



Evaluating Surface Water Quality in Ninh Kieu District, Can Tho City, Vietnam

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ABSTRACT: This study aimed to evaluate water quality in the canals in Ninh Kieu district, Can Tho city in the period of 2018-2019. Monitoring data were collected at 10 locations distributed on Tham Tuong canal (TT1, TT2), Cai Khe canal (CK1-CK4), Bun Xang lake (BX1-BX2), Cai Son - Hang Bang canal (HB1, HB2). Water quality parameters assessed include temperature, pH, turbidity, total suspended solids (TSS), biological oxygen demand (BOD), chemical oxygen demand (COD), orthophosphate ($\text{PO}_4^{3-}\text{-P}$), nitrate ($\text{NO}_3^- \text{-N}$), ammonia ($\text{NH}_4^+ \text{-N}$), nitrite ($\text{NO}_2^- \text{-N}$) and coliforms. The results showed that water quality in the canals in Ninh Kieu district, Can Tho city were contaminated with coliforms, TSS, BOD, and COD. The temperature and pH parameters were very little fluctuated, while BOD, coliforms, and DO tended to decrease in the period from 2018-2019. Particularly, the mean P-PO_4^{3-} in 2019 was higher than that in 2018. BOD, COD, TSS, P-PO_4^{3-} , and coliforms in Tham Tuong canal were higher than those in other water bodies because several production and business activities are taking place. Water pollution problem in Ninh Kieu district, Can Tho city needs to be solved as soon as possible to ensure healthy environment, attracting tourists to visit in Can Tho city.

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Can Tho city has a total natural area of 1,409.0 km², accounting for 3.49% of the total area of the region and a population of 1.282 million people, population density as of 2018 was 995 persons/km². Can Tho is the fourth largest city in the country, and also the most modern and largest city in the lower Mekong region. Along with the development of the country, Can Tho is gradually making positive changes. The average economic growth rate of the city reaches 12.19% (2011-2015) (Can Tho's People Committee, 2015). Due to favorable natural conditions, a dense system of canals, with more than 158 rivers, canals, large and small for fresh water during the dry and wet seasons, creating conditions for farmers to irrigate and reclaim land, develop economic agriculture, industry and services. Water is an extremely important resource, decisive for the existence and development of life on earth. Water is used in most daily activities from serving daily activities such as food, sanitation, healthcare to agriculture, industry, fisheries, etc. In recent years, Vietnam is facing many pollutants from many different causes. Population growth, production and services, agricultural activities are the major causes of surface water pollution. Former studies revealed that surface water quality in large and small rivers in the Mekong delta of Vietnam was seriously polluted (Lien *et al.*, 2016; Ly and Giao, 2018; Tuan *et al.*, 2019; Giao, 2020, Giao and Nhien, 2020).

However, surface water quality in the water bodies in Ninh Kieu district, Can Tho city has not been reported. The economic development of Can Tho city has caused many environmental problems, especially the quality of surface water (Can Tho's People Committee, 2015). In addition, surface water resource in Can Tho city is also at risk from pollutants outside source such as urban areas, residential areas, areas where trade, service and production are concentrated in the Vietnamese Mekong delta. The main rivers and canals in Can Tho city are directly affected by waste discharges from socio-economic development activities leading to the need of assessing water quality and proposing solutions for protection and preservation. Surface water quality information could help the local environmental managers to take appropriate measure to improving water quality by strictly control of polluting sources thus protecting human health. Therefore, assessment of surface water quality at the monitoring points in Ninh Kieu district, Can Tho city is necessary.

MATERIALS AND METHODS

Data collection: The two-year monitoring data were collected at 10 locations distributed on Tham Tuong canal (TT1, TT2), Cai Khe canal (CK1-CK4), Bun Xang lake (BX1-BX2), Cai Son - Hang Bang canal (HB1, HB2) from Department of Natural Resources

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and Environment, Can Tho city. Water quality parameters assessed including temperature ($^{\circ}\text{C}$), pH, turbidity (NTU), total suspended solids (TSS, mg/L), biological oxygen demand (BOD, mg/L), chemical oxygen demand (COD, mg/L), orthophosphate ($\text{PO}_4^{3-}\text{-P}$, mg/L), nitrate ($\text{NO}_3\text{-N}$, mg/L), ammonia ($\text{NH}_4^+\text{-N}$, mg/L), nitrite ($\text{NO}_2\text{-N}$, mg/L) and coliforms (MPN/100 mL). pH (HANNA HI 8224, Rumani), temperature and DO (Milwaukee SM 600, Rumani) were measured at the sampling sites while the other parameters were cooled at 4°C , stored, and transported to the laboratory of the Center for Environment and Natural resources monitoring, Can Tho city. The samples were analyzed using the procedures in the Standard Methods for Examination of Water and Wastewater (APHA, 1998).

