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Effect of Industrial Activities on Surface Water Quality in the An Giang Province, Vietnam

Tran Thi Kim Hong[a] and Nguyen Thanh Giao[a*]

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

**Corresponding Author Email: ntgiao@ctu.edu.vn*

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Abstract

This study aims at assessing the variation of water quality in regions affected by industrial production activities in An Giang province, Vietnam. Seven surface water quality parameters including temperature, pH, total suspended solids (TSS), biological oxygen demand (BOD), chemical oxygen demand (COD), ammonium (NH_4^+), and coliform were used for the assessment. The water samples were taken at three locations in the rivers influenced by industrial clusters three times per year (March, June and September). The results show that the water quality parameters including, TSS, BOD, COD, NH_4^+ exceeded the limits of column A1 of the national regulation of suface water quality (QCVN 08-MT:2015/BTNMT). In addition, the water is heavily microbially contaminated since coliform density exceeded the limits by 3 to 18.4 times. The water quality index (WQI) water quality index ranges from 15 to 72 indicating the overall water quality from moderate to poor. The dry season is the most polluted time, especially at My Quy industrial park (CNI). In the rainy season, the water quality improves although pollution still occurs. The main causes can be not only industrial activity but agricultural production activities, domestic wastewater services, circulation processes since the collected water samples have been polluted by several integrated polluting sources.

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1. Introduction

In line with the economic development trend of Vietnam as well as in the Mekong Delta region, An Giang province has begun to accelerate the process of industrialization with continuously forming industrial clusters, industrial parks with medium and large scale have been invested and developed.

According to the Economic Zone Authority of An Giang province (2020) [1], there are currently four (4) industrial parks in operation, three have already been put into use and 4 are awaiting investment. Industrial production activities contribute to changing the economic structure and local labor. Working people in the area have improved their income sources. It is undeniable that the great benefits that the industrial sector brings to An Giang province, however, activities in the production process of the industrial sector have created negative impacts on the environment. especially surface water.

Inadequate treatment of wastewater and waste and direct discharge into rivers or surrounding basins leads to serious damage to surface water quality [2]. Therefore, research to monitor and find solutions to improve water quality is very necessary. This study was conducted to assess the current status and seasonal variation of water quality under the impact of industrial production.
The results of the current study could provide necessary scientific information as a basis for planning, treatment and effective use of surface water resources in the study area.

2. Materials and methods

2.1. Study area

Study on surface water quality monitoring is carried out at three locations in parts of the rivers affected by production activities from industrial clusters in An Giang province. The monitoring sampling locations are denoted CN1, CN2, CN3 respectively as indicated in Figure 1 and are described in Table 1. Monitoring samples were collected at the same time with 3 sampling periods (March, June and September) in 2020.

Table 1. Description of monitoring locations

No.	Site	Code	River	Description	Coordinates (VN2000)	
					X	Y
1	My Quy industrial park	CN1	Hau river	The sampling point on Hau River, near My Quy industrial sluice gate.	577.294	1.146.119
2	Phu Hoa industrial park	CN2	Mac Can Den river	The sampling point on Rach Gia - Long Xuyen canal, near Phu Hoa industrial sluice gate.	567.789	1.145.919
3	Tan Trung industrial park	CN3	Vam Nao river	The sampling point on Hau River, near Tan Trung industrial sluice gate.	566.371	1.168.450

