating in the industrial sector, 765 industrial establishments; Besides, there is agricultural production with the tradition of growing rice in combination with planting fruit trees. Parallel to the economic development is the increasing pressure on natural resources and the environment, in which, surface water pollution is one of the issues of concern. According to Massoud (2012) [1], the declining water quality threatens human health and the functioning of aquatic ecosystems. Wastewater from agriculture, industry, and domestic activities pollutes directly through surface runoff, indirectly through sewers and river estuaries, from accumulation in space and time [2]. The impact of point and non-point pollution sources on water quality is a critical issue in many parts of the world; Especially in the study area, which receives waste from many different sources. Therefore, research on surface water quality in water bodies in Phong Dien district was conducted to detect and warn changes in water quality to have appropriate management and treatment measures, which help to limit adverse effects on human health and ecosystems.

2. Methodology

2.1 Water sampling and analysis

The study was conducted to evaluate surface water quality in 2019 at 5 locations in Phong Dien district (Table 1). With 4 sampling cycles (March, May, September, December) corresponding to 2 times (dry season [March and May] and rainy season [September and December]) in a year. Each sampling time was collected according to low tide and high tide of the water sampling time. The surface water quality parameters of pH, temperature (^oC), dissolved oxygen (DO), biochemical oxygen demand (BOD), chemical oxygen demand (COD), and suspended solids (TSS), ammonium (NH_4^+-N), nitrite (NO_2^-- N), nitrate (NO_3^-- N), orthophosphate (PO_4^{3-}- P), iron (Fe) and coliform were evaluated. pH, temperature and DO were measured in the field while BOD, COD, TSS, NH_4^+-N, NO_2^-- N, NO_3^-- N, PO_4^{3-}- P, Fe and coliform were analyzed in the laboratory by standard method [3].

Table 1: Coding and sampling site description

No	Code	Site description
1	MK	The site was at My Khanh. Assessment of water quality in Can Tho river affected by domestic activities and navigation.
2	PD	The site was at Phong Dien Market. Assessment of water quality in Can Tho River affected by trade.
3	GX	The site was at Giai Xuan Commune People's Committee. Assessment of water quality of Can Tho river affected by domestic activities.
4	TL	The site was at Ong Hao junction, Truong Tho A Hamlet, Truong Tho Commune. Assessment of water quality of Can Tho river affected by domestic activities.
5	VS	The site was at Rach Xa No (opposite Vam Sang ferry). Assessment water quality of Xa No canal before flowing into Can Tho river.

2.2 Data analysis

The data were arranged by location, tide (low and high), season (dry season and rainy season) of the year. One-Way ANOVA with Duncan test was used to compare the means of water quality according to location, tide and season at the significance level of 5%. In addition, the water parameters were compared with the QCVN 08-MT: 2015/BTNMT, national technical regulation on surface water quality.

Table 2: Limits of water quality variables according to *QCVN: 08-MT: 2015/BTNMT*

Variables	**Unit**	**QCVN*, A1**
pH	-	6-8.5
DO	mg/L	≥6
BOD	mg/L	4
COD	mg/L	10
TSS	mg/L	20
NH_4^+-N	mg/L	0.3
NO_2^--N	mg/L	0.05
NO_3^--N	mg/L	2
PO_4^{3-}-P	mg/L	0.1
Fe	mg/L	0.5
Coliform	MPN/100mL	2500

**National technical regulation on surface water quality (QCVN: 08-MT: 2015/BTNMT). A1 means water quality used for domestic purposes (after normal treatment has been applied), conservation of aquatic plants and animals and other purposes; A2 is used for domestic purposes but treatment technology must be applied.*