Data analysis: Water quality is assessed using national technical regulations on surface water quality (QCVN 08-MT: 2015/BTNMT).

Table 1. Limited value of surface water quality parameters

Parameter	Units	Limit values	
		QCVN*A1	QCVN*A2
pH	-	6-8.5	6-8.5
Temp.	$^{\circ}\text{C}$	-	-
TSS	mg/L	20	30
DO	mg/L	≥ 6	≥ 5
BOD	mg/L	4	6
COD	mg/L	10	15
$\text{NH}_4^+\text{-N}$	mg/L	0.3	0.3
$\text{NO}_2\text{-N}$	mg/L	0.05	0.05
$\text{NO}_3\text{-N}$	mg/L	2	5
$\text{PO}_4^{3-}\text{-P}$	mg/L	0.1	0.2
Coliforms	MPN/100mL	2500	5000

*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.

The water quality was also evaluated using water quality assessment index (WQI). The formula for calculating WQI is shown as follow:

$$WQI = \frac{WQI_{pH}}{100} \left[\frac{1}{5} \sum_{a=1}^5 WQI_a \times \frac{1}{2} \sum_{b=1}^2 WQI_b \times WQI_c \right]^{1/3}$$

In which: WQI_a : WQI for DO, BOD₅, COD, $\text{NH}_4^+\text{-N}$, $\text{PO}_4^{3-}\text{-P}$; WQI_b for TSS and turbidity; WQI_c for coliform; WQI_{pH} for pH. The WQI is ranging from 0 to 100 dividing water quality into five levels. Level 1 ($100 > \text{WQI} > 91$) is good water quality that could be used for purposes of water supply. Level 2 ($90 > \text{WQI} > 76$) is also used for water supply for domestic uses but suitable treatment measures are required. Level 3 is for irrigation and other similar

purposes ($75 > \text{WQI} > 51$). Level 4 ($50 > \text{WQI} > 26$) is the water suitable for transport and equivalent purposes while Level 5 ($25 > \text{WQI} > 0$) is considered to be heavily polluted water that proper treatment measures are urgently needed. The difference in water quality by space and time was assessed using IBM SPSS statistics for Windows software, Version 20.0 (IBM Corp., Armonk, NY, USA), Duncan test at significance level 5 %.

RESULTS AND DISCUSSION

Temperature and pH: The results of comparing the mean values of the temperature over 2018 and 2019 showed that the positions from TT1 to HB2 were statistically significant differences ($p < 0.05$) (Figure 1). Between the two years, there was also no large fluctuation, consistent with the general temperature and does not affect the aquatic life in the water bodies. The average temperature across the survey points in 2018 ranged from 26.83 ± 1.02 to $26.98 \pm 1.01^{\circ}\text{C}$. Figure 1 presented that through the survey points there was no statistically significant difference ($p > 0.05$). In 2019, the mean temperature across the survey points did not largely fluctuate much (28.45 ± 0.80 - $28.62 \pm 0.96^{\circ}\text{C}$), and there was no statistically significant difference ($p > 0.05$) through the survey points in Ninh Kieu district, Can Tho city. The previous studies showed that temperature in Hau River was from 27.1 - 32.0°C (Lien *et al.*, 2016; Ly and Giao, 2018) and the Mekong River was 19.9 - 32.2°C (Ongley, 2009; MRC, 2015). The temperature in the water bodies in Ninh Kieu district was in the range in the favorable ranges for aquatic organisms (Boyd, 1998; Phu and Ut, 2006).

