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SURFACE WATER QUALITY IN THE CANALS INFLUENCED BY AGRICULTURAL ACTIVITIES IN AN GIANG PROVINCE

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Abstract

Surface water plays an important role in human life and ecosystems. Monitoring surface water quality to identify tendency and causes of change, and to propose management solutions is very necessary. This study evaluates surface water quality in the canals of An Giang province in the periods from 2009 to 2016 using water quality monitoring data provided by the Department of Natural Resources and Environment of An Giang province. The results show that the surface water quality of the canals is contaminated by organic matter and microorganisms and is unsuitable for the water supply as well as the conservation of aquatic life. The water quality parameters such as dissolved oxygen (DO), biological oxygen demand (BOD), total suspended solids (TSS), orthophosphate ($P\text{-}PO_4^{3-}$) and coliform levels in the wet season are found to be higher than those in the dry season. The problem of organic pollution and microorganisms has been known for over a long period of time, but no solution has been found out. Agriculture is the main contributor to the pollution of surface water in interior canals along with daily and industrial activities. This impacts the surface water of the Hau river due to its water exchange with the connected canals. Thus, good agricultural practices should be implemented to reduce the pollution of surface water resources in Mekong Delta.

Keywords: Surface water quality; In - field canals; Suspended solids; Dissolved oxygen concentration; Coliforms.

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1. Introduction

An Giang is an upstream province of the Lower Mekong River System and one of the four key economic regions of the Mekong Delta. It has a unique hydrological regime and closely relies on the Mekong river water regime with two major rivers: the Tien river (80 km long) and the Hau river (100 km long). In addition, An Giang also has a natural canal system spreading across the province with a length of several kilometers to several tens of kilometers. The system of rivers and canals of the province has 280 routes with a general density of about 0.72 km/ km^2, creating favorable conditions for the development of agricultural, industrial and service economy. In 2012, the agricultural production value of the province was over VND 8,000 billion and is increasing over the years (up 2.3% compared to that of 2011) [1]. Average GDP growth rate was 8.63% during the periods 2011 - 2015 [2]. Along with the socio - economic development, environmental pollution in general and surface water pollution in particular are becoming increasingly serious. In agricultural production, due to

the overuse of plant protection chemicals or pesticides, polluted water sources in canals and ditches are adversely affecting human health and the environment. Aquaculture is contaminating the water due to mass farming, lack of planning, improper technical processes along with the large amount of misused feeding. In industry, the development of construction and service industries has been increasing in recent years. Industrial zones are still in the development stage; factories and production facilities are still scattered and not concentrated in industrial zones. As a result, untreated or improperly treated waste is one of the causes of water pollution in the rivers. In addition, domestic wastewater from rural to urban areas is not routed through wastewater collection and treatment systems. Hydroelectric dam construction upstream also has a negative impact on the quality of surface water sources of the area. Field canals in An Giang province are directly affected by socio-economic activities such as traditional villages and poor agricultural practices. Regular and long-term water quality assessments of interior canals is an urgent need (1) to identify problems of environmental pollution of surface water, (2) to promptly handle polluting sources to ensure water quality for human health and ecosystems.

2. Methodology

Eight years of data (2009 - 2016) on water quality in the Hau river and field canals including pH, temperature, total suspended solids (TSS), dissolved oxygen (DO), biochemical oxygen demand (BOD), nitrogen nitrate ($NO3^-$-N), orthophosphate (PO_4^{3-}-P), and coliforms were provided by the An Giang Department of Natural Resources and Environment at 20 sampling locations which were shown in Fig. 1. The difference in mean values between the surface water quality parameters at the sampling sites was analyzed by one-way ANOVA using IBM SPSS statistics for Windows, Version 20.0 (IBM Corp., Armonk, NY, USA); Duncan was used to compare the difference in surface water quality parameters at a significance level of 5% ($p < 0.05$). Surface water quality parameters in the studied areas were compared with Vietnamese national technical standard or QCVN 08-MT: 2015/BTNMT.