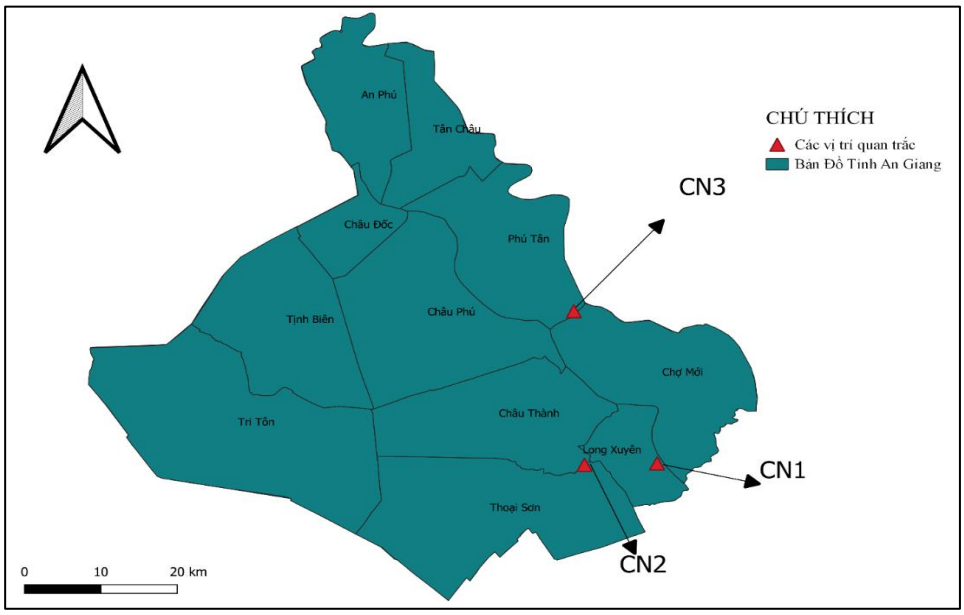

Figure 1. Map of surface water quality sample collection

2.2. Data collection and evaluation

The study uses monitoring data collected from the Department of Natural Resources and Environment of An Giang province in 2020. Water quality monitoring includes eight evaluation parameters, these are temperature, pH, and total suspended solids (TSS).), biological oxygen demand (BOD), chemical oxygen demand (COD), ammonium (NH_4^+), and coliform. In which, temperature and pH were measured directly in the field. While TSS (mg/L), COD (mg/L), BOD (mg/L), NH_4^+ (mg/L), total oil and grease (mg/L) and coliform (MPN/100mL) were measured from samples collected and analysed according to standard methodology [3]. The data of the monitoring parameters at the locations are synthesized, processed and analyzed using Microsoft Excel 2013. The analysis results of each parameter are also compared to the allowable limits of the National Technical Regulation on quality of surface water used for domestic water supply and aquatic life conservation (column A1) (QCVN 08-MT:2015/BTNMT) [4]. Surface water quality at locations is also assessed by water quality index (WQI) based on decision 1460/QD-TCMT in 2019 on technical guidance for calculation and publication of Vietnam water quality index [5]. The WQI value (according to the WQI scale) at the locations will represent the quality of surface water as indicated in Table 2.

Table 2. Water quality rating according to WQI

WQI	Description of rating of water quality	Rating
91 - 100	Good use for domestic water supply purposes	Excellent
76 - 90	Used for domestic water supply purposes but need appropriate treatment measures	Good
51 - 75	Use for irrigation and other equivalent purposes	Moderate
26 - 50	Use for navigation and other equivalent purposes	Poor
10 - 25	Water is heavily polluted, needs future treatment measures	Very bad
<10	Poisoned water, need to take measures to overcome and treat	Heavily polluted

3. Results and discussion

3.1. Evolution of surface water quality parameters

Research results through 3 surveys show that the temperature in the study area did not have significant variations between locations at the time of monitoring. Specifically, at CN1 location, the temperature fluctuated between 29.8 and 31.7 ^oC (average 30.5 ^oC), at CN2 the highest value ranges from 30.4 to 31.3^oC (average is 30.7 ^oC) and CN3 has a temperature in the range of 28.9 - 30.2 ^oC (average is 29.7 ^oC). The period of March has the lowest temperature and the highest temperature in June. The temperature in the study area tends to decrease low in March, then increase in June and gradually decrease in September. Thereby, it shows that, the water temperature in the dry season will be higher than in the rainy season. Previous study of Giao et al. [6] indicated that this temperature difference could be due to the increase in air temperature in the dry season and decrease in the rainy season. The water temperature in the study area is relatively stable, there are few strong fluctuations, so it still ensures the normal growth and development of aquatic organisms.