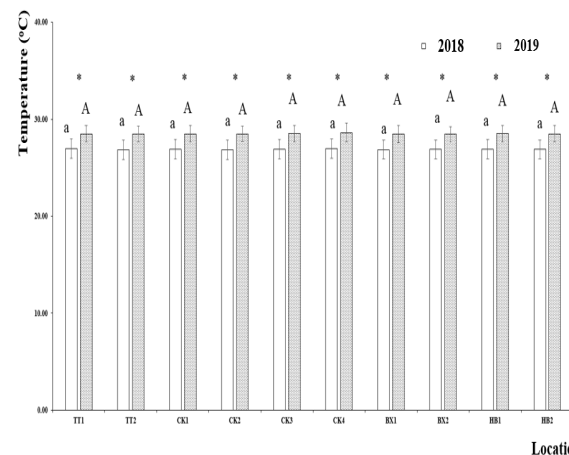


Fig 1. Temperature in canals in Ninh Kieu district, Can Tho city in 2018-2019

The pH values in 2018 and 2019 were presented in Figure 2. pH in 2018-2019 was in the range of 7.01 ± 0.26 - 7.38 ± 0.37 , in which, the CK4 position was significantly different from the other years ($p < 0.05$).

In 2018, the maximum pH value was 7.38 ± 0.37 at TT2 position and the lowest was 7.01 ± 0.26 at CK3 position. It can be seen that this CK3 position was statistically significant ($p < 0.05$) different from the other locations (except for CK1 and CK2). pH in all locations fluctuates around the neutral pH value ($pH = 7$), without affecting the life of the aquatic organism (Phu and Ut, 2006). In 2019, there was no significant difference in pH values at the survey locations (7.03 ± 0.29 - 7.20 ± 0.24). All pH values in locations from TT1 to HB2 in 2018 and 2019 in the canals in Ninh Kieu district, Can Tho city were within the allowable limit of column A ($pH = 6-8.5$) of QCVN 08-MT: 2015/BTNMT. Similar to the other studies, pH in the main rivers and tributaries of Hau River in 2016 fluctuated from 6.3-8.0 (Lien *et al.*, 2016) and the water bodies in the Mekong delta from freshwater to saline water from 7.27-7.92 (Giao and Nhien, 2020; Giao, 2020). pH and temperature do not highly fluctuate in the water bodies in Ninh Kieu district since it is common condition in tropical region (Chounlamany *et al.*, 2017).

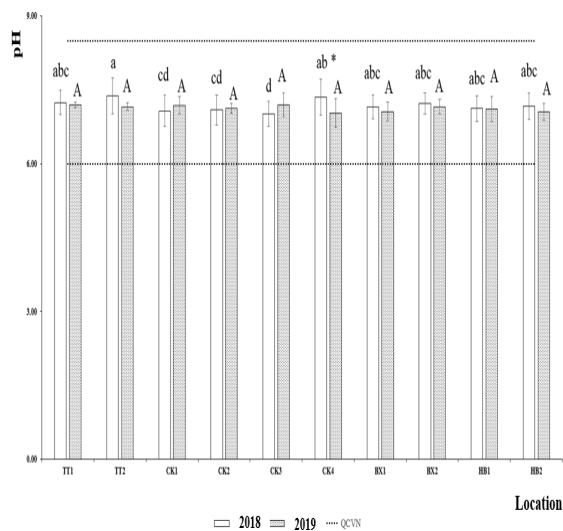


Fig 2. pH in canals in Ninh Kieu district, Can Tho city in 2018-2019

Turbidity and total suspended solids: Turbidity in the two years 2018 and 2019 through the survey locations was relatively large, fluctuating in the range from 18.82 ± 10.22 to 47 ± 32.02 NTU (Figure 3). There was no significant difference in turbidity at the survey locations ($p > 0.05$). Turbidity in 2019 tended to be higher than that in 2018. Turbidity in 2018 in the positions from TT1 to HB2 fluctuated slightly (18.82 ± 10.22 - 30.64 ± 15.21 NTU) and was not significantly different in the survey locations ($p > 0.05$). Turbidity in 2019 at 10 locations was shown in Figure 3, showing that CK4 position had the highest value (47 ± 32.02 NTU) and was significantly different from the other

locations, excepting BX1, BX2 and HB1. Turbidity in the rivers and canals in the Vietnamese Mekong delta ranged from 3.25-59.17 NTU (Giao and Nhien, 2020), ranged from 12.6 ± 7.2 to 131.8 ± 62.3 NTU in the river (Zeinalzadeh and Rezaei, 2017). The national technical standards on water quality does not regulate the turbidity parameters. Normally, turbidity high results in high in total suspended solids (TSS), therefore, the QCVN 08-MT: 2015/BTBMT only sets the standard for TSS.