3. Results and Discussion

3.1 pH

The analytical results showed that pH values at the monitoring positions between the low and high tide was not statistically significant ($p>0.05$). At the time of high tide, pH at locations ranged from 6.98 ± 0.16-7.19 ± 0.13 with the lowest at Truong Long monitoring position and highest in Phong Dien Market. In low tide, pH at all locations ranged from 7.08 ± 0.16-7.15 ± 0.05, the lowest was in Vam Sang and highest in My Khanh (Table 3). Similarly, the changes in pH value between the dry and rainy seasons at different locations were not statistically significant ($p> 0.05$). In the dry season, the lowest value was 6.95 ± 0.18 in Truong Long, the highest in Phong Dien with 7.09 ± 0.13 and this was also the place with the highest pH value in the rainy season with 7.22 ± 0.04; In the rainy season, the pH value was the lowest in Giai Xuan with 7.13 ± 0.08 (Table 4). pH difference was not statistically significant between the rainy season and the dry season, it was found that the pH value in the rainy season was always higher than that in the dry season. The former study by Lien et al. (2016) [4], also showed that the pH value in rainy season was higher than that in the dry season, pH fluctuated between sampling areas in the range of 6.3-8.0. pH in Hau river, An Giang-Hau Giang section, ranged from 6.7-7.1 [5]. pH in the Can Tho area ranged from 7.00-7.80 with an average of 7.40 [6]. In general, pH in the study areas was within the permissible limits in column A1 of QCVN 08-MT: 2015/BTNMT. The reason for the change in pH value may be that many algae cause a large fluctuation in pH during the day, too much algae would make pH very high (8.8-9.1) in the afternoon, but when less algae reduce the pH [7].

3.2 Temperature

The temperature between high and low tide at 5 monitoring positions in Phong Dien district was not statistically significant ($p>0.05$). In Truong Long, the lowest temperature at both low and high tide at the sampling time was 26.88 ± 0.08 ^oC and 27.00 ± 0.07 ^oC respectively; The value of temperature 27.25 ± 0.24 ^oC was the highest in Giai Xuan during high tide, also the highest value at low tide at

Phong Dien Market sampling site (Table 3). The temperature difference between the rainy season and the dry season at the 5 monitoring locations was also not statistically significant (p>0.05). Temperature in Truong Long was also the lowest in the dry season (27.00 ± 0.07 ^oC), in the rainy season (26.88 ± 0.08 ^oC); The highest was found in the dry season in Phong Dien Market (27.35 ± 0.24 ^oC), the highest was found in the rainy season in Giai Xuan (27.05 ± 0.18 0C) (Table 4). The temperature in the dry season was always higher than that in the rainy season at the monitoring locations. Similarities with the study of Truc et al. (2019) [7], temperature of Tien river in the surface water flowing through Tan Chau (An Giang) had the highest value in May 2018 (32.1^oC), the lowest was found in December 2017 (25.1 ^oC). This temperature is suitable for aquatic species to develop, in fact the temperature affects biological processes, the speed of the processes will take place faster when the temperature is high, organisms usually develop best at temperatures between 25 and 32 °C [8].

Table 3. Spatial variation of water quality in water bodies in Phong Dien district, Can Tho city

Variables	Unit	Sampling time	My Khanh	Phong Dien	Giai Xuan	Truong Long	Vam Sang
pH	-	High tide	7.11±0.14a	7.19±0.13a	7.06±0.11a	6.98±0.16a	7.02±0.20a
		Low tide	7.15±0.05a	7.12±0.07a	7.14±0.09a	7.15±0.15a	7.08±0.16a
Temp.	^0C	High tide	27.03±0.21a	27.13±0.17a	27.25±0.24a	26.88±0.08a	26.91±0.23a
		Low tide	27.08±0.29a	27.25±0.24a	27.10±0.14a	27.00±0.07a	27.20±0.20a
DO	mg/L	High tide	5.77±0.23ab	5.95±0.13b	5.93±0.16b	5.78±0.18ab	5.67±0.21ab
		Low tide	5.61±0.21ab	5.38±0.86a	5.44±0.1ab	5.5±0.11ab	5.57±0.12ab
BOD	mg/L	High tide	6.32±0.74a	5.99±0.97a	6.67±0.77a	7.17±0.57a	7.28±0.84a
		Low tide	6.42±1.07a	6.79±1.04a	8.13±1.09a	7.82±0.74a	7.85±1a
COD	mg/L	High tide	14.75±1.55a	14.23±1.72a	14.25±0.76a	14.23±1.27a	14.28±1.66a
		Low tide	17.40±1.76a	18.43±2.25a	19.28±1.18a	18.73±1.32a	17.68±1.09a
TSS	mg/L	High tide	42.13±4.26ab	40.38±6.15ab	43.38±5.65ab	47.63±3.42ab	34.25±2.47a
		Low tide	42.50±5.34ab	43.13±6.34ab	53.88±4.64b	49.50±2.83ab	41.50±3.05ab
NH_4+-N	mg/L	High tide	0.13±0.03a	0.15±0.04a	0.13±0.03a	0.1±0.01a	0.17±0.05a
		Low tide	0.17±0.02a	0.21±0.05a	0.18±0.03a	0.24±0.09a	0.22±0.06a
NO_2^--N	mg/L	High tide	0.02±0.00a	0.02±0.00a	0.02±0.00a	0.01±0.00a	0.02±0.01a
		Low tide	0.02±0.01a	0.02±0.01a	0.03±0.00a	0.02±0.00a	0.02±0.01a
NO_3^--N	mg/L	High tide	0.58±0.15a	1.15±0.22ab	1.20±0.38ab	1.15±0.27ab	1.60±0.27b
		Low tide	0.85±0.12a	1.23±0.10ab	1.23±0.09ab	0.95±0.25ab	0.95±0.1ab
PO_4^{3-}-P	mg/L	High tide	0.05±0.01a	0.06±0.01ab	0.05±0.01a	0.06±0.01ab	0.07±0.02ab
		Low tide	0.09±0.02abc	0.10±0.01bc	0.09±0.01abc	0.09±0.01abc	**0.12±0.02c**
Fe	mg/L	High tide	0.13±0.04a	0.10±0.03a	0.15±0.04a	0.21±0.05a	0.18±0.07a
		Low tide	0.17±0.04a	0.13±0.04a	0.18±0.05a	0.14±0.02a	0.17±0.06a
Coliform	MPN/ 100mL	High tide	KPH	KPH	KPH	KPH	KPH
		Low tide	1783±456a	**3150±492a**	**2675±545a**	**2825±715a**	**2575±322a**