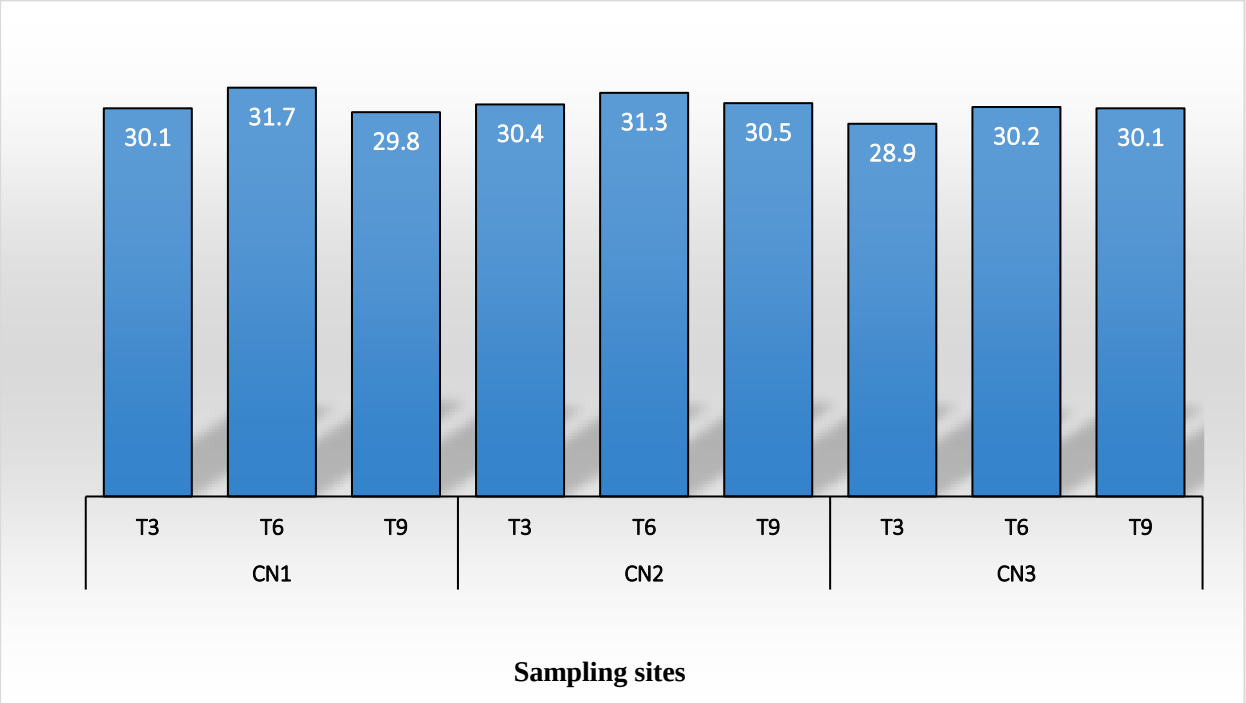

Figure 2. Temperature in the study area

The results in Figure 2 show that for position of CN1 pH parameter has the lowest value ranging from 6.81 to 7.24 (average is 7), CN2 has an average value of 7.2 and fluctuates around 7.15 to 7.23 and CN3 was the site with the highest pH ranging from 7.17 to 7.41 (average 7.3). There is a difference in pH value between positions CN1 and CN3 and there is a difference in statistical significance at 5% significance level. The pH in the basins near the industrial zones in An Giang province occurs seasonally, tends to decrease in the dry season (March) and rainy season (September) and reaches a high value at the time of the change of season. June). However, at position CN3, during the dry season, pH has the highest value. Research by Lien et al. [7] indicated that, the pH value in the rainy season is higher than in the dry season, pH fluctuates in the range of 6.3 - 8.0 between the main river areas and the Hau river basin. Thereby showing a difference in pH in water in the basin compared to previous studies. Despite fluctuations, the pH parameters in the water in the study area are within the allowable thresholds of QCVN 08-MT:2015/BTNMT [4] for the purpose of domestic water supply and aquatic life conservation (QCVN 08-MT:2015/BTNMT).