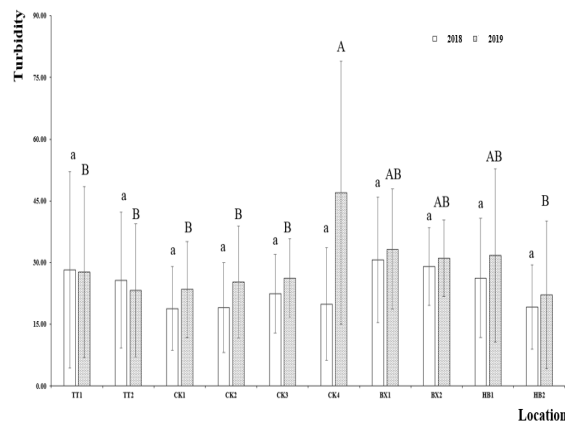


Fig 3. Turbidity in canals in Ninh Kieu district, Can Tho city in 2018-2019

TSS over the two years 2018 and 2019 have a relatively large difference (Figure 4). TSS at the locations TT2, CK3, CK4 exceeded the allowable standard for column A2 and at the remaining sites all exceeded the permitted standard of column A1 of QCVN 08-MT: 2015/BTNMT. In addition, the results showed that there was no significant difference in TSS between 2018 and 2019 ($p > 0.05$). The mean TSS concentration at all locations in 2018 ranged from $(16.09 \pm 7.03$ - 37.09 ± 21.71 mg/l). At TT2 position, the highest TSS concentration (37.09 ± 21.71 mg/l) was significantly different from CK1, CK2, BX2 and HB2 positions ($p < 0.05$). TSS concentration at the locations CK1 and HB2 did not exceed the standards of QCVN 08-MT: 2015/BTNMT, column A1 and A2. The mean TSS concentrations at the survey locations in 2019 fluctuates relatively large, in which, the highest value was still at the position TT2 (42.73 ± 14.78 mg/l) and the lowest at HB2 position (17.91 ± 14.10 mg/l), and were significantly different ($p < 0.05$). Only TSS at HB2 position did not exceed the standard of QCVN 08-MT: 2015/BTNMT, column A1 (20 mg/l) and column A2 (30 mg/l). Sources of TSS could be from improper disposal of garbage, growth of phytoplankton, and overflow water from the streets and river banks. TSS in Hau River was from 41.2 ± 33.7 to 89.57 ± 31.31 mg/L (Lien *et al.*, 2016), TSS in Hau river in 2018 was 41.16 ± 35.81 - 48.67 ± 9.07

mg/L (Giao, 2020), TSS in water bodies in An Giang province was 25.0 ± 11.5 to 93.7 ± 28.3 mg/L (Ly and Giao, 2018), and TSS in water bodies in Soc Trang province was 16-176 mg/L (Tuan *et al.*, 2019). TSS is the main concern for water quality in the Vietnamese Mekong delta since it results in lower water quality and higher treatment cost (Giao, 2020).

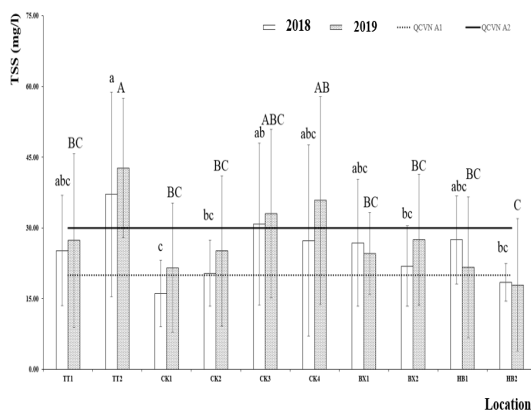


Fig 4. TSS in canals in Ninh Kieu district, Can Tho city in 2018-2019

Dissolved oxygen, chemical and biological oxygen demand: The mean dissolved oxygen concentrations across the survey points from TT1 to HB2 in 2018 and 2019 were relatively large (Figure 4). DO in the positions CK1, CK2, BX1, BX2 and HB2 were statistically significant difference ($p < 0.05$), in which DO in 2019 was lower than that in 2018. As in Figure 4, DO at the survey points was lower than the permissible limits in column A1 and A2 of QCVN 08-MT: 2015/BTNMT. The highest DO concentration in 2018 was recorded in the HB2 position (6.03 ± 0.50 mg/l) and the lowest in the TT2 position (3.87 ± 1.13 mg/l).

