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Characteristics of Surface Water Quality in the Areas of Agriculture and Aquaculture in An Giang Province, Vietnam

Tran Thi Kim Hong[1] and Nguyen Thanh Giao[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 was carried out to evaluate surface water quality in agricultural production and aquaculture areas in An Giang province, Vietnam. Water samples were collected at 42 monitoring locations (23 locations in agricultural areas, 19 locations in fisheries) with 10 surface water quality indicators including temperature, pH, total suspended solids (TSS), dissolved oxygen (DO) biochemical oxygen demand (BOD), chemical oxygen demand (COD), nitrate ($N\text{-}NO_3^-$), ammonium ($N\text{-}NH_4^+$), orthophosphate ($P\text{-}PO_4^{3-}$) and coliforms. Water quality was assessed using national technical regulations on surface water quality (QCVN 08-Mt:2015/BTNMT). The results show that surface water at agriculture and aquaculture areas were contaminated with organic matters (low DO and high TSS, BOD, COD), nutrients (high $N\text{-}NH_4^+$, $P\text{-}PO_4^{3-}$), and microorganisms (Coliform), in which surface water in the agricultural production area tended to be more polluted than that of aquaculture area. The causes of water pollution could be fertilizer residues, wastewater, and untreated solid waste that are discharged directly into the water source. There is urgent need to find out appropriate measures for the management of wastewater from agriculture and aquaculture to improve surface water quality.

1. Introduction

An Giang is the upstream province of the lower Mekong River in the Mekong Delta region. An Giang province is blessed by nature when it has a unique hydrological regime combined with a dense network of rivers, which has created favorable conditions for the development of agricultural production and aquaculture. Since then, agricultural production and aquaculture have become two fields that are considered as two great strengths of An Giang province and are increasingly invested in development compared to other provinces in the same region. Along with the strong economic development, the problem of water pollution, especially surface water pollution from wastewater of agricultural and aquaculture production activities, has become more serious. Many studies show that An Giang province has many typical pollution problems, such as organic and microbial pollution that has taken place for a long time without any treatment; many canals do not circulate, creating flows that cause stagnant water and accumulate pollution making water not suitable for domestic water supply and aquatic life conservation purposes [1-3]. There are many causes of surface water pollution in the area, but the cause of pollution comes from agricultural and fishery activities, the abuse of pesticides in the process of rice cultivation or fertilizer application. Aquaculture production occurs massively, there is a lack of planning, the amount of leftover food in the farming process is not treated, and the waste water of the livestock process is discharged directly into the surface water environment. This study aims to assess the surface quality and

pollution characteristics of each indicator according to the study area, thereby recommending monitoring and issues related to water use.

2. Materials and methods

Surface water samples were collected at 42 locations, in which the aquaculture area has 23 positions, symbols from Agr1 to Agri 23; 19 locations in the aquaculture area (symbols Aqua1 to Aqua19). Surface water samples were collected at a frequency of 3 times per year in the months of March, June and September. The sampling location map is shown in Figure 1.

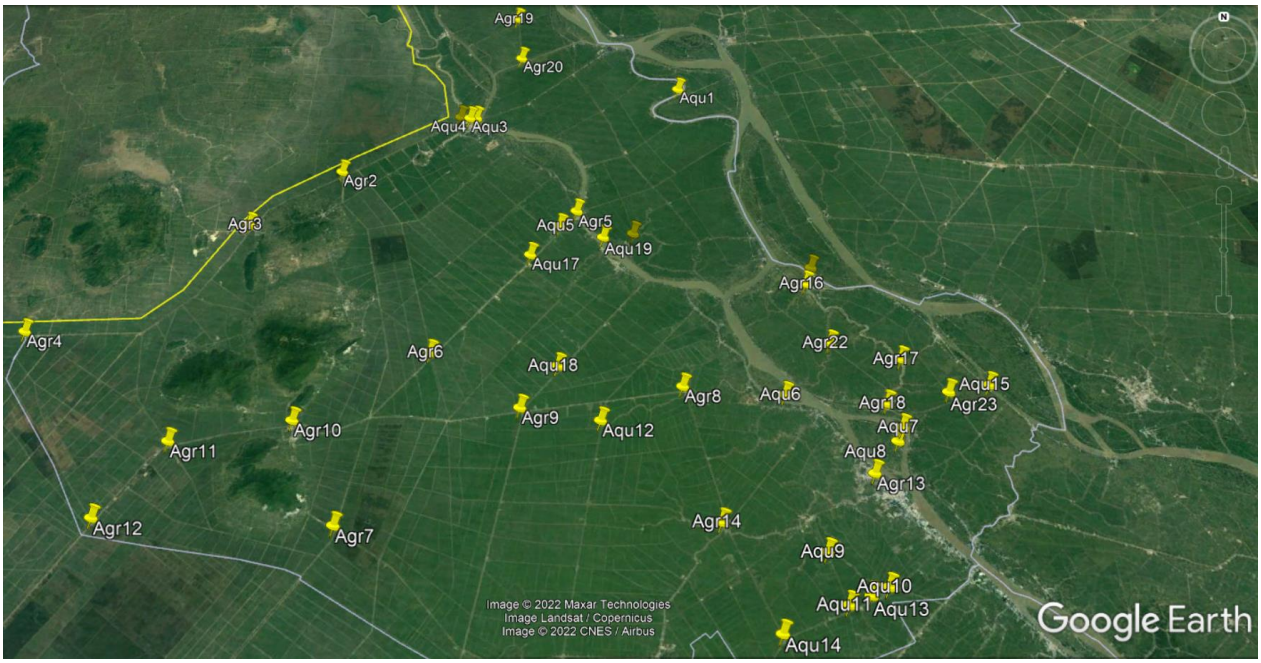

Figure 1. Map of the sampling locations

Ten surface water indicators including temperature, pH, total suspended solids (TSS), dissolved oxygen (DO), biochemical oxygen demand (BOD), chemical oxygen demand (COD), nitrate (N-NO_3^-), ammonium (N-NH_4^+), orthophosphate (P-PO_4^{3-}) and coliform were used to assess surface water quality. In which, the criteria including temperature, pH, DO were measured at the field and the remaining criteria were collected, preserved and analyzed according to the standard methods [4] which is presented in Table 1.