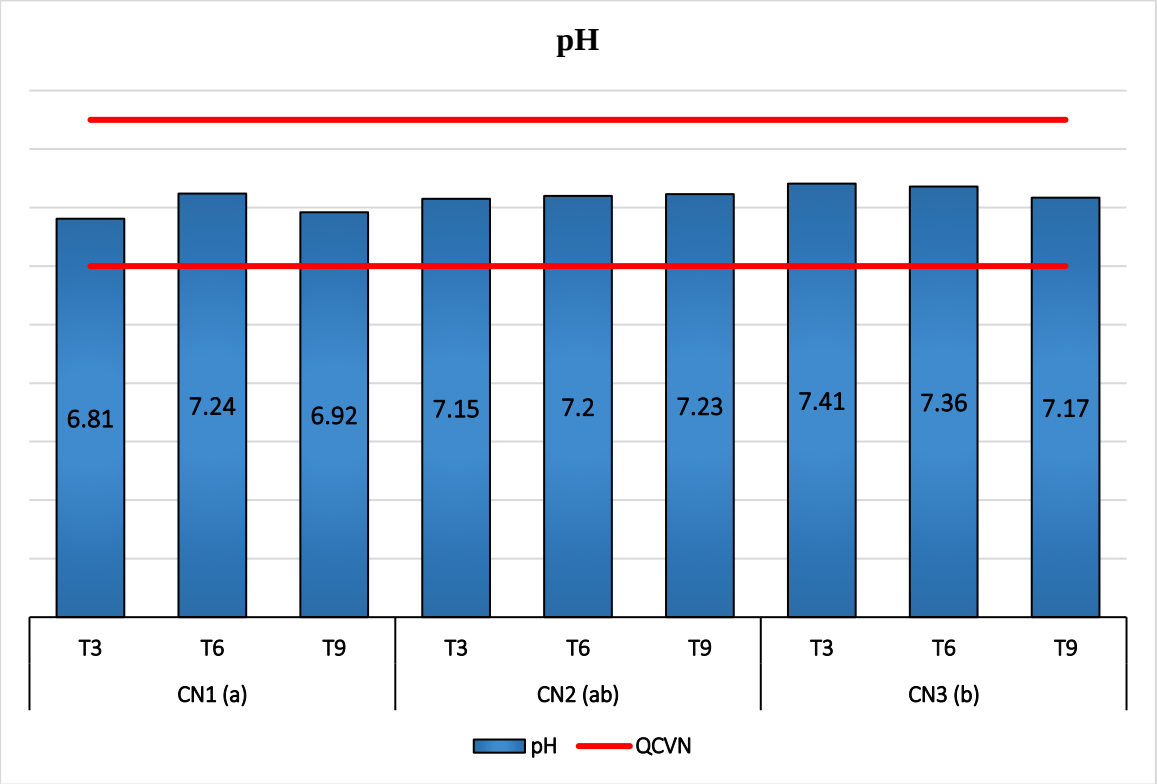

Figure 3. pH in the study area

Total suspended solids (TSS) in the study area is currently very high. The CN1 site has TSS values ranging from 50 to 55 (mg/L), with an average of 52 mg/L. CN2 is the site with the highest concentration of TSS, ranging from 50 to 58 mg/L (average 54mg/L). At CN3 recorded the lowest TSS value, averaged 49 mg/L and ranged from 45 to 52 mg/L. There is a difference in TSS content between sites, but there is no difference in terms of statistical significance. All sampling locations of surface water quality in all 3 monitoring periods have TSS values higher than the permissible threshold from 2.25 to 2.9 times compared to column A1 (20 mg/L) QCVN 08-MT :2015/BTNMT [4]. Compared with the study of Ly and Giao (2018), the TSS concentration in the study area was in the range previously recorded in the canals of An Giang province in the period of 2009 - 2016 from 25 ± 11.5 mg/L to 93.7 ± 28.3 mg/L. According to MRC [8], the presence of a large concentration of TSS in water will affect aquatic life, increase the cost of domestic water treatment and transport many pathogens that are widely dispersed. The results also show that TSS in the monitored basins has seasonal fluctuations, with high TSS concentrations in the rainy season and low in the dry season. The cause may be from rainwater runoff, erosion and the amount of alluvium coming from upstream during the rainy season [7,9]. High TSS could lead to high cost of water supply treatment process

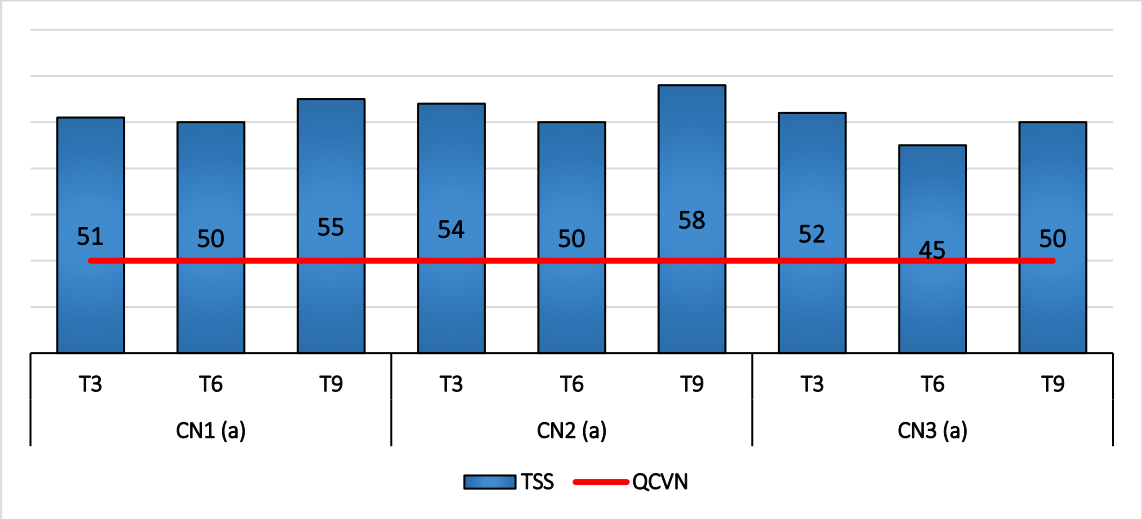

Figure 4. TSS in the study area

The results of Figure 5 show that the BOD concentration at the monitoring sites ranges from 9 to 39 mg/L. CN1 had the highest BOD value, ranging from 12 to 39 mg/L (mean 21 mg/L), CN2 and CN3 had a lower BOD content of 12 - 15 mg/L, respectively (average was 14 mg/L). mg/L) and 9-14 mg/L (mean 12 mg/L). Although there is a difference in TSS values between positions, there is no statistically significant difference at the 5% level. All BOD values recorded in the study area exceeded the allowable limit in column A1 QCVN 08-MT:2015/BTNMT [4]. The BOD content of the water bodies near the CCNs is currently at a high level and is higher than the previous research results of Ly and Giao [10], the BOD content in the water bodies in An Giang province is 6.6 ± 1. ,2 – 8.2 ± 2.5 mg/L in the period 2009 – 2016. The fluctuations of BOD parameters are similar to TSS, as BOD values tend to be low in the dry season and high in the dry season. rain. However, the dry season (March) at the CN1 site had an unusually high value (39 mg/L). Sudden high levels of BOD in water can lead to oxygen deficiency in the water, creating harmful compounds that affect health when used and affect aquatic life [11]. The reason for the high BOD in the study area may come from wastewater from agricultural production, domestic activities, landfilling (MRC, 2015). Along with TSS pollution, organic pollution from high BOD is a common problem of the Mekong Delta water bodies [8,12].