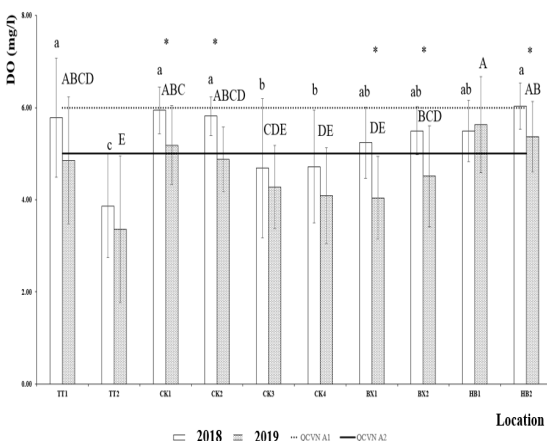


Fig 5. DO in canals in Ninh Kieu district, Can Tho city in 2018-2019

Dissolved oxygen concentrations in 2019 ranged from 3.36 ± 1.59 - 5.63 ± 1.04 mg/l. It was showed that only CK1, HB1 and HB2 positions had DO meet the

permitted standards. The largest fluctuation in position TT2 (3.36 ± 1.59 mg/l) was significantly different ($p < 0.05$) compared to DO measured at the other locations (except for points CK3, CK4 and BX1). DO in the water bodies in Ninh Kieu district was not really favorite for aquatic organisms (Ongley, 2009). The low DO indicated water quality is contaminated by organic matters.

The higher DO concentration could indicate better self-purification capacity of water bodies. The mean concentrations of COD over the two years 2018 and 2019 at the survey locations was relatively large, ranging from 6.5 ± 3.14 to 25.6 ± 11.34 mg/l (Figure 5). There were only three positions (CK1, CK2 and HB2) that did not exceed QCVN 08-MT: 2015/BTNMT. The COD at the positions BX1 and HB1 were significant difference from the rest ($p < 0.05$) and COD in 2019 was lower than that in 2018. COD in 2018 was highest at TT2 (25.6 ± 11.34 mg/l) and significantly different from all remaining positions ($p < 0.05$).

The lowest value was found in the position BX2 (7.3 ± 3.42 mg/l). Compared with QCVN 08-MT: 2015/BTNMT, the positions CK1, CK2, BX2 and HB2 did not exceed standard column A1 (10 mg/l) and column A2 (15 mg/l), the remaining points exceeded both column A1, A2. COD in 2019 from TT1 to HB2 positions ranged from 6.5 ± 3.14 to 22.9 ± 16.50 mg/l. TT2 position had the highest value (22.9 ± 16.50 mg/l) and was significantly different from the rest positions ($p < 0.05$). COD at the positions TT1, CK1, CK2, HB1 and HB2 did not exceed the permitted values in QCVN 08-MT: 2015/BTNMT. In Hau River, COD ranged from 11.68 ± 3.76 - 13.54 ± 4.72 mg/L (Giao, 2020) considered nutrient-rich (Cat *et al.*, 2006). In this study, COD indicated that the water bodies in Ninh Kieu district ranged from medium to rich, also indicating polluted water quality.

BOD over 2 years (2018 and 2019) was shown in Figure 6. Figure 6 showed that BOD in 2018 tended to be higher than those in 2019, across the locations from TT1 to HB2. However, at the survey sites, there was no significant difference between the two years ($p < 0.05$), except for the position HB1. In 2019, BOD in HB1 was lower than that in 2018. The reason may be due to the good management of wastes from polluting activities in the study area. At the position TT2, BOD was high in both 2018 and 2019. BOD at all locations over the past two years exceeded QCVN 08-MT: 2015/BTNMT, especially BOD at the position TT2 in 2018 exceeded the permitted standard 5 times and exceeded 4 times in 2019.