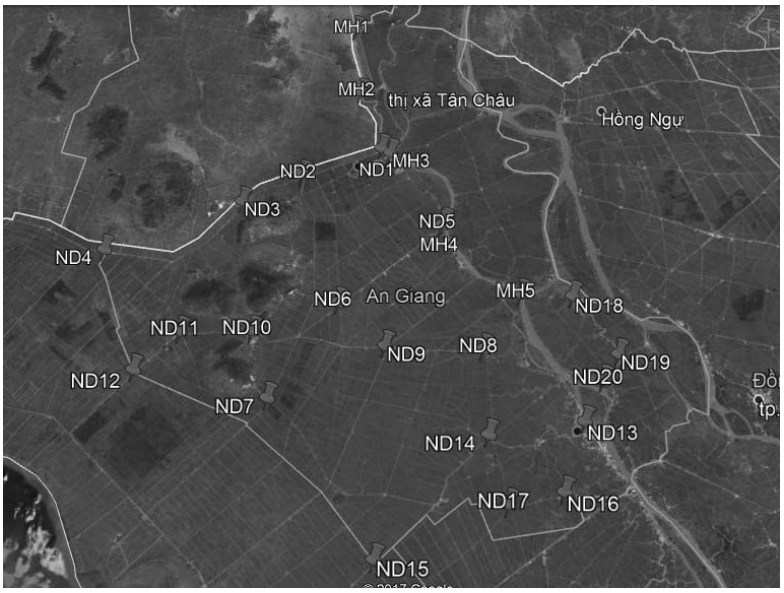

Figure 1: Locations of sampling sites of field canals and the Hau river

From the Fig. 1, ND1 belongs to Chau Doc town; ND2, ND3, and ND6 belong to Tinh Bien district; ND4, ND7, ND10, ND11 and ND12 belong to Tri Ton district; ND5 belongs to Chau Phu district; ND8, ND9, ND14 belong to Chau Thanh district; ND13 belongs to Long Xuyen city; ND15 belongs to Thoai Son district; ND18, ND19, ND20 belong to Cho Moi district; MH2 - MH6 belong to the Hau River.

3. Results and discussion

a) Temperature

Water temperatures in the field canals ranged from 28.1 to 31.3°C with the highest temperature found in the Long Xuyen area (31.3 ± 2.0°C in 2010) and the lowest was in Chau Doc area (28.1 ± 0.9°C in 2014). The water temperature in the Hau River ranged from 27.7 to 31.6°C with the highest temperature in 2009 (31,0 ± 1.0°C) and the lowest in 2015 (28.7 ± 1.9°C). Water temperatures in the dry season were in the range of 29.5 - 30.6°C which were higher than those in the rainy season (28.6 - 29°C) (Fig. 2). The average temperature was the lowest in the Cho Moi area (28.6°C) and the highest in the Hau river (30.6°C). The temperature difference between the Hau river and the field canals in the An Giang province during the rainy and dry season was approximately 2.1°C. The average water temperature over the years in the field canals and the Hau River (Fig. 3) showed that the temperature fluctuated between 29 - 30°C, and averaged at 29.7 ± 0.7°C. There was a significant difference ($p < 0.05$) in temperatures among Chau Phu and Tri Ton, Chau Thanh, Long Xuyen, Thoai Son, and the Hau river.

Generally, the temperature fluctuation in the canals is small in accordance with the temperature of the region. This temperature is suitable for aquatic life [4]. Several studies have suggested that water has the function of regulating the temperature, especially in large and depth canals or rivers.

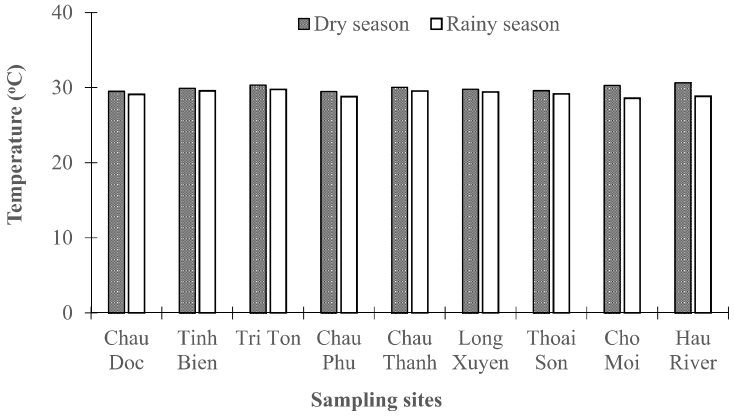

Figure 2: Seasonal and spatial fluctuation of water temperature from 2009 to 2016