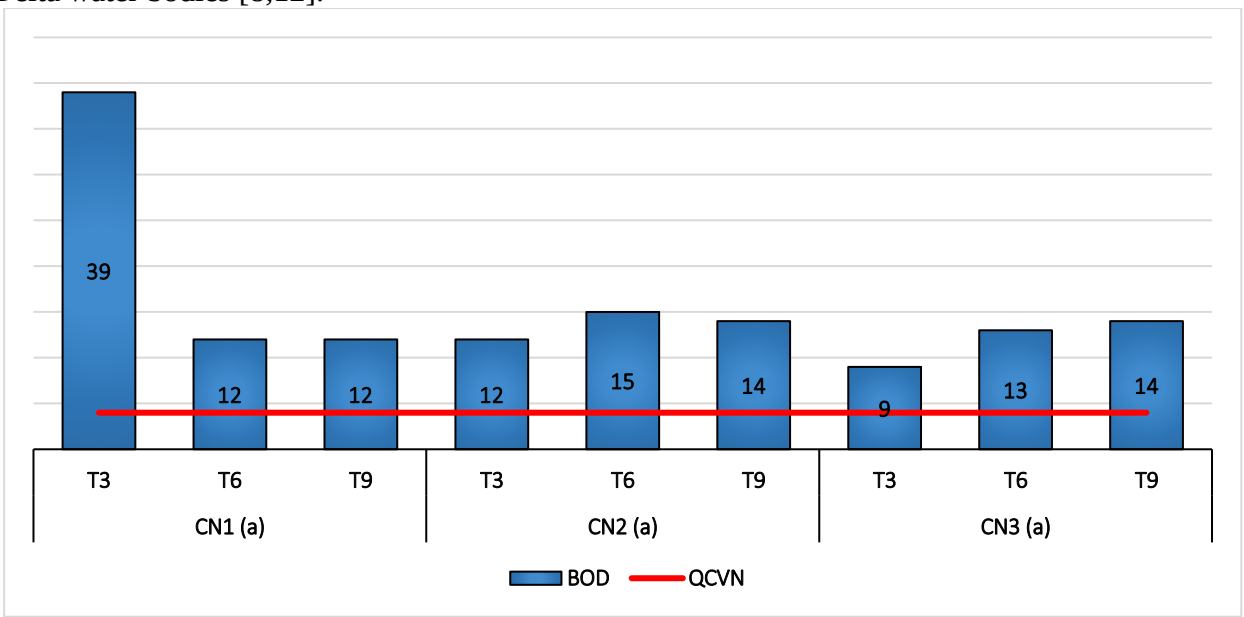

Figure 5. BOD in the study area

Chemical oxygen demand (COD) in the study area ranged from 18 to 60 mg/L at site CN1 (average was 32 mg/L), 20 to 23 mg/L at site CN2 (average reached CN2). 22 mg/L) and at the CN3 position, the average was 18 mg/L (ranged from 14 to 21 mg/L). Position CN1 has the highest amplitude and COD content, position CN2, CN3 has similarity in COD content. Although there is a difference in COD content between locations, there is no statistical difference (significant level of 5%). The values of COD parameters all exceed the permissible limits of the national technical regulations on surface water quality for domestic purposes and aquatic life conservation (column A1, QCVN 08-MT:2015/BTNMT) [4]. There is not a big difference between the dry season and the rainy season in the study area, however, there is a tendency for COD to be lower in the dry season and high in the rainy season. The cause comes from erosion, domestic waste and especially wastewater from industrial production activities [13,14]. Besides, the high concentration of TSS in the study area is also one of the reasons why COD and BOD are high in water [15]. Similar to the BOD parameter, the COD content was unusually high in the dry season at the CN1 position (60 mg/L). The cause of this abnormal sign may be that the basin at CN1 location has received a large amount of wastewater and untreated waste from the industrial park or nearby residential area. In the study area, the values of both BOD and COD parameters were high and exceeded the allowable limit, indicating that the water quality was contaminated with organic matter.