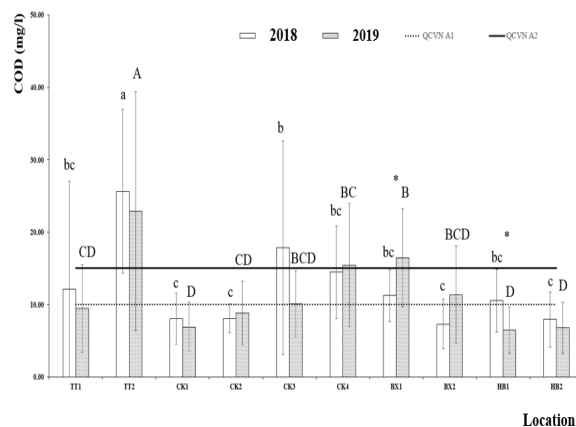


Fig 6. COD in canals in Ninh Kieu district, Can Tho city in 2018-2019

Former studies presented that BOD concentration in water bodies in An Giang province was 6.6 ± 1.2 - 8.2 ± 2.5 mg/L (Ly and Giao, 2018) and in Soc Trang province was 2.2 - 22.4 mg/L (Tuan *et al.*, 2019). BOD and COD are water quality parameters which can indicate organic pollutants (Kazi *et al.*, 2009) originating from livestock, landfills, domestic activities, services, and other activities (MRC, 2015).

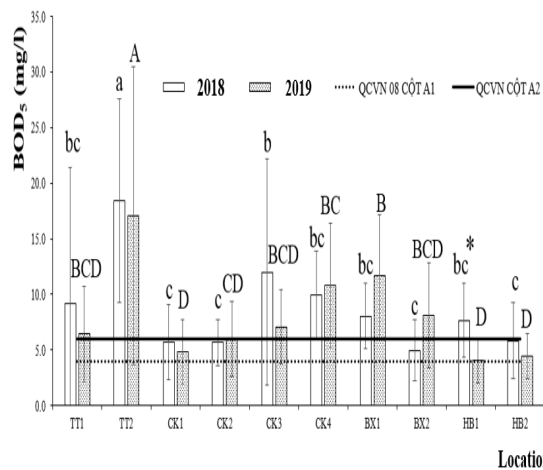


Fig 7. BOD in canals in Ninh Kieu district, Can Tho city in 2018-2019

Ammonia, nitrite and nitrate: From the results of Figure 7 shows, the concentration of N-NH₄⁺ across the positions changed greatly. There was a large concentration difference between the locations. At the positions TT2, CK3, CK4, BX1, BX2, the concentration of N-NH₄⁺ was high and exceeded the permitted threshold of QCVN 08-MT: 2015/BTNMT. The remaining positions such as TT1, CK1, CK2, HB1, HB2 were lower than the standard. Ammonium concentration in the Mekong delta ranged from 0 to 0.94 mg/L (Giao and Nhien, 2020) which was higher

than the permitted level indicating nutrient-rich water bodies.

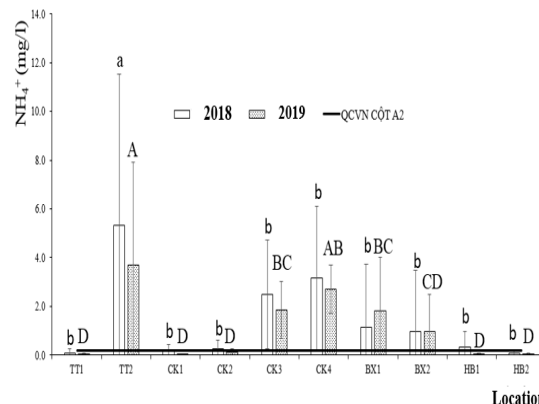


Fig 8. Ammonium in canals in Ninh Kieu district, Can Tho city in 2018-2019

Figure 8 showed the fluctuation of NO₂⁻ at all locations in the period 2018-2019. Results showed that at the CK2 position, nitrite concentration was significantly different between two years ($p < 0.05$). In 2018, NO₂⁻ at the BX2 site was the highest concentration (0.7 ± 1.4 mg/l). In 2019, the CK3 position has the highest concentration (0.2 ± 0.2 mg/l) and HB2 has the lowest concentration (0.0 ± 0.1 mg/l) of NO₂⁻. The results showed that the nitrite concentration exceeded the standard QCVN 08-MT: 2015/BTNMT. NO₂⁻ at position BX2 exceeded 67 times in 2018 and NO₂⁻ at position CK3 exceeded 19 times in 2019. The occurrence of nitrite in water bodies in Ninh Kieu district was consistent with the measurement of DO (low) and ammonium (high) in the previous discussion. Nitrite is the intermediate substance generated by the oxidation of ammonia under presence of ammonia oxidizing microorganisms. Nitrate could form nitric acid and cause toxicity for aquatic species (Giao *et al.*, 2017).