Table 1. Analytical methods and limit values of water quality parameters

No.	Parameters	Analytical methods	Limit values
1.	Temp	SMEWW 2550B:2012	
2.	pH	TCVN 6492:2011	6-8.5
3.	DO	TCVN 7325:2004	≥ 5
4.	COD	SMEWW 5220C:2012	15
5.	BOD	SMEWW 5210B:2012	6
6.	TSS	SMEWW 2540D:2012	30
7.	Nitrate (N-NO_3^-)	SMEWW 4500-NO_3^-.E:2012	5
8.	Ammonium (N-NH_4^+)	SMEWW 4500-NH_3.B&F:2012	0.3
9.	Orthophosphate (P-PO_4^{3-})	SMEWW 4500-P.E:2012	0.3
10.	Coliform	TCVN 6187-2:1996	5,000

3. Results and discussion

Temperature: The water temperature in agricultural areas fluctuates in the range of 28.47 - 31.43 ^{o}C, the Agr21 site has the smallest value and the highest value is at the Agr13 position. In aquaculture areas, the smallest value is at Aqu9 and the largest is at Aqu13, ranging from 29.03 to 30.9 ^{o}C. The temperature difference in the two study areas appears to be different, the temperature in the agricultural area tends to be higher with a larger fluctuation amplitude than that of the aquaculture. Compared with previous studies, the temperature in the study area is similar to that in Tien River (29.35 - 30.2 ^{o}C), Hau River (27.1-32 ^{o}C) and higher than that of Mekong River (19.9 – 32.2 ^{o}C) [1, 5-6]. The temperature in the study area tends to increase gradually in the dry season, then decrease in the rainy season. The temperature in the aquaculture area is always lower than that in agriculture, but there is not a big difference, so it still ensures the normal growth and development of aquatic organisms in the water.

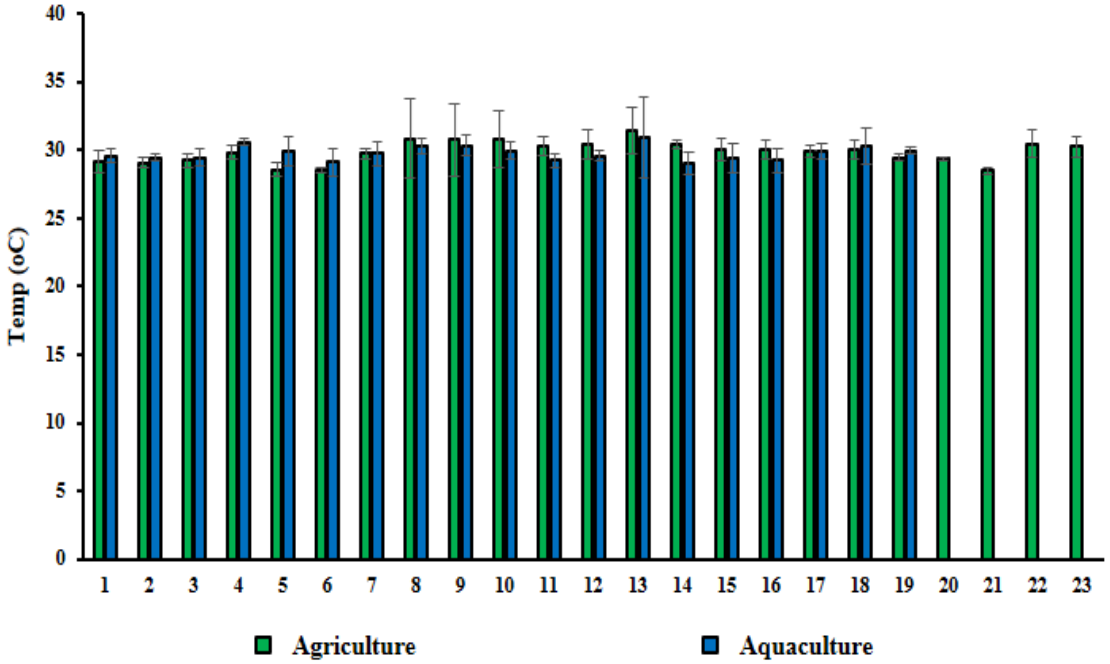

Figure 2. Temperature in the study area

pH: The results of Figure 3 show that the pH value in the study areas do not have too much difference between the values of the two areas, and all monitoring locations are within the allowable threshold for column A2 of QCVN 08- MT:2015/BTNMT when the pH of agriculture fluctuates between 7.02 - 7.33 (highest at Agr16, lowest at Agr3) and pH of aquaculture is about 7.08-7.32, lowest at Aqu16, highest at Aqua5). Agricultural production areas often have lower pH values than aquaculture, but there is not too much difference between the two. Besides, the pH value tends to increase gradually from the dry season to the rainy season. Research by Lien et al. [7], also showed that the pH value in the rainy season is higher than that in the dry season, the pH fluctuating between the main river areas and the Hau River basin ranges from 6.3 to 8.0. If the pH is too high or too low, it is detrimental to the growth of aquatic species [8]. In this study, pH in both types is at neutral level, not affecting organisms in the study area.