3.3 Suspended solids

Suspended solids at the time of sample collection low and high tide at the monitoring positions fluctuated 34.25 ± 2.47-47.63 ± 3.42 mg L, 41.50 ± 3.05-53.88 ± 4.64 mg/L (Table 3). Vam Sang had the lowest TSS value in both low and high tide. TSS was highest at the time of high tide in Truong Long and low tide at Giai Xuan. The difference in TSS value between high and low tide at each monitoring position was not statistically significant (p>0.05). As can be seen from Table 3, the difference between TSS in each monitoring position in dry season and rainy season has no statistical meaning (p>0.05). In the dry season, TSS was the highest in Truong Long (51.25 ± 3.61 mg/L) and the lowest in Vam Sang (36.25 ± 4.50 mg/L); The highest and lowest TSS in rainy season were in

Giai Xuan (54.63 ± 3.95 mg/L) and My Khanh (39.38 ± 4.22 mg/L) (Table 4). Through former studies on water environment, it was found that TSS had fluctuated between the water bodies and TSS is a problem causing water quality degradation. TSS in the wet season in My Khanh, Phong Dien and Truong Long was significantly higher than that in the dry season. Initial study by Lien et al. (2016) [4] also showed that water quality was heavily influenced by time, in which the TSS rainy season was always higher than the season due to the effects of storm water runoff and erosion. TSS upstream tended to be higher than downstream because of the flow rate and the amount of sediment contained in the water column [5].

Table 4. Seasonal variation of water quality in water bodies in Phong Dien district, Can Tho city