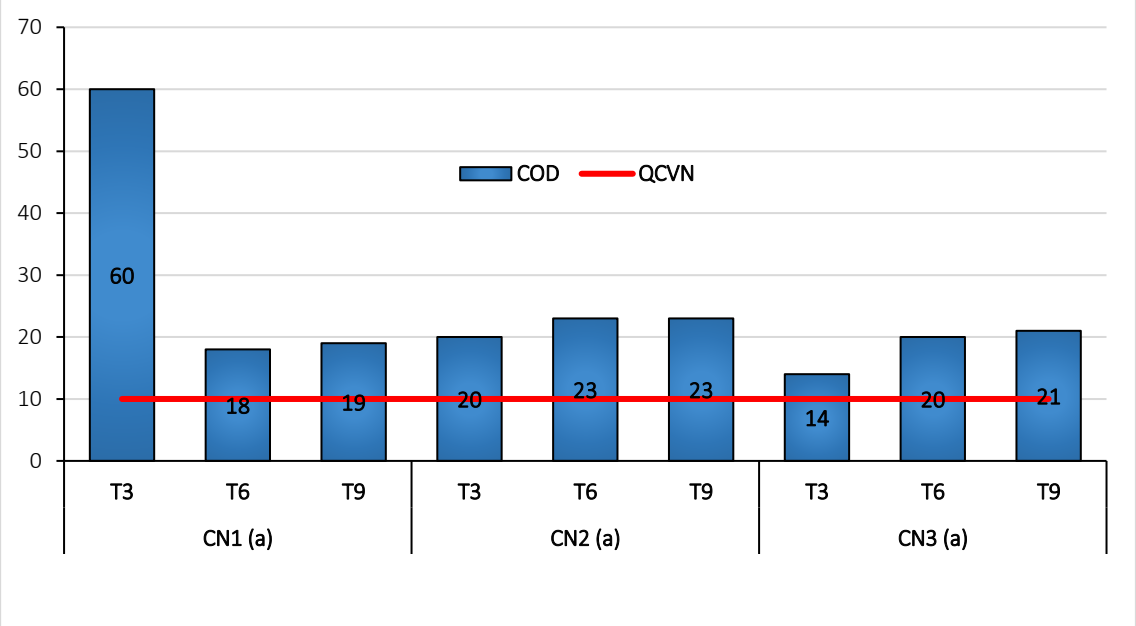

Figure 6. COD in the study area

The results of Figure 7 show that the ammonium (NH_4^+) parameter has a large variation between locations. At CN1, the NH_4^+ parameter has the highest value (average 1.2 mg/L) ranging from 0.232 to 3.08 mg/L, CN2 has an average of 0.9 mg/L, ranging from 0.476 to 1 .45 mg/L and the CN3 position recorded the lowest NH_4^+ ranging from 0.109 to 0.449 mg/L (average 0.3 mg/L). Most of NH_4^+ monitoring locations have values exceeding the allowable threshold in column A1 QCVN 08-MT:2015/BTNMT [4]. This result shows that the water quality in the present study area has been contaminated with nutrients. Besides, the seasonal variation of NH_4^+ parameters in the basins near the CCNs is shown very clearly. NH_4^+ tends to increase in the dry season, especially at CN1 and CN2 positions, the NH_4^+ content is 10.27 times and 4.83 times higher than the allowable limit of QCVN 08-MT:2015/BTNMT [4], respectively. The rainy season is the time when the NH_4^+ parameter decreases, with very low values (at CN1 (0.232 mg/L) and CN3 (0.109 mg/L) positions), NH_4^+ values are within the allowable threshold of column A1). The causes of high NH_4^+ in water originate from different metabolic processes such as agriculture, domestic and industry [2].