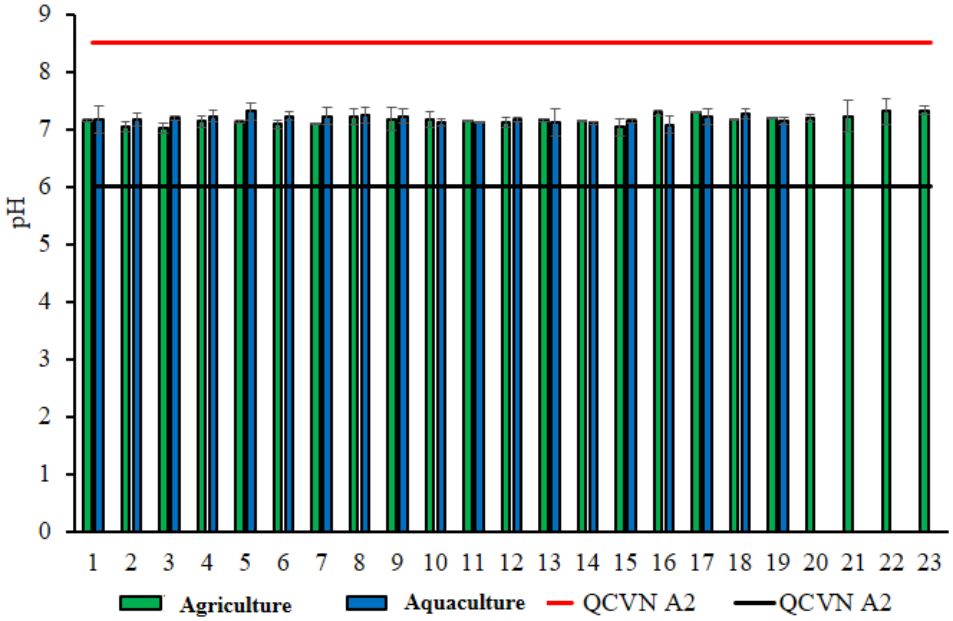

Figure 3. Temperature in the study area

Total suspended solids: Total suspended solids (TSS) in the study area ranged from 42.33 to 69.67mg/L. All TSS monitoring positions in agriculture and aquaculture areas exceeded the allowable threshold according to column A2 of QCVN 08-MT:2015/BTNMT from 1.41 to 2.32 times. Although TSS concentration in the area is at a high level compared with some previous studies such as TSS ranges from 41.2 to 89.57 mg/L in main rivers and tributaries of Hau River [7]. TSS in canals in Soc Trang province reached 16-176 mg/L [9]. When TSS is high, it causes many adverse effects on aquatic life, increases water treatment costs and is a carrier of other pollutants in the aquatic environment [6]. In addition, the high TSS is likely to lead to high organic matters (BOD and COD) in the water leading to organic pollution in the study area. The cause of TSS may come from the study area in the upstream area, the high sediment content in the water column resonates with the flow rate [2].

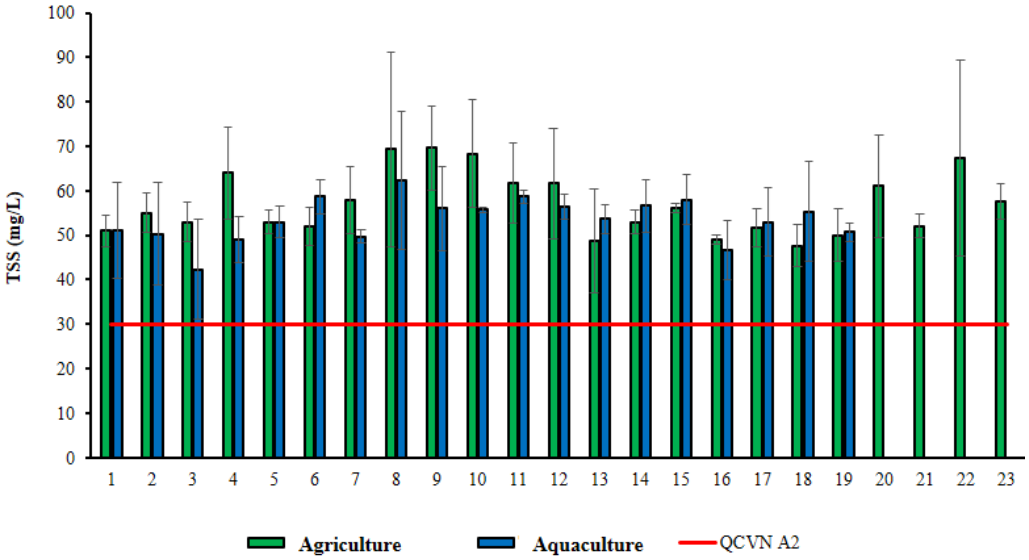

Figure 4. TSS in the study area

In agricultural areas, TSS concentrations ranged from 47.67 (Agr18) to 69.67 mg/L (Agr9) and the lowest in aquaculture was at Aqu3 (42.33 mg/L) and highest at Aqu8 (62.33 mg/L). During the dry season and the rainy season, TSS in agricultural production areas had a higher value than

that in aquaculture. Thereby, TSS in the agricultural production area is much higher than that in the aquaculture area. The cause can be from aquaculture sites that are often located in locations with good circulation or from erosion and the impact of stormwater runoff [6].