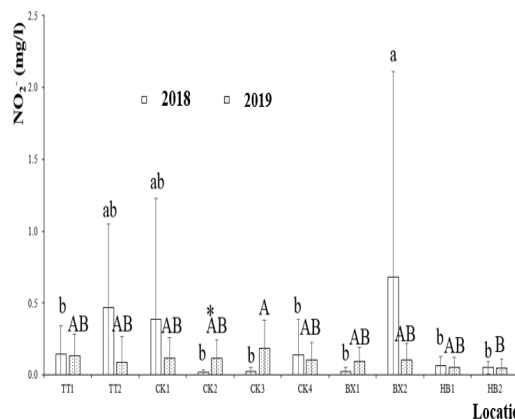


Fig 9. Nitrite in canals in Ninh Kieu district, Can Tho city in 2018-2019

The highest concentration of $N-NO_3^-$ was found at position BX2 (1.5 ± 0.9 mg/l), and the lowest was found at CK1 (0.8 ± 0.5 mg/l). In 2019, $N-NO_3^-$ did not exceed the permitted level in QCVN 08 - MT: 2015 / BTNMT in column A1. In 2018, $N-NO_3^-$ at the positions TT2, CK4, BX2 exceeded the permitted threshold of QCVN 08-MT: 2015/BTNMT, column A1. There is no risk of eutrophication in the water bodies in Ninh Kieu district. Previous studies indicated NO_3^- -N in water bodies in An Giang province was 0.31 ± 0.3 to 0.58 ± 0.64 mg/L (Ly and Giao, 2018), in Soc Trang province was 0.05-0.14 mg/L (Tuan *et al.*, 2019). Nitrate does not exceed the permitted standard QCVN 08-MT: 2015/BTNMT, column A1, in most studies of nitrate in rivers in the Vietnamese Mekong delta. Ongley (2009) stated that the concentration of $N-NO_3^-$ of greater than 0.7 mg/L possibly result in eutrophication. The suitable range of nitrate for aquaculture is from 2-10 mg/L (Boyd, 1998). Nitrate is not the problem for human health and aquatic ecosystems in the water bodies in the present study, however, if the DO increases and the waste sources would not be controlled, nitrate could potentially cause serious pollution for the water bodies.

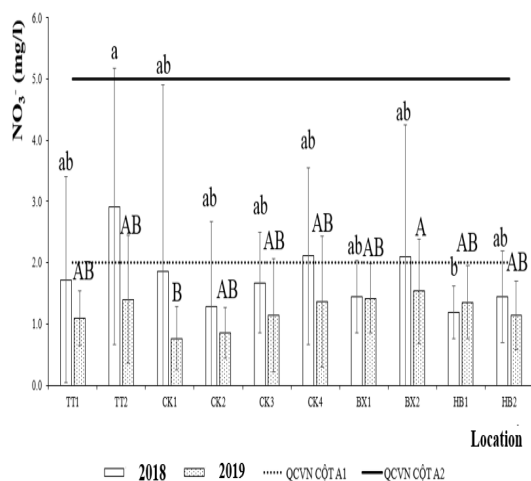


Fig 10. Nitrate in canals in Ninh Kieu district, Can Tho city in 2018-2019

Orthophosphate: The concentrations of orthophosphate in the water bodies in Ninh Kieu district were presented in Figure 10. Orthophosphate concentrations in 2019 across the locations did not have significant differences ($p > 0.05$). The dissolved phosphate concentrations in 2018 were the highest at TT2 (5.0 ± 4.2 mg/l), and the lowest at TT1 (1.3 ± 2.0 mg/l). Orthophosphate concentrations at the position of CK4 and BX1 were significantly different ($p < 0.05$) between 2018 and 2019. Orthophosphate concentrations exceeded the permitted threshold (column A2: 0.2 mg/l) of QCVN 08-MT:

2015/BTNMT. Orthophosphate concentrations at all locations in 2019 were higher than those in 2018. Thus, water pollution due to phosphate tends to increase, and appropriate management measures are required. Orthophosphate in river system in An Giang province was 0.02-0.47 mg/L (Ly and Giao, 2018), water bodies in Soc Trang province was 0.05-0.9 mg/L (Tuan *et al.*, 2019) and in the river of Marikina (Philippine) was 0.60-0.79 mg/L (Chounlamany *et al.*, 2017). The allowable concentration of orthophosphate according to the national regulation (QCVN 08-MT: 2015/BTNMT) is 0.1 mg/L which is far exceeding the actual measurement at the study area and those in former studies. The water bodies in Ninh Kieu district are highly at risk of eutrophication. Eutrophication can have serious effects, like algal blooms that block light from getting into the water and harm the plants and animals that need it. If there's enough overgrowth of algae, it can prevent oxygen from getting into the water, making it hypoxic and creating a dead zone where no organisms can survive (Onley, 2009).