Variables	Unit	Sampling time	My Khanh	Phong Dien	Giai Xuan	Truong Long	Vam Sang
pH	-	Dry	7.08±0.14a	7.09±0.13a	7.07±0.12a	6.95±0.18a	7.08±0.22a
		Wet	7.18±0.05a	7.22±0.04a	7.13±0.08a	6.95±0.18a	7.02±0.13a
Temp.	^{0}C	Dry	27.20±0.29a	27.35±0.24a	27.30±0.19a	27.00±0.07a	27.18±0.19a
		Wet	26.90±0.18a	27.03±0.11a	27.05±0.18a	26.88±0.08a	26.93±0.25a
DO	mg/L	Dry	5.47±0.11ab	5.54±0.13ab	5.54±0.11ab	5.48±0.11ab	5.34±0.03a
		Wet	5.91±0.24b	5.79±0.22ab	5.82±0.22ab	5.80±0.17ab	5.90±0.09b
BOD	mg/L	Dry	**5.61±0.92a**	**5.75±0.61a**	**6.66±1.11ab**	**7.02±0.31ab**	**6.33±0.69ab**
		Wet	**7.14±0.68ab**	**7.04±1.21ab**	**8.14±0.73ab**	**7.96±0.84ab**	**8.80±0.52b**
COD	mg/L	Dry	**16.98±1.74a**	**18.03±1.77a**	**15.40±1.44a**	**17.25±1.94a**	**15.18±1.72a**
		Wet	**15.18±1.76a**	**14.63±2.42a**	**18.13±1.69a**	**15.70±1.60a**	**16.78±1.58a**
TSS	mg/L	Dry	**45.25±4.80ab**	**42.75±6.57ab**	**42.63±5.67ab**	**51.25±3.61ab**	**36.25±4.50a**
		Wet	**39.38±4.22a**	**40.75±5.95ab**	**54.63±3.95b**	**45.88±1.55ab**	**39.50±1.47a**
NH_4^+-N	mg/L	Dry	0.15±0.02abc	0.25±0.03cd	0.18±0.03abcd	0.24±0.09bcd	0.30±0.03d
		Wet	0.15±0.04abc	0.11±0.02a	0.13±0.02ab	0.10±0.01a	0.10±0.01a
NO_2^--N	mg/L	Dry	0.03±0.01a	0.03±0.01a	0.02±0.00a	0.02±0.01a	0.03±0.01a
		Wet	0.01±0.00a	0.03±0.01a	0.02±0.00a	0.02±0.00a	0.02±0.00a
NO_3^--N	mg/L	Dry	0.58±0.09a	1.43±0.11b	1.53±0.27b	1.13±0.28ab	1.50±0.31b
		Wet	0.85±0.17ab	0.95±0.10a	0.90±0.12a	0.98±0.25ab	1.05±0.16ab
PO_4^{3-}-P	mg/L	Dry	0.07±0.01a	0.09±0.02a	0.06±0.02a	0.07±0.01a	**0.12±0.02a**
		Wet	0.07±0.03a	0.07±0.01a	0.08±0.01a	0.08±0.01a	0.07±0.01a
Fe	mg/L	Dry	0.14±0.04a	0.13±0.02a	0.17±0.04a	0.22±0.04a	0.24±0.07a
		Wet	0.16±0.05a	0.10±0.05a	0.15±0.05a	0.13±0.03a	0.11±0.03a
Coliform	MPN/ 100mL	Dry	1865±935a	**2600±200a**	**3300±1000a**	**3700±900a**	2400±0.00a
		Wet	1700±600a	**3700±900a**	2050±50a	1950±850a	**2750±750a**

3.4 Dissolved oxygen

Dissolved oxygen (DO) at high tide of the sample collection ranged from 5.67 ± 0.21-5.95 ± 0.13 mg/L between the monitoring locations with the lowest value was found at Vam Sang and the highest in Phong Dien; DO at the low tide sampling ranged from 5.38 ± 0.09-5.61 ± 0.21 mg/L, the lowest value and highest values were found in Phong Dien and My Khanh, respectively (Table 3). Particularly for Phong Dien, the difference in DO value between high and low tide was statistically significant ($p < 0.05$). In the dry season, DO ranged from 5.34 ± 0.03-5.54 ± 0.11 mg/L, the lowest was in Vam Sang and the highest was in Giai Xuan; In the rainy season, DO ranged from 5.79 ± 0.22-5.80 ± 0.17 mg/L, the lowest DO was found in Phong Dien and the highest was found in Truong Long. DO values between rainy and dry seasons at Vam Sang was statistically significant ($p < 0.05$) (Table 4). DO in the rainy season was always higher than that in the dry season in the study area in 2019. The DO was low and fell below the allowable threshold of QCVN 08-MT: 2015/BTNMT.

Former studies of Nga and Thu (2005) [9] in Rach Ban canal, Can Tho city also showed low DO value (0-2.5 mg/L); Hau river in 2018 was 5.29 ± 0.03-5.56 ± 0.56 mg/L [5]; in Can Tho river was 3.5-5.8 mg/L [10]. Giau et al. (2019) [10] explained that in the rainy season there is a relatively strong flow regime that causes water disturbance, making the process of diffusing oxygen into the water resulting in higher DO in this season. According to Boyd (1998) [11], suitable dissolved oxygen in water is 5-7 mg/L. DO depend on temperature and decomposition processes of organic compounds and photosynthesis of aquatic plants. Waste sources from agricultural production and domestic wastewater contain a lot of organic matter, so the decomposition of organic matter consumes the dissolved oxygen, thereby low DO [4].