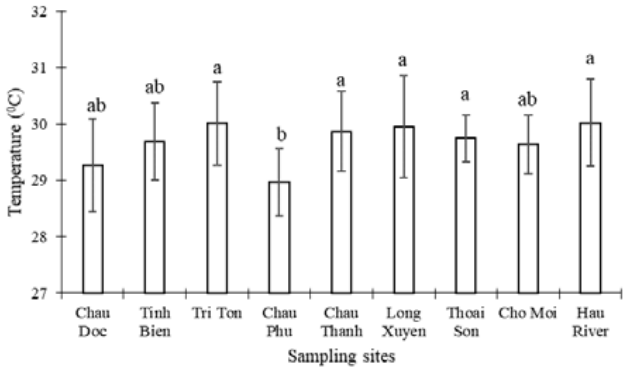

Figure 3: The mean temperatures at different sampling sites over the period of 2009 - 2016. The different letters (^{a,b}) indicate significant level at 5%

b) pH

pH values in the dry and rainy season at all sites ranged from 6.9 to 7.1 indicating a very small seasonal and spatial fluctuation over the period of eight years (Fig. 4).

From Fig. 5, the mean pH values over the years in the study areas varied from 6.7 to 7.1, with an average value of 7.0 ± 0.2. pH value in the Tri Ton area was significantly different from that of Chau Doc, Chau Phu, Long Xuyen, Thoai Son and Hau river ($p<0.05$). The pH of the canals was in line with the one regulated in the national technical standards on surface water quality (QCVN 08-MT:2015/BTNMT).

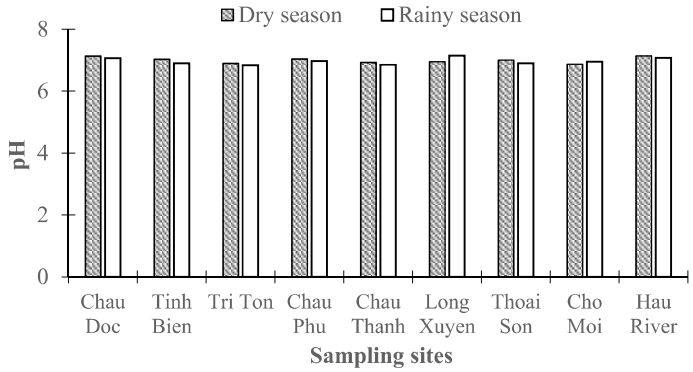

Figure 4: Seasonal and spatial fluctuation of pH of water from 2009 to 2016

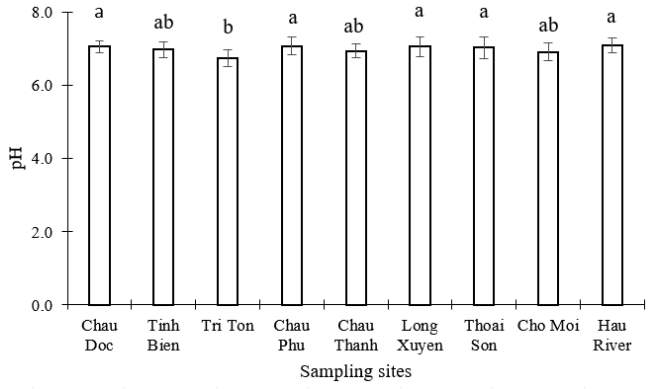

Figure 5: The mean pH at different sampling sites over the period of 2009 - 2016. The different letters (^{a,b}) indicate significant level at 5%

c) Total suspended solids

Total suspended solids (TSS) in the field canals tended to increase over time and exceeded the limit allowed under QCVN 08-MT: 2015/BTNMT. In all survey sites, TSS ranged from 25.0 to 93.7 mg/L in which the lowest concentration (25.0 ± 11.5 mg/L) was found in 2011 and the highest concentration (93.7 ± 28.3 mg/L) was measured in the Tri Ton in 2015. The lowest and highest concentrations exceeded permitted standard by 1.25 and 4.7 times, respectively. The concentration of TSS in the Hau River ranged from 40.1 - 68.0 mg/L which exceeded the allowed standard from 2 to 3.4 times. It could be seen that the level of TSS in the survey areas tended to increase over the years, and TSS values of the canals (smaller rivers) were higher than those in the Hau River (large river). The causes of this difference could originate from the difference in flow rate and water volume between small

and large rivers. In addition, these field canals also directly receive wastewater from agricultural production, surplus feeding from aquaculture and domestic wastewater.