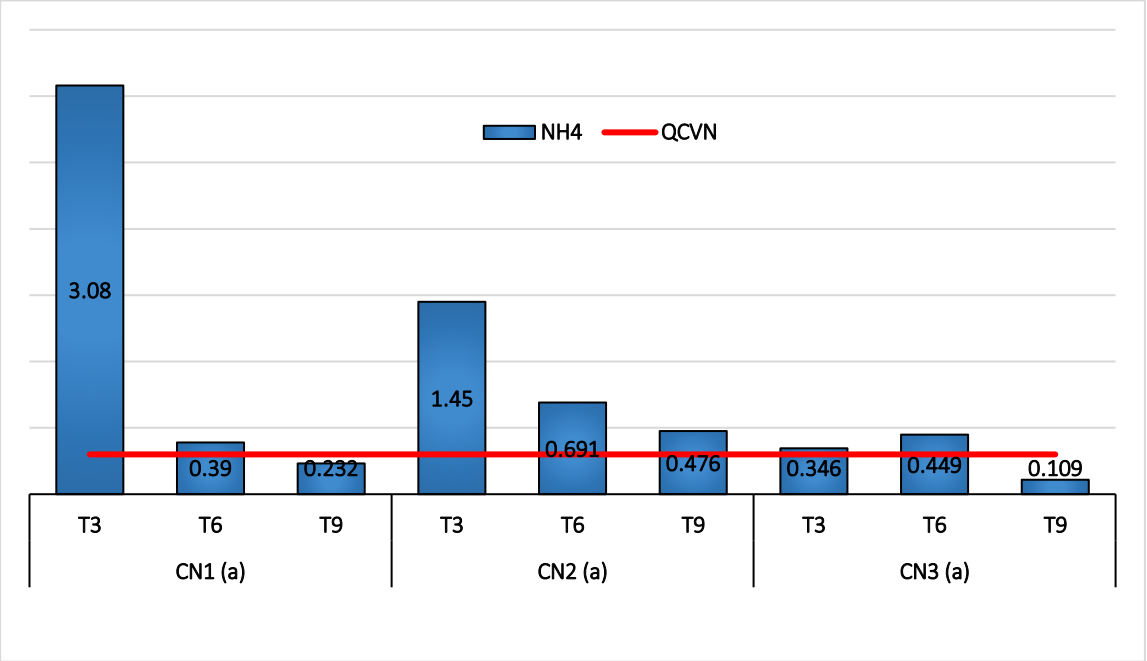

Figure 7. NH_4^+ in the study area

The concentration of coliforms in the water in the study area varied significantly (Figure 8). At CN1, coliform fluctuates greatly when the value ranges from 7500 to 46000 MPN/100mL. The CN2 site had the lowest coliform density ranging from 7500 to 24000 MPN/100mL and the CN3 site had the lowest coliform density ranging from 2400 to 24000 MPN/100mL. The difference in coliform density between sites was not statistically significant at the 5% level of significance. Compared with the allowable limit of column A1 QCVN 08-MT:2015/BTNMT [4] on coliform density in water. In the study area, only CN3 position at the time of June met the standard, the remaining results exceeded the threshold many times (from 3 to 18.4 times). The current research results are much higher than the previous study by Ly and Giao [10], when coliforms in surface water of An Giang province in the period 2009 - 2016 exceeded the allowable limit by 2.14 - 7.02 times. The fluctuation of coliform density in the water tends to increase both in the rainy and dry seasons but to decrease in the season change (June). The CN1 site in the dry season had an abnormally high concentration of coliform (18.4 times higher than the allowable limit). The position CN3 tends to increase in the rainy season, CN1 and CN2 increase in the dry season and decrease in the rainy season. The presence of a large density of harmful microorganisms in the water shows that the water sources in these areas are receiving a large amount of human and animal excreta. At the same time, the level of circulation of the flow is also the cause of increased coliform [15].