3.5 Biological oxygen demand

BOD at 5 monitoring positions in Phong Dien district in 2019 between high and low tide was not statistically significant ($p > 0.05$). BOD at high tide ranged from 5.99 ± 0.97-7.28 ± 0.84 mg/L, the lowest was found in Phong Dien and the highest was found in Vam Sang; For low tide, BOD ranged from 6.42 ± 1.07-8.13 ± 1.09 mg/L, the lowest and highest in My Khanh and Giai Xuan, respectively (Table 3). In the dry season, BOD fluctuated between 5.61 ± 0.92-7.02 ± 0.31 mg/L, the lowest was found in My Khanh and the highest was found in Truong Long; In the rainy season, BOD ranged from 7.04 ± 1.21-8.80 ± 0.52 mg/L with the lowest and highest levels in Phong Dien and Vam Sang (Table 4). BOD between rainy and dry seasons was not statistically significant ($p > 0.05$). BOD in the study area exceeded the permitted threshold in column A1 of QCVN 08-MT: 2015/BTMNT. In accordance with the low DO results, it showed that the surface water environment in Phong Dien district was polluted with organic matters. BOD in rivers and canals including infield canals and Hau river of An Giang province were in the range of 6.6 ± 1.2-8.2 ± 2.5 mg/L, exceeding the standard by 1.2-1.6 times [12]; canals in Soc Trang province were in the range of 2.2-22.4 mg/L [13]. According to Nga and Thu (2005) [9], the water quality of Can Tho river on the Rach Ban canal, a tributary canal of the Can Tho river, had BOD exceeding the standard for domestic water (Column A) from 2.5-46.3 times. Seasonal variation of BOD was previously recorded [12]. The source of BOD can be generated by wastes from cultivation, animal husbandry, landfills, daily life and services that have discharged waste directly into the environment.

3.6 Chemical oxygen demand

COD ranged from 14.23 ± 1.72-14.75 ± 1.55 mg/L at high tide and ranged from 17.40 ± 1.76-19.28 ± 1.18 mg/L at low tide (Table 3). COD between the tides was not statistically significant ($p > 0.05$). In the dry season, COD fluctuated 15.40 ± 1.44-18.03 ± 1.77 mg/L, the lowest and highest were found in Giai Xuan and Phong Dien, respectively. In the rainy season, COD was the highest in Giai Xuan (18.13 ± 1.69 mg/L) and the lowest was found in Phong Dien (14.63 ± 2.42 mg/L) (Table 4). Between the rainy and dry seasons, the differences in BOD at the sampling sites were not statistically significant ($p > 0.05$). The results were similar to that was found in the Hau river in 2016, the average COD of 14.3 mg/L [4], COD in Hau river in 2018, 11.68 ± 3.76-13.54 ± 4.72 mg/L [5], COD in Rach Ban canal, Can Tho city exceeded the standard 4.3 -18.9 times [9]. In general, COD in the rainy season was lower than that in the dry season, due to the high amount of water in the rainy season, which contributed to the dilution of organic matter in the water. In short, COD in the study area exceeded the permitted threshold of QCVN 08-MT:2015/BTNMT. COD exceeded the threshold with high levels of BOD and low DO, indicating that the surface water environment in the area was heavily organically polluted.

3.7 Ammonium

NH_4^+-N at high and low tide ranged from 0.10 ± 0.01-0.17 ± 0.05 mg/L, respectively. NH_4^+-N was not statistically significant ($p > 0.05$) between high and low tide at the monitoring locations. The sampling site at Truong Long had both the lowest and the highest concentration of NH_4^+-N of 0.10 ± 0.01 mg/L and 0.24 ± 0.09 mg/L at high and low tide, respectively. NH_4^+-N was found the highest