Total suspended solids were significantly different between dry season and rainy season (Fig. 6) in most surveyed sites. In the rainy season, TSS increased dramatically which could be resulted from high rainfall leading to run-off carrying eroded matters into the river in the rainy season. In addition, materials washed away from the river banks also contributed to the increase of suspended solids. The highest TSS concentration was found in Chau Phu (107.8 mg/L) and the lowest one was recorded in the Hau river (28.4 mg/L). The average values of TSS over eight years indicated that TSS was the highest (68.3 ± 21.2 mg/L), and the lowest (39.8 ± 10.1 mg/L) in Tri Ton and Chau Doc respectively. The two sites differed from each other and greatly differed from the other sites ($p < 0.05$) (Fig. 7).

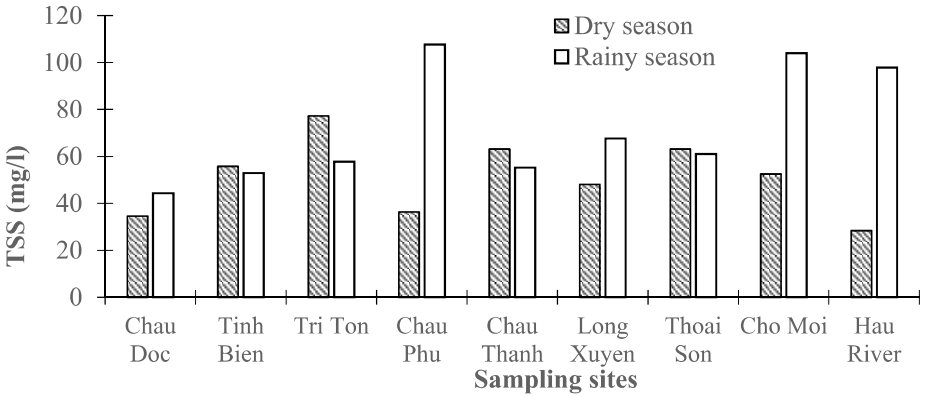

Figure 6: Seasonal and spatial fluctuation of TSS from 2009 to 2016

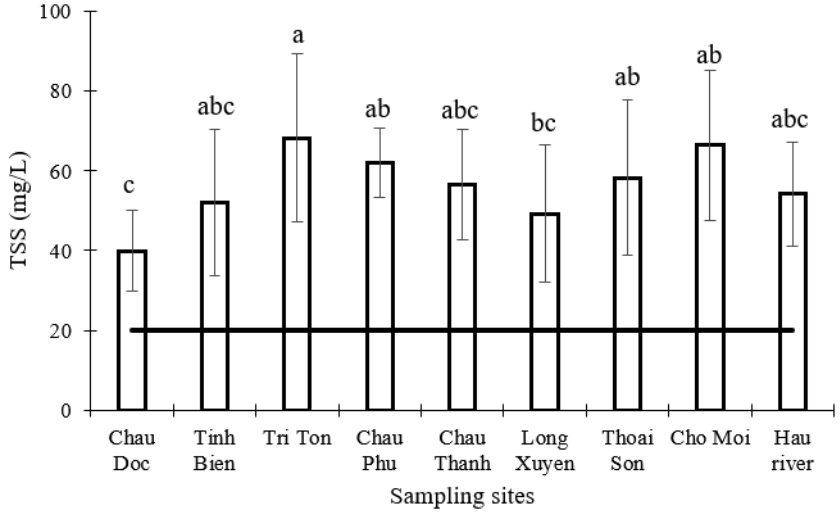

Figure 7: The mean TSS at different sampling sites over the period of 2009 - 2016. The different letters (^{a,b}) indicate significant level at 5%

d) Dissolved oxygen

Fig. 8 shows that the dissolved oxygen (DO) concentration varied unevenly and tended to increase in the period of 2011-2012 and gradually decreased in the period of 2014 - 2016. DO varied from 3,2 - 6.3 mg/L over the eight years period at all sampling sites. The highest value of DO was measured in Chau Phu (6.3 ± 1.1 mg/L) and the lowest was found in Thoai Son (3.2 ± 1.3 mg/L). DO values at all sites were lower

than the permitted level of QCVN 08-MT: 2015/BTNMT except in Chau Phu area (2012) and the Hau river (2014). Dissolved oxygen concentration at the survey sites tended to decrease over the years.

Mean DO in the rainy season and dry season in Hau river and in the field - connected canals were 5.5 mg/L and 4.9 mg/L; 5.3 mg/L and 4.1 mg/L, respectively. The values of DO in the rainy season were higher than those in the dry season in all study sites. The finding in this study was consistent with a prior study which found that the dissolved oxygen concentration in the rainy season was usually higher than in the dry season due to the lower organic content of the rainy season and slower oxidation rates in the dry season [8]. The prior study also found that DO concentrations in the rainy season were higher than those in the dry season in most survey areas in the Hau river [4].