Dissolved oxygen: Dissolved oxygen (DO) concentration is essential in the living activities of aquatic organisms, maintaining metabolism and respiration in water. According to MRC [6], suitable dissolved oxygen in water is 5-7 mg/L to ensure normal growth and development of aquatic organisms. Therefore, the fact that many monitoring sites in the study area, especially aquaculture, do not guarantee the DO level, it will greatly affect the species of aquatic animals being cultured, leading to damage to aquatic economy. The analysis results show that the DO concentration in the water in the study area is very low. The DO concentration in the agricultural area ranges from 3.71 to 5.1 mg/L and the aquaculture is 3.39 - 5.52 mg/L. Most of the monitoring sites of study areas are below the allowable threshold according to QCVN 08-MT:2015/BTNMT, column A2. In which, in the agricultural area, only four locations (Agr13, Agr16, Agr17 and Agr18) had DO content reaching the allowable threshold, however, the highest DO value was only 5.1 mg/L and other locations were just met the threshold. Aquaculture with five sites (Aqu2, Aqu5, Aqu8, Aqu9 and Aqu16) reaching the allowable DO threshold and Aqu16 position (5.52 mg/L) was recorded with the highest value in the study areas. Compared with the study of Ly and Giao [1], the concentration in the upstream water bodies of An Giang province fluctuated in the range of 4 - 5.2 mg/L, which was similar to this study. The receipt of wastewater from agriculture, aquaculture, domestic wastewater containing a lot of organic matter is the cause of reducing DO content in water [7].

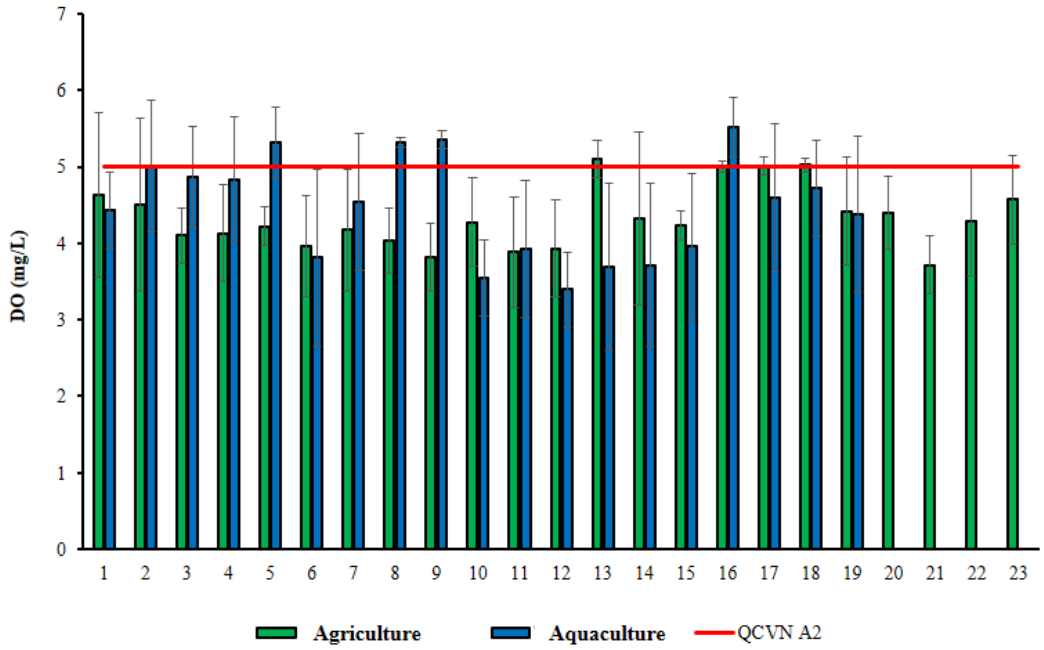

Figure 5. DO in the study areas

Compared with TSS parameter, DO in the study area has more pronounced seasonal variation. DO gradually increases from dry to rainy season. In particular, in the dry season, the DO concentration in agricultural areas had a higher value than that in aquaculture. The time of season change extends to the rainy season when DO in the aquaculture area had a higher value. The cause of this situation may be due to the speed of the flow in the rainy season causing strong water disturbances, increasing the diffusion of oxygen into the water [10].

Biological oxygen demand: The BOD parameter is often used as a proxy for the level of organic pollution in water [11]. Figure 6 shows that the value of agricultural BOD ranges from 8.67 - 22.67 mg/L, average 15.67 mg/L and the BOD of aquaculture ranges from 9 - 23.67 mg/ L, medium (16.335 mg/L). All monitoring sites have BOD content exceeding the allowable threshold according to QCVN 08-MT:2015/BTNMT from 1,445 to 3,945 times. Organic pollution due to high BOD

along with TSS is a common problem of water bodies in the Mekong Delta [6]. The presence of BOD indicates that the study area is suffering from moderate to severe organic pollution (2–8 mg/L) (in excess of 8 mg/L) [12]. This situation is very alarming when they affect aquatic life in the water and are very dangerous to human health when used [13]. Wastewater from untreated agricultural and aquaculture production activities directly into the environment is likely the cause of organic pollution in the study area [14].