(0.17 ± 0.05 mg/L) at high tide in Vam Sang while it was found the lowest (0.17 ± 0.02 mg/L) at the low tide at the site in My Khanh. In the dry season, NH_4^+-N fluctuated in the range of 0.15 ± 0.02-0.30 ± 0.03 mg/L, the lowest and the highest NH_4^+-N were found at the sites in My Khanh and Vam Sang, respectively. The concentrations of NH_4^+-N in the rainy season ranged from 0.10 ± 0.01-0.15 ± 0.04 mg/L, the lowest was at the site in Vam Sang and the highest was found at the site in My Khanh (Table 4). In the monitoring positions at Phong Dien and Truong Long markets in the rainy and dry seasons, the concentrations of NH_4^+-N were statistically significant difference for each location ($p<0.05$). NH_4^+-N concentration in the rainy season was always lower than that in the dry season. Similar to the study of Ty et al. (2018) [8], NH_4^+-N was found in the rainy season was 0.14 ± 0.11 mg/L, and in the dry season was 0.49 ± 0.86 mg/L. In other studies, NH_4^+-N in the canals in Soc Trang province 2012-2018 ranged from 0.35-4.14 mg/L [13]; in Tham General canal (TT2), Cai Khe canal (CK3-CK4), Bun Sang lake in Ninh Kieu district in 2019, NH_4^+-N concentration was high and exceeded the permitted threshold [14]. In the current study, NH_4^+-N concentrations in the water bodies in Phong Dien district was still within the permissible limit for column A1 of QCVN 08-MT: 2015/BTNMT.

3.8 Nitrite

NO_2^--N is a product of nitrification and anti-nitrification, NO_2^-- N is capable of causing toxicity to aquatic organisms at the concentration of 0.1 mg/L. According to Boyd (1998) [11], the nitrite suitable for cultured fish should be less than 0.3 mg/L. In the water environment, NO_2^-- N could combine with hemoglobin in blood of aquatic animals to form methemoglobin, reducing the ability to transport oxygen to cells resulting harmful impact to the diversity of the aquatic species. In this study, NO_2^-- N was always low and little variation was found (Tables 3, 4). NO_2^-- N at all the monitoring points were within the allowable limits of QCVN 08-MT: 2015/BTNMT, column A. There was no difference between low tide and high tide as well as dry and wet season.

3.9 Nitrate

NO_3^--N at the monitoring positions at high tide ranged from 0.58 ± 0.15-1.60 ± 0.27 mg/L while that of the low tide ranged from 0.85 ± 0.12-1.23 ± 0.09 mg/L. The sampling site at My Khanh had the lowest NO_3^--N concentration at the high tide sample collection time and the highest NO_3^--N concentration was found at the low tide. At Vam Sang site, NO_3^--N was found to be the highest at high tide whereas it was found the highest at Giai Xuan site during low tide (Table 3). There was no significant difference in the concentration of NO_3^--N ($p> 0.05$) during low and high tide. In the dry season, NO_3^-- N ranged from 0.58 ± 0.09-1.53 ± 0.27 mg/L, the lowest amount of NO_3^-- N was found at the sampling site in My Khanh and the highest was found at the site in Giai Xuan. In the rainy season, NO_3^--N ranged from 0.85 ± 0.17-0.98 ± 0.25 mg/L, in which the lowest and highest concentrations of NO_3^--N were found at the site in My Khanh and Truong Long, respectively (Table 4). NO_3^--N between the dry season and the rainy season differed statistically ($p<0.05$) at each sampling location, particularly in Phong Dien and Giai Xuan markets. NO_3^--N in the dry season was higher than that in the rainy season at all monitoring locations. This result was consistent with the study of Lien et al. (2016) [4], concentrations of NO_3^--N at the sampling locations on main rivers and tributaries of Hau river ranged from 0.002-0.395 mg/L, averaged at 0.11 ± 0.07 mg/L and NO_3^--N in the dry season was always higher than that in the rainy season in Can Tho river in the period 2010-2014 [10]. The current study and former studies show that NO_3^--N are always within the permitted limits of QCVN 08-MT: 2015/BTNMT.