Average DO over the period of 2009 - 2016 (Fig. 9) showed that the DO at the survey sites ranged from 4.0 to 5.2 mg/L and this range was below the allowed threshold of the standard. According to QCVN 08-MT: 2015/BTNMT on surface water quality and Ongley (2009), the limit of DO concentration for aquatic life in the Lower Mekong Basin must be 5mg/L or higher. The DO range in this study suggested that DO concentrations were relatively lower than the one needed for aquatic life reflecting organically polluted water environment. In general, the DO concentrations in the Hau river were higher than those in the field connected/ adjacent with the canals due to the fact that the in - field rivers directly received wastewater containing rich organic matters from agricultural production and daily activities. The decomposition of organic matters consumes dissolved oxygen, thereby reducing DO in water.

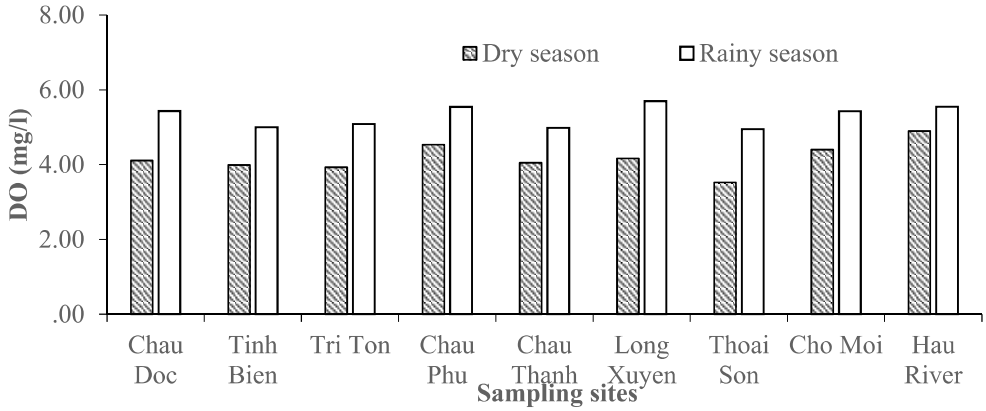

Figure 8: Seasonal and spatial fluctuation of DO from 2009 to 2016

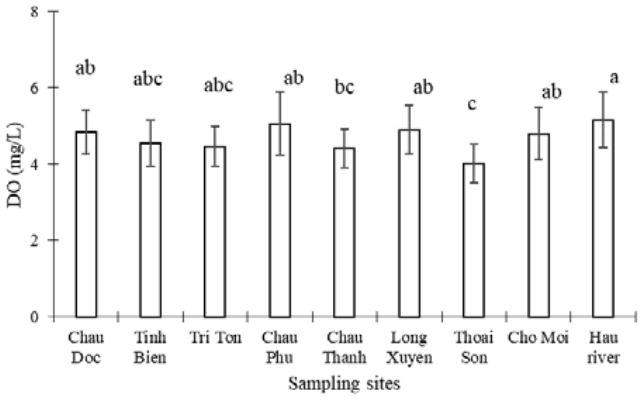

Figure 9: The mean DO at different sampling sites over the period of 2009 - 2016. The different letters (^{a,b}) indicate significant level at 5%

e) Biological oxygen demand

The analysis of the monitoring results indicated that biological oxygen demand (BOD) values in the field - connected canals were relatively low in fluctuation at the survey sites. The highest BOD concentration in Chau Phu area was 12.3 ± 9.2 mg/L (in 2012), the lowest ones in the areas of Long Xuyen were (4.7 ± 1.2 mg/L in 2009), and Chau Thanh (4.7 ± 2.3 mg/L in 2010) respectively. It was clearly indicated that BOD at all monitoring points exceeded the limit allowed by QCVN 08-MT:2015/BTNMT. BOD in the Hau River has not been changed significantly over the years except 2011, which has suddenly surpassed the standard of QCVN 08-MT:2015/BTNMT. The difference in BOD between the Hau river and in - field canals tended to increase over the years.