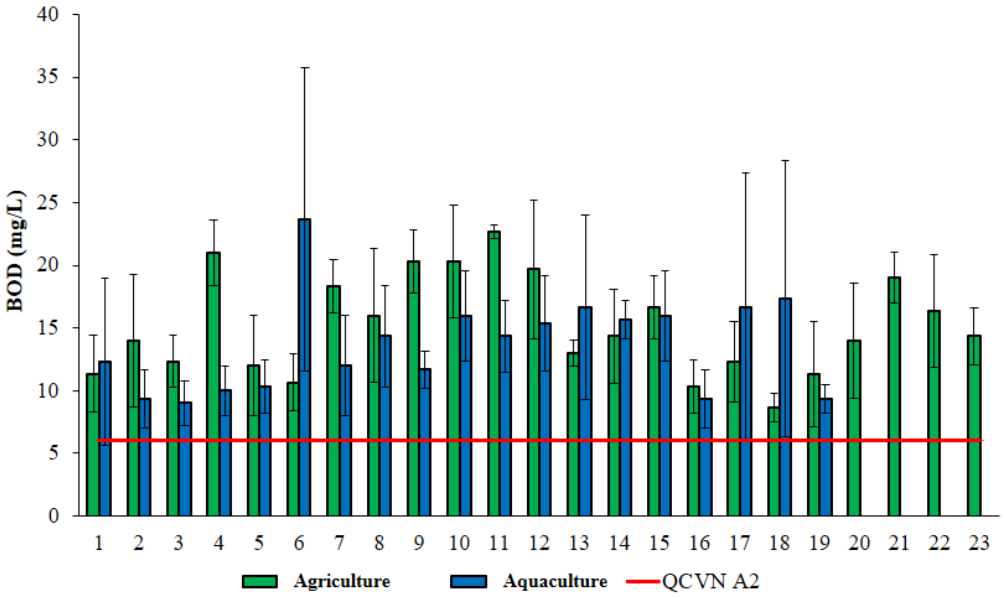

Figure 6. BOD in the study areas

Both studies areas experienced strong seasonal fluctuations in BOD values. The agricultural BOD was higher than the aquatic BOD in both seasons. BOD in agricultural areas reached the highest value in the dry season, then tended to decrease in the changing seasons, peaking in the dry season and the rainy season. Compared with the BOD in the agricultural area, the fishery area has a contrast when the time of the change of season BOD reaches the highest value, decreases to the lowest level in the rainy season. According to previous research by Ly and Giao [1], in river water bodies in An Giang in the period 2009-2016, the BOD concentration in the rainy season is usually higher than that in the dry season. It shows that the present study area is subjected to more organic wastes in the dry season than before and is diluted after the occurrence of rain.

Chemical oxygen demand: The results showed that COD in agricultural areas ranged from 13.33 to 35mg/L, and in aquaculture, COD content was from 13.67 to 36.33 mg/L (Figure 7). There was only one site with COD content within the allowable threshold (Agr18 and Aqu3), all the remaining sites exceed the threshold of column A2 (QCVN 08-MT:2015/ BTNMT). High TSS, high BOD and low DO could be the cause of high COD concentration in the study area. In addition, other causes can originate from wastewater and solid waste from daily activities of people directly discharged into the environment. There are similarities between the seasonal BOD and COD parameters in the study area. In the agricultural sector, COD tends to decrease gradually towards the time of transition, then reaches a high value in the dry and rainy seasons and reaches an almost equal value. In contrast, in the aquaculture area, COD concentration increased from the dry season to the time of transition, then decreased in the rainy season. Although there is a decrease, the COD value at all times of the year is still high.