3.10 Orthophosphate

PO_4^{3-}- P at high tide and low tide ranged from 0.05 ± 0.01-0.07 ± 0.02 mg/L and 0.09 ± 0.02-0.12 ± 0.02 mg/L, respectively (Table 3). At these two sampling times, the highest value of orthophosphate was found in Vam Sang and the lowest was found in My Khanh. In Phong Dien and Vam Sang, PO_4^{3-}- P differed statistically ($p <0.05$) between high and low tide at each sampling point

(Table 3). In the dry season, PO_4^{3-}- P fluctuated in the range of 0.06 ± 0.02-0.09 ± 0.02 mg/L, the lowest value was found in Giai Xuan and the highest in Phong Dien market. PO_4^{3-}- P in the rainy season was relatively stable between the sampling locations ranging from 0.07-0.08 mg/L (Table 4). The difference of PO_4^{3-}- P in the dry and rainy seasons was not statistically significant ($p>0.05$). An earlier study in Ninh Kieu district showed that PO_4^{3-}- P (1.30 ± 2.00-5.00 ± 4.20 mg/L [14] was relatively higher than that in the study. In general, PO_4^{3-}- P at most of the monitoring locations were within the allowable limits of QCVN 08-MT: 2015/BTNMT, except at Vam Sang position where the PO_4^{3-}- P exceeded the standard. It was possible that this place was strongly affected by domestic waste, detergents and agricultural activities.

3.11 Iron

Fe fluctuated between 0.10 ± 0.03-0.21 ± 0.05 mg/L at high tide, and 0.13 ± 0.04-0.18 ± 0.05 mg/L at low tide. The difference of Fe between low and high tide was not statistically significant among the sampling locations ($p> 0.05$); Phong Dien market had the lowest Fe value at both low and high tide, Truong Long had the highest Fe at high tide and Giai Xuan had the highest Fe at low tide (Table 3). In the dry season, Fe fluctuated in the range of 0.13 ± 0.02-0.24 ± 0.07 mg/L, the lowest and highest in Phong Dien and Vam Sang markets, respectively; Fe in the rainy season ranged from 0.10 ± 0.05-0.16 ± 0.05 mg/L, the lowest was also in Phong Dien market, the highest in My Khanh, the difference was not statistically significant ($p> 0.05$) (Table 4). The research results showed Fe was still within the allowable limit of QCVN 08-MT: 2015/BTNMT.

3.11 Coliform

The study results showed that coliforms detected only at low tide and ranged from 1783 ± 456-3150 ± 492 MPN/100mL (Table 3), reaching the highest value in Phong Dien market and the lowest in My Khanh. Coliform values at the different monitoring positions were not statistically significant ($p>0.05$). In My Khanh, the lowest coliform value in both dry and rainy seasons were 1865 ± 935 MPN/100mL and 1700 ± 600 MPN/100mL, respectively. The highest coliform value was 3700 ± 900 MPN/100mL in Truong Long in the dry season, and also the highest value in the rainy season in Phong Dien (Table 4). The coliform value between the dry and rainy seasons at the different locations was not statistically significant ($p>0.05$). In general, in the study area, the concentration of coliforms exceeded the permitted threshold in column A1 of QCVN 08-MT: 2015/BTNMT. Compared with the studies in the same area of Can Tho city, coliform values in Phong Dien district area were much lower than in other areas. Specifically, the total coliform in surface water of Rach Ban canal ranged from 240,000-2,400,000 MPN/100mL, exceeding the quality standard of surface water at Column A from 48-480 times, Column B from 24-240 times. Surface water was seriously contaminated with microorganisms, receiving excreted wastes from humans and animals [9]; on the Can Tho River in the period 2010-2014, the coliform density ranged from 3,448-27,327 MPN/100mL [10]. The presence of coliforms showed that the surface water source in the study area is contaminated with microorganisms from the excreted waste of humans and organisms.

4. Conclusion

Through monitoring results and compared with the national technical regulations on surface water quality, it showed that surface water in Phong Dien district, Can Tho city was polluted since the water parameters including BOD, COD, TSS and coliform exceeded the allowable limits of QCVN 08-MT: 2015/BTNMT, column A1. pH and temperature were suitable for aquatic life. The concentrations of NH_4^+-N, NO_2^--N. NO_3^-- N, PO_4^{3-}-P were relatively low and within the allowable limits of QCVN 08-MT: 2015/BTNMT, column A1. However, the results showed that at Vam Sang location, PO_4^{3-}-P exceeded the standard during low water and dry season. In general, surface water quality during high tide and in rainy season was improved and was better than during high tide and in dry season. The main source of pollution from domestic wastewater, cultivation and animal husbandry in the area discharging directly into rivers and canals without treatment, increasing

pollutants in the surface water environment. Proper treatment and management of wastewaters and solid wastes for point and non-point sources are urgently needed to improve and sustain water quality in the district. Community-based management of water quality could be a good strategy for water resources management.

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