Fig. 10 showed that the average BOD concentrations in the rainy and dry season in the Hau River area were 5.5 mg/L and 4.9 mg/L respectively, and in-field canals were 5.3 mg/L and 4.1 mg/L respectively. BOD in the rainy season was generally higher than that in the dry season at all sites. From Fig 11, the average BOD values over the period of eight years in the study sites varied between 6.6 ± 1.2 and 8.2 ± 2.5 mg/L reaching the mean value of 7.4 ± 2.2 mg/L. BOD values were relatively stable but they exceeded the permitted level of QCVN 08-MT: 2015/BTNMT from 1.2 to 1.6 times. This indicated that the water quality in the study areas was organically contaminated.

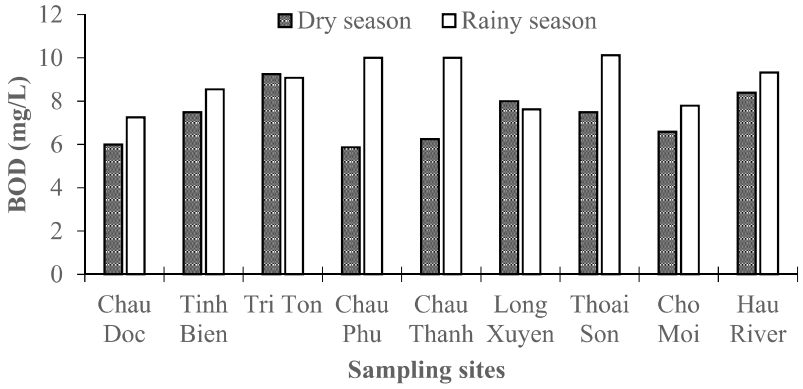

Figure 10: Seasonal and spatial fluctuation of BOD from 2009 to 2016

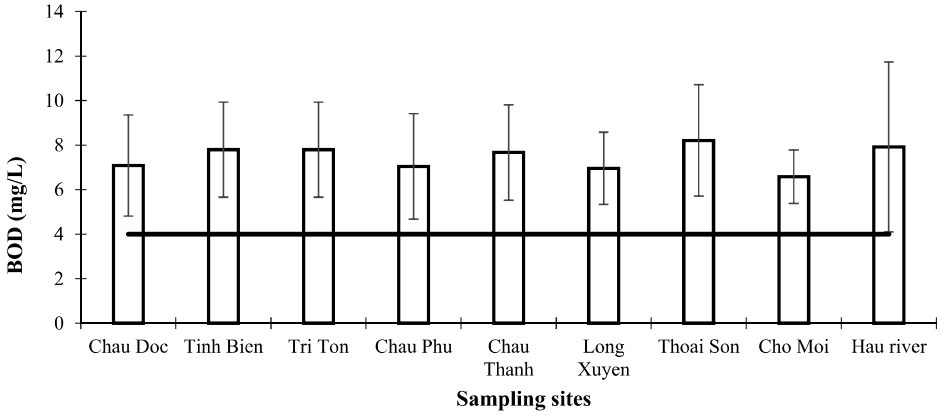

Figure 11: The mean BOD at different sampling sites over the period of 2009 - 2016. The different letters (^{a,b}) indicate significant level at 5%

g) Nitrate

Nitrate ($N\text{-}NO_3^-$) concentrations in the in-field canals fluctuated in the range of 0.03-1.76 mg/L. The highest value was found in Thoai Son (1.79 ± 1,06 mg/L in 2012) while the lowest one was found in Chau Phu (0.03 ± 0.04 mg/L). Nitrate in the Hau River ranged from 0.05 ± 0.03 to 1.45 ± 1.02 mg/L. In general, the concentration of nitrate increased

sharply during the period of 2010 - 2012 and gradually decreased in the period of 2013-2016. Nitrate concentrations in the study areas did not exceed the permitted limit of QCVN 08-MT: 2015/BTNMT.

The nitrate concentration at the survey sites was seasonally fluctuated (Fig. 12). Generally, the nitrate values in the dry season were higher than those in the rainy season at all sites. However, nitrate concentrations were in the tolerable range of aquatic life. According to Phu and Ut (2006), the nitrate concentration suitable for aquatic life was in the range of 0.1 - 10 mg/L. The high nitrate concentration would not be always toxic but it might cause eutrophication ($N\text{-}NO_3^-$ > 0.7 mg/L) which could degrade water quality.