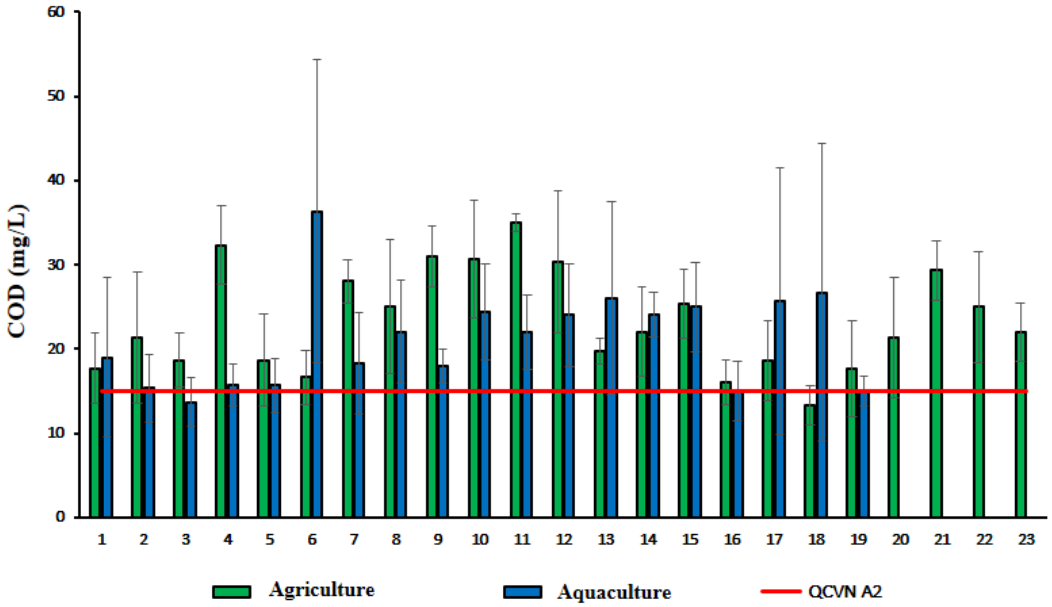

Figure 7. COD in the study area

Nitrate: The $N\text{-}NO_3^-$ concentrations in the study areas ranged from 0.07 to 0.5 mg/L. In which, in the agricultural area, $N\text{-}NO_3^-$ has a value from 0.07 to 0.5 mg/L and in the aquaculture area it is 0.07 to 0.16 mg/L. Comparison with the standard (5.5 mg/L) shows that the $N\text{-}NO_3^-$ concentration in the area is currently very low, suitable for domestic water supply through appropriate treatment technology. Compared with the previous study by Ly and Giao [1], $N\text{-}NO_3^-$ was recorded ranging from 0.31 to 0.58 mg/L in the water bodies of An Giang province, showing that the study has similarities. In addition, the $N\text{-}NO_3^-$ concentration in agricultural areas is still more disparate than that in aquaculture, especially when $N\text{-}NO_3^-$ at locations with higher values than 0.2 mg/L poses a risk of eutrophication [6]. The cause of the appearance of higher $N\text{-}NO_3^-$ concentration in agricultural areas than in aquatic areas can be attributed to excess fertilizers in agricultural wastewater. The $N\text{-}NO_3^-$ concentrations of study areas are similar as both tend to reach high values in the dry season, then decrease sharply at the time of season change and gradually increase in the rainy season.

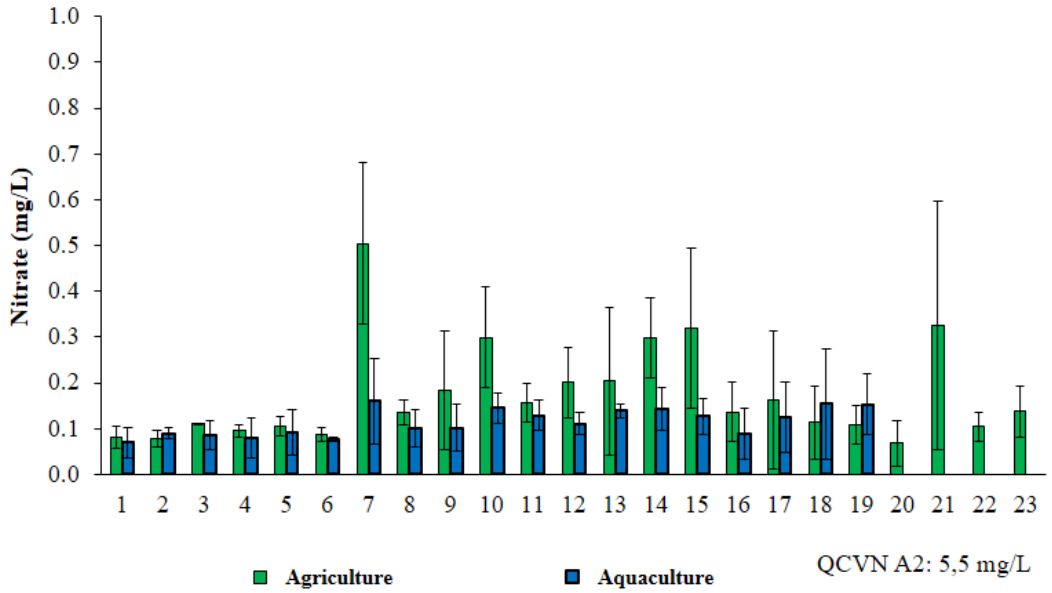

Figure 8. Nitrate in the study area

Ammonium: The results of analysis in Figure 9 show that the $N\text{-}NH_4^+$ concentration in the agricultural area ranges from 0.31 to 2.58 mg/L and in the aquaculture, area ranges from 0.03 to 1. 71 mg/L. The aquaculture area has only 4/19 monitoring positions within the allowable threshold and all the locations of the agricultural area exceed the allowable threshold according to QCVN 08-MT:2015/BTNMT, column A2. The location Agr13 had the highest $N\text{-}NH_4^+$ value in the study area (8.6 times higher than the limit) and Aqu6 position (5.7 times higher than the standard) was the highest in the aquaculture area. It proves that the water source in the study area is at high risk of being contaminated with nutrients. Compared with the previous study of Tuan et al. [9], $N\text{-}NH_4^+$ concentration in river water bodies of Soc Trang province ranges from 0.35 to 4.14 mg/L, which is higher than in the study areas. The cause of high $N\text{-}NH_4^+$ concentration in water can come from domestic waste, wastewater from aquaculture and especially wastewater from the leaching of excess fertilizers in agricultural cultivation resulting risk of eutrophication in the receiving environment [6].