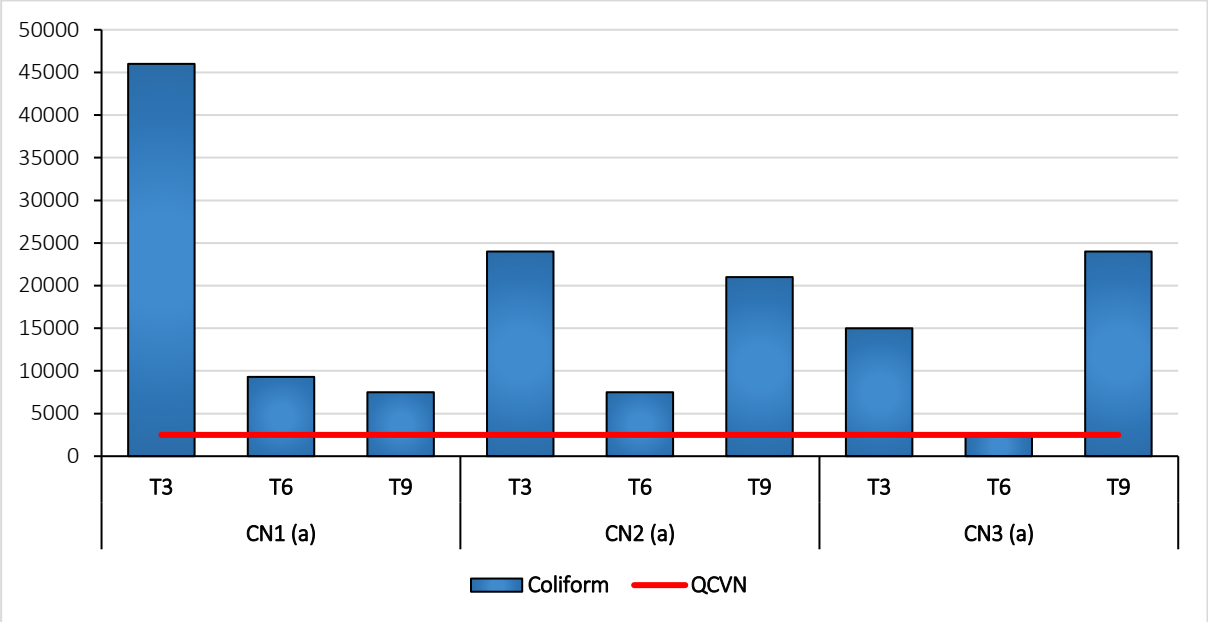

Figure 7. Coliform in the study area

3.2. Evaluating surface water quality using WQI

The results of water quality assessment according to WQI at monitoring locations at 3 monitoring times ranged from 15 to 72 (Figure 9). At location CN1, the water quality index has a large variation, ranging from poor to moderate (15-66) and tends to gradually increase the assessment index from poor in the dry season to the rainy season. water quality is improved to average level. The locations CN2 and CN3 have similar water quality index, the fluctuation range of these two locations is in the bad to moderate level, the trend is to increase from March to June and then decrease to low in September. In the dry season, the water quality is always poor to bad (15 - 37), in the rainy season the water quality is better and ranges from 33 to 66 (bad to moderate). June is the time when water quality has the best evaluation index, fluctuating at an average level (51 – 72).

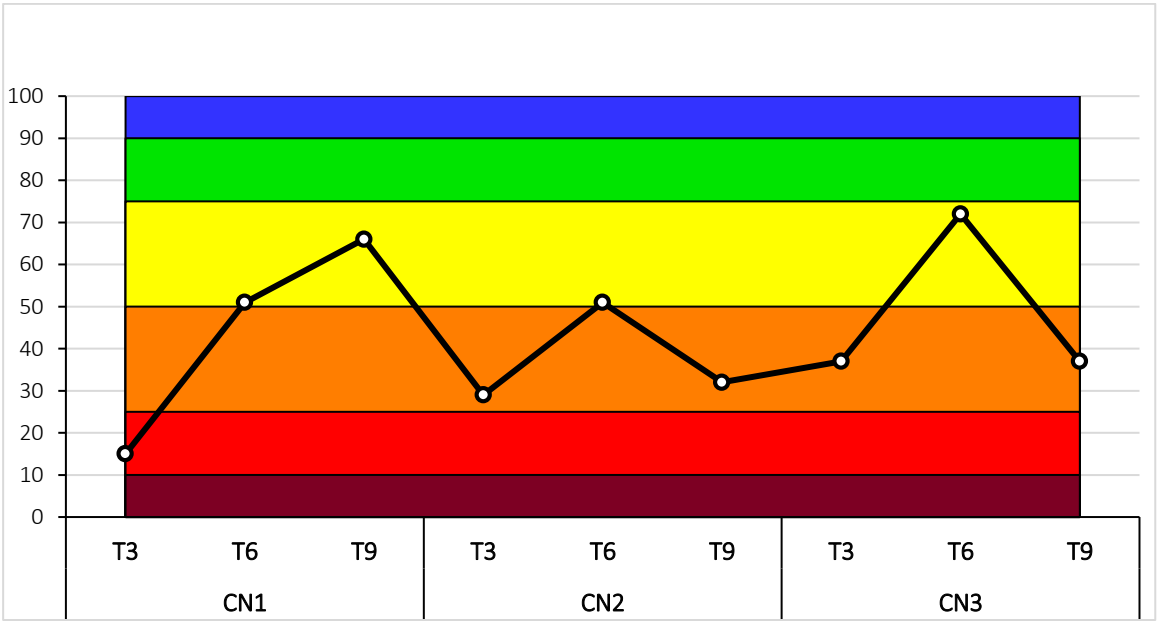

Figure 9. Water quality evolution according to WQI in the study area

4. Conclusions

Surface water quality in basins near industrial clusters is currently polluted. In 8 parameters to evaluate surface water quality, up to 5 parameters appear polluted including TSS, BOD, COD, NH_4^+ and coliform leading to organic, nutritional and microbial pollution in the water environment. The observed values of these parameters are many times higher than the allowable limit of column A1 QCVN 08-MT:2015/BTNMT. As a result, the water quality index in the study area decreased. The WQI water quality assessment index in watersheds near industrial clusters ranges from poor water quality to normal water quality and is highly concentrated in bad quality. There is a clear seasonal variation of pollution in each monitoring parameter and a clear difference between the two seasons. The dry season is the time when the pollution is heaviest, especially at location CN1 when most of the monitoring parameters exceed the allowable threshold and are many times higher than at other times or locations. Although the water quality is improved compared to the dry season, at the time of the rainy season water still appears polluted. Pollution causes can originate from agricultural production activities, wastewater, waste from domestic processes and especially from industrial production activities. It is necessary to strengthen monitoring at CN1 position in the dry season and take timely remedial measures.

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