Fig. 13 indicates that the average nitrate level over the period of eight years in the sampling sites varied from 0.31 ± 0.3 to 0.58 ± 0.64 mg/L. The nitrate concentrations were not significantly different ($p > 0.05$) among the sites. The nitrate concentrations were in line with the permitted value of the National Technical Regulation on Surface Water Quality (QCVN 08-MT: 2015/ BTNMT). According to Ongley (2009), the concentration of $N\text{-}NO_3^-$ > 0.7 mg/L would be highly potential for algae bloom. According to Boyd (1998), recommended suitable levels of $N\text{-}NO_3^-$ concentration for aquaculture were from 0.2 - 10 mg/L. There was no risk of nitrate associated with human health and ecosystems.

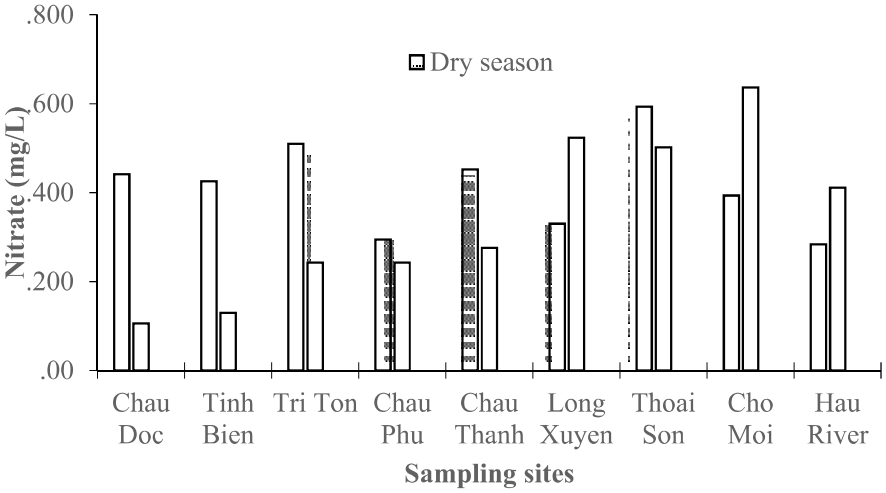

Figure 12: Seasonal and spatial fluctuation of $N\text{-}NO_3^-$ from 2009 to 2016

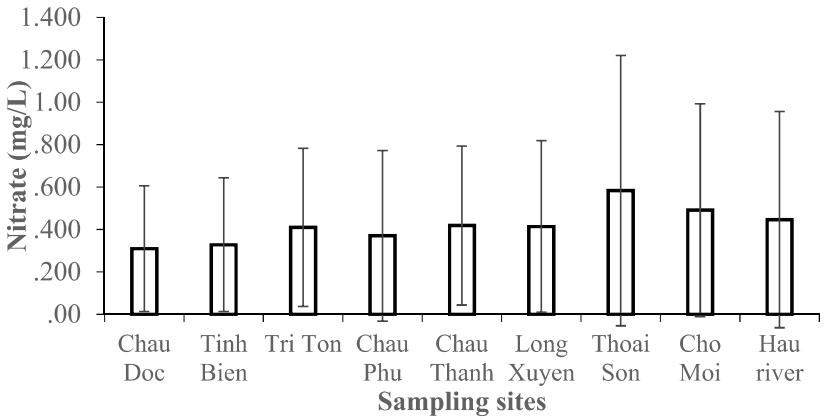

Figure 13: The mean nitrate at different sampling sites over the period of 2009 - 2016

h) Orthophosphate

The results showed that orthophosphate concentration ($P\text{-}PO_4^{3-}$) at the sites in the field canal varied from 0.02 to 0.47 mg/L, and averaged at 0.16 ± 0.12 mg/L. The phosphorus concentrations between the dry and the wet seasons (Fig. 14) at the monitoring points were slightly differed in which orthophosphate in the rainy season was higher than that in the dry season except Cho Moi area. The orthophosphate concentration in the Hau river was lower than that in the in - field canals. This could be because of the volume of water and fertilizers used in agricultural practices and other activities.

The average concentrations of orthophosphate in the study sites for the period 2009 - 2016 (Fig. 15) showed that there was not a significant difference among the study sites ($p>0.05$). However, phosphorus at the monitoring points exceeded the permitted level of QCVN 08-MT: 2015/BTNMT.