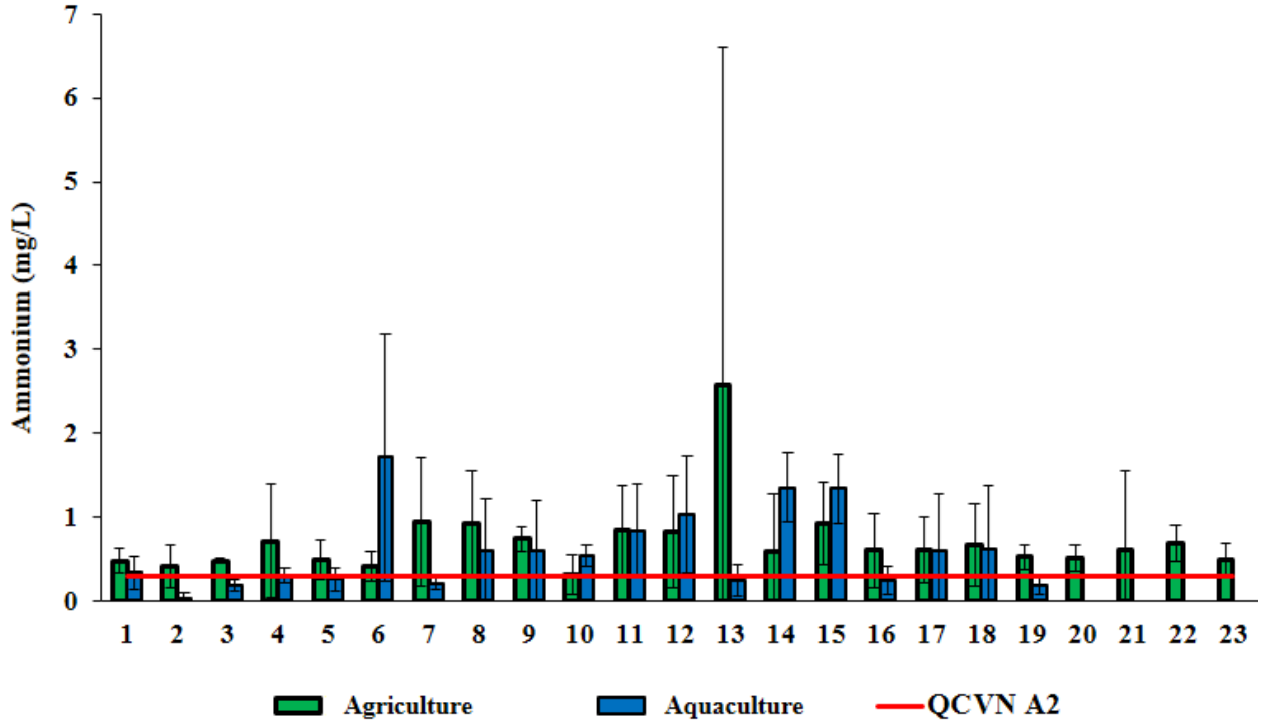

Figure 9. Ammonium in study areas

Although the agricultural area always has a high $N\text{-}NH_4^+$ compared to the aquaculture area, in the dry season and the change of season, $N\text{-}NH_4^+$ in the aquaculture area had a higher value. The rainy season is the time when $N\text{-}NH_4^+$ in the agricultural area had the highest value and vice versa in the aquaculture area the lowest value. According to the study of Giao and Minh [15], $N\text{-}NH_4^+$ concentration fluctuates according to the season, tends to be high in the rainy season and low in the dry season. This is similar to the results obtained in the agricultural area of the study. The aquaculture area had the opposite trend when $N\text{-}NH_4^+$ gradually increases in the dry season, lowers in the rainy season and reaches the highest value at the time of season change. The reason for the opposite trend in the $N\text{-}NH_4^+$ concentration in the aquaculture area may be due to the rainy season, the amount of rainwater diluting the $N\text{-}NH_4^+$ concentration in the environment at the time of monitoring.

Orthophosphate: The results show that the $P\text{-}PO_4^{3-}$ in the agricultural area ranges from 0.05 to 0.91 mg/L and the aquaculture area has the $P\text{-}PO_4^{3-}$ ranging from 0.02 to 0.90. mg/L. Compared with the limit of QCVN 08-MT:2015/BTMNT, column A2, there are four locations (Aqu6, Aqu7, Aqu17 and Aqu18) in the aquatic area and four locations (Agr2, Agr6, Agr13 and Agr20) in the agricultural area have been exceeded the threshold. The remaining positions have the parameter $P\text{-}PO_4^{3-}$ but the

concentration is within the allowable threshold. In which, Aqu6 (0.9 mg/L) and Agr (0.91 mg/L) sites had the highest P-PO_4^{3-} concentration. The cause may come from phosphorus residues in fertilizers, detergents from domestic wastewater and agricultural production activities [11].