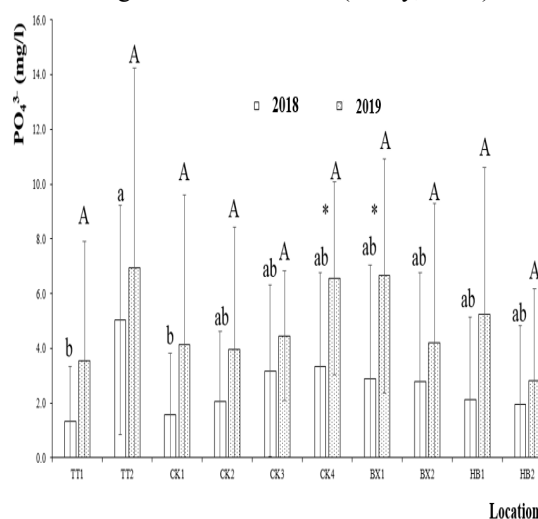


Fig 11. Orthophosphate in canals in Ninh Kieu district, Can Tho city in 2018-2019

Coliforms: Coliforms between 2018 and 2019 at the positions CK1, CK2, CK3 were significant difference ($p < 0.05$). The mean density of coliforms in 2018 tended to be higher than in those in 2019. In 2019, highest density of coliforms was found at the location TT1 (9584.5 ± 14406.8 MPN/100ml) in 2019. Coliform at all locations in 2018 and 2019 exceeded the allowable limits of QCVN 08-MT: 2015/BTNMT, column A1. Similar to other studies, the presence of coliforms is the largest constraints for safe water use in the Vietnamese Mekong delta water bodies (Onley, 2009; Lien *et al.*, 2016; Ly and Giao, 2018; Tuan *et al.*, 2019). The frequent occurrence of coliforms in the water bodies indicates the human and animal wastes,

especially the fecal materials are currently not well managed (Bolstad and Swank, 1997).

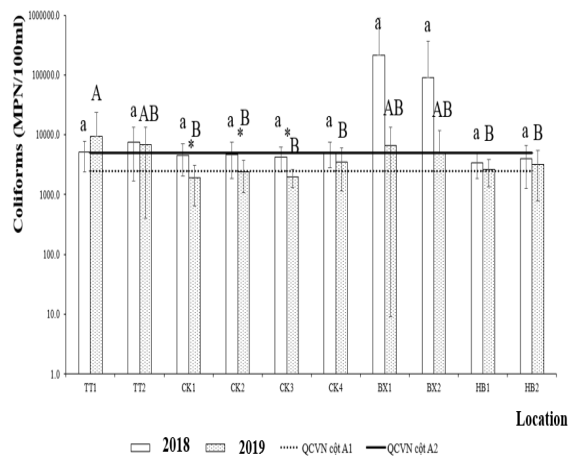


Fig 12. Coliforms in canals in Ninh Kieu district, Can Tho city in 2018-2019

Water quality index: The calculation results of WQI showed that the surface water quality in Ninh Kieu district in 2018 ranged from heavy pollution to good (WQI = 15-90), in which the positions BX1 and BX2 were heavily polluted. The reason could be because BOD and coliforms were highly presented. The water quality at the locations CK1, CK2, HB2 was better quality, suitable for domestic water supply purposes but need appropriate treatment measures. In 2019, the water quality in the study area was better with the WQI value ranging from 26 to 90, indicating water quality from moderate pollution to good. The values of WQI at BX1 and BX2 positions of 2018 were higher than those of 2019, proving that the water quality has been improved.

Conclusion: Surface water quality in the water bodies in Ninh Kieu district, Can Tho city during 2018-2019 was examined. The water environment was different at various water bodies and years. The overall water quality by WQI was from heavy pollution to good and limited water supply capacity for the inhabitants, in which water quality in 2019 tended to be better than that of 2018. Most water quality parameters tended to decrease in the period from 2018-2019 (expected $P-PO_4^{3-}$). The water quality in Tham Tuong canal were more polluted than those in other water bodies.

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