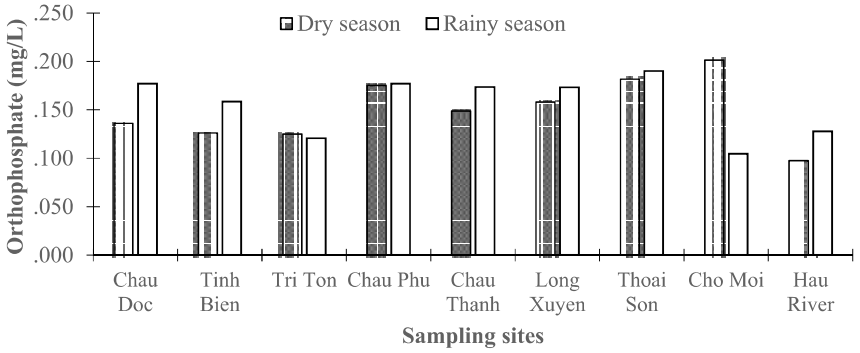

Figure 14: Seasonal and spatial fluctuation of orthophosphate from 2009 to 2016

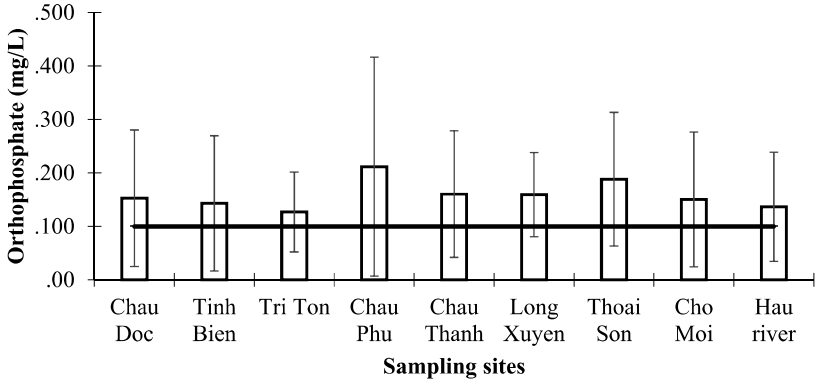

Figure 15: The mean orthophosphate concentration at different sampling sites over the period of 2009 - 2016

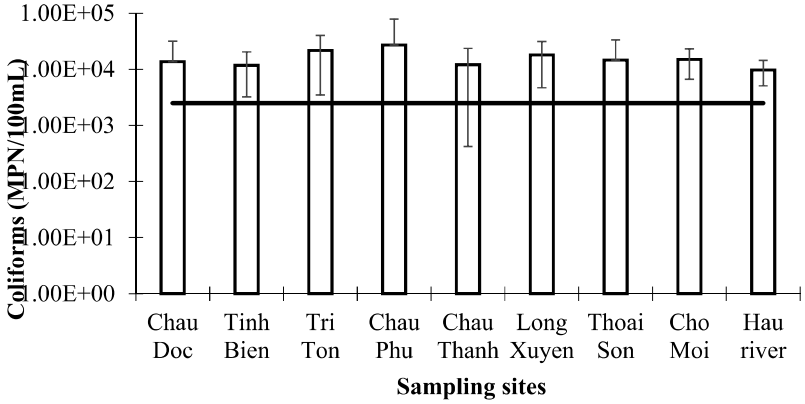

Figure 16: The mean coliforms density at different sampling sites over the period of 2009 - 2016

i) Coliforms

The mean densities of coliforms in the in-field canals ranged from 2.26E + 03 to 1.55E + 05 MPN/100 mL. Coliforms density in the Hau River ranged from 5.36E + 03 to 1.76E + 04, exceeding 2.14 - 7.04 times compared to permitted threshold regulated in QCVN 08-MT: 2015/BTNMT. Coliforms are bacteria that are used to evaluate the quality of natural water, and commonly presented the digestive tract. The presence of coliforms indicated that the water has been contaminated by organic matters originating from human and animal wastes.

4. Conclusion

This study indicated that surface water quality of the in-field canals and the Hau river in An Giang province for the period 2009 - 2016 showed signs of organic and microbial contamination, not meeting the permitted surface water quality for the purpose of domestic water supply, and aquatic life as stated in the national technical standard of QCVN 08-MT:2015/BTNMT. The pollution of the in - field canals was more serious than that in the Hau river which could be attributed to the size of the rivers. The surface water quality parameters such as DO, BOD, TSS, orthophosphate and coliforms tended to be higher during the rainy season indicating their seasonal variations. Agriculture was a major contributor to surface water pollution via the generation of pollutants as non - point sources. The practice of environmentally friendly agriculture should be implemented as soon as possible to limit the pollution of surface water resources of the Mekong Delta.

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