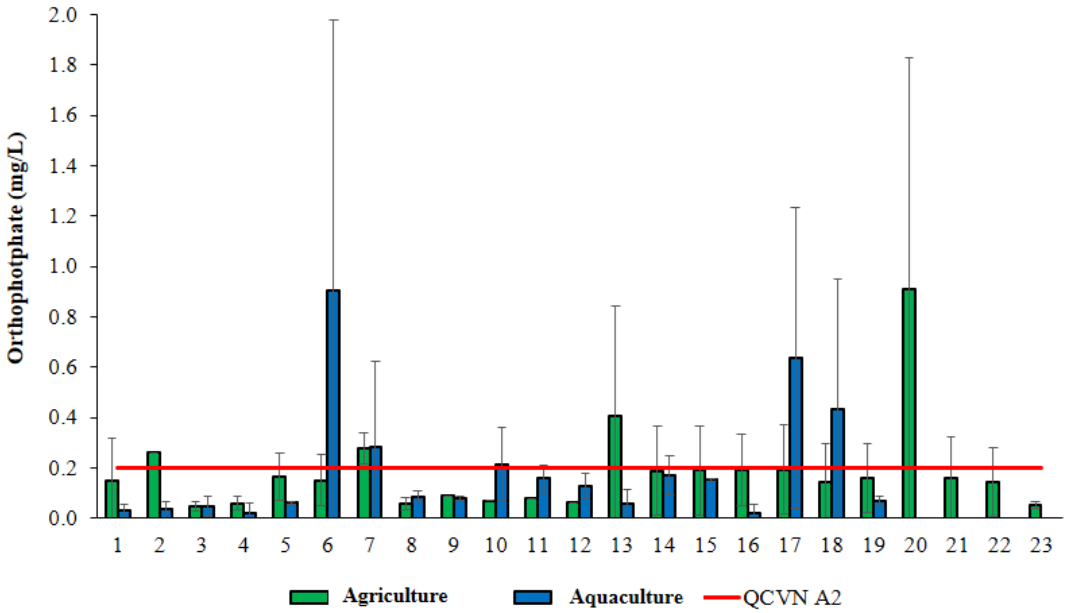

Figure 10. Orthophosphate in the study areas

The seasonal variation in P-PO_4^{3-} of the two types of studies also varied significantly. During the dry season, the agricultural sector recorded P-PO_4^{3-} at a low level, then continued to decrease at the time of the change of season, but increased excessively during the rainy season. Meanwhile, in the fisheries area in the rainy season, the concentration of P-PO_4^{3-} reached the lowest value, then gradually increased in the dry season and reached the highest value at the time of season change. High values of P-PO_4^{3-} together with ammonium and nitrate easily lead to eutrophication in the water, which can cause algae to thrive, which can affect the flow and be detrimental to aquatic species in the water especially for aquaculture area.

Coliform: Coliform concentration in the current study area had a great fluctuation. Specifically, in agricultural areas, coliform concentrations ranged from 5966 to 42866 MPN/100mL (highest in Agr14 and lowest in Agr21) and in aquaculture with values ranging from 6966 - 37666 MPN/100mL (lowest at Aqu18 and highest at Aqu8), exceeding allowable threshold of column A2 of QCVN 08-MT:2015/BTNMT. In which, the coliform in agricultural area exceeds the allowable threshold from 1.19 to 8.57 times and the aquaculture area is 1.39 to 7.53 times. The amount of harmful microorganisms present in the water comes from human and animal excreta. The seasonal evolution of coliform in the study areas was similar when the coliform concentration reached the lowest value in the dry season, then gradually increased and reached the highest value in the rainy season. In the dry season, the agricultural area had higher coliform values than that in the aquaculture area. The value of coliform in the aquatic area began to increase sharply, reaching a higher value than the agricultural area at the time of the change of seasons and the rainy season. The former research by Giao [5] also shows that microbial contamination in water in the Tien River in the rainy season is always higher in value than in the dry season.

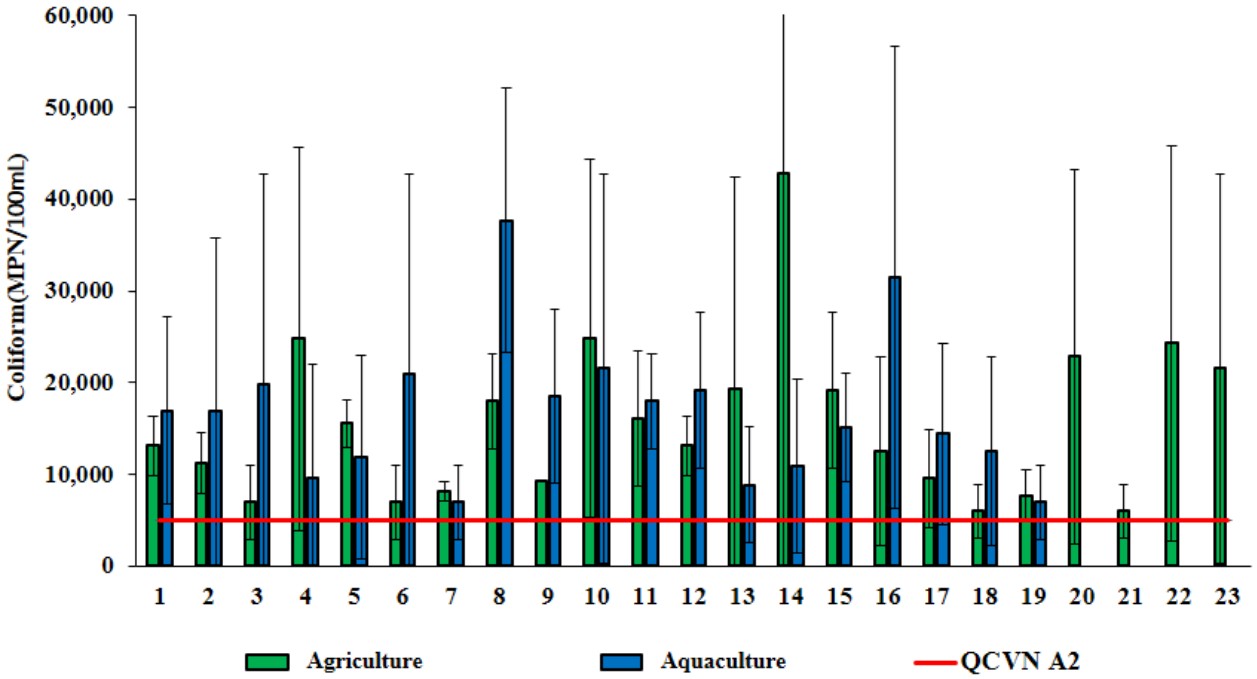

Figure 11. Coliform in the study areas

4. Conclusion

The results indicate that the water quality in the current study areas is polluted by TSS, DO, COD, BOD, P-PO_4^{3-}, N-NH_4^+ and coliform. In agricultural area, low DO concentration along with high TSS, COD and BOD made this area organic pollution. Coliform density is several times higher than the limit of QCVN 08-MT:2015/BTNMT, column A2. Excess fertilizer residues in the agricultural production process are the cause of nutrient pollution in surface water. In aquaculture areas, organic, nutrient and microbial pollution are also encountered. However, the pollution level was lower compared to that of the agricultural area. Wastewater from aquaculture is the cause of higher COD and BOD in water. There is urgent need for treatment of aquaculture and agriculture wastewater to conserve surface water quality.

Acknowledgement

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