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Key Variables Influencing Surface Water Quality in the Flood Control Area in An Giang province, Vietnam

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Abstract

The study was conducted to assess the water quality in the Bac Vam Nao flood control area in 2020. Surface water quality in the Bac Vam Nao area was collected at 7 locations with symbols from VN1-VN7. Water samples were collected three times per year in March, June and September. The water indicators include temperature, pH, total suspended solids (TSS), dissolved oxygen (DO), biological oxygen demand (BOD), chemical oxygen demand (COD), ammonium ($N\text{-}NH_4^+$), nitrate ($N\text{-}NO_3^-$) and coliform were used to assess water quality in the study area. Water quality is assessed using national technical regulations on surface water quality (QCVN 08-MT:2015/BTNMT, column A1), water quality index (WQI). The main sources of variation and the main indicators affecting the water quality were identified using principal component analysis (PCA). The results show that the water in the flood control area is contaminated with organic matter (low DO, high TSS, BOD and COD), nutrient pollution ($P\text{-}PO_4^{3-}$, $N\text{-}NH_4^+$) and microbiological contamination (Coliform). The WQI index (29-88) shows that surface water quality in the flood control area is classified from bad to good, corresponding to the use of navigation and domestic purposes, but needing appropriate treatment. The indicators of temperature and pH have little seasonal variation. DO, TSS, $N\text{-}NO_3^-$ in the dry season were higher than that in the rainy season while BOD, COD, $N\text{-}NH_4^+$, $P\text{-}PO_4^{3-}$, coliform in the rainy season were higher than that in the dry season. Water quality in the Bac Vam Nao flood control area is influenced by four main sources, PC1-PC4, which explain 84.8% of the variation in water quality. The parameters of temperature, pH, $N\text{-}NH_4^+$, $N\text{-}NO_3^-$, $P\text{-}PO_4^{3-}$, DO, and coliform have the main impact on water quality and need to be continuously monitored. The findings show that the water quality in the flood control area has been polluted, it is necessary to have appropriate solutions to improve the water quality.

1. Introduction

An Giang is the southwestern upstream province of the country and the lower Mekong River, one of four provinces in the key economic region of the Mekong Delta. An Giang is also considered as a convergence of many potentials for agricultural development, commerce, services, and tourism [1]. In the context of integration and development, An Giang still faces many challenges, besides the very important development steps and practical benefits of the process of industrialization -

modernization bring about The pressure on the environment is increasing day by day, giving rise to problems of environmental pollution, especially water pollution and many urgent environmental problems that have been taking place, affecting the quality of life. life and sustainable development, especially in the context that global climate change is taking place very quickly and complicatedly [1-3]. The Bac Vam Nao Water Control Project originates from the development concept in the Mekong Delta Master Plan completed by the Dutch Technical Consulting Company. Following the proposal of the Government of Vietnam to the Australian Government in 1992, the first pre-feasibility project and design tasks for the Bac Vam Nao Project were carried out in 1993 and 1994. From 2002 to 2007, the Project Bac Vam Nao Water Control has been implemented in Tan Chau and Phu Tan districts, An Giang province. Bac Vam Nao looks like an island surrounded by Tien and Hau rivers, connected by a system of canals dividing neighboring parts of the island. The objective of the project is to assist An Giang Province in establishing and operating an effective water management system in Bac Vam Nao that is socially and environmentally sustainable, beneficial to the local economy by supporting poverty alleviation. Furthermore, the project aims to demonstrate economic and social benefits to the Vam Nao community, especially environmental protection, and through a coordinated approach to water and land management. This study was conducted to assess the water quality in the Bac Vam Nao flood control area and identify the water quality criteria affecting the water quality in the study area. The research results can be used for environmental monitoring in this flood control area.

2. Materials and methods

Surface water quality in Bac Vam Nao area was collected at 7 locations with symbols from VN1-VN7 (Figure 1). Water samples were collected 3 times per year in March, June and September. Indicators include temperature, pH, total suspended solids (TSS), dissolved oxygen (DO), biological oxygen demand. (BOD), chemical oxygen demand (COD), ammonium ($N\text{-}NH_4^+$), nitrate ($N\text{-}NO_3^-$) and coliform were used to assess water quality in the study area. The characteristics of surface water in the Bac Vam Nao flood control area were evaluated using the national technical regulation on surface water quality (QCVN 08-MT:2015/BTNMT, column A1) [4]. Details of allowable limits and analytical methods [5] of the indicators are presented in Table 1. The WQI index is calculated based on parameters including temperature, pH, DO, BOD, COD, $N\text{-}NH_4^+$, $N\text{-}NO_3^-$, coliform according to the guidance of Decision 1460/QD-TCMT dated November 12, 2019 of the General Department of Environment on promulgating the manual for calculating the water quality index [6]. The WQI parameter has a value from 0 to 100. In which, a value from 91-100 presents very good water quality that is considered good for domestic water supply purposes; a value of WQI from 76 to 90 shows good water quality suitable for use for domestic water supply but need suitable treatment measures; WQI value between 51-75 shows average water quality to be used for irrigation and other equivalent purposes; WQI values from 26 to 50 shows bad water quality used for navigation and other equivalent purposes; WQI values from 10 to 25 shows poor quality so the water is heavily tarnished, needing treatment measures in In the future, water with a WQI value < 10 is water of very heavy quality, contaminated water, and needs to be remedied and treated [6].

Principal Component Analysis (PCA) was used to reduce the complexity of the original data set from a large number of variables to a smaller number of factors. The resulting PCA generates a new set of variables called principal components or principal factors (PC). The eigenvalue coefficient is considered as a measure of the importance of the principal component. The absolute value of the significant correlation coefficient greater than 0.75 means that there is a strong correlation between the main component and the water quality parameter, from 0.5-0.75 is the average correlation and less than 0.5 is the weak correlation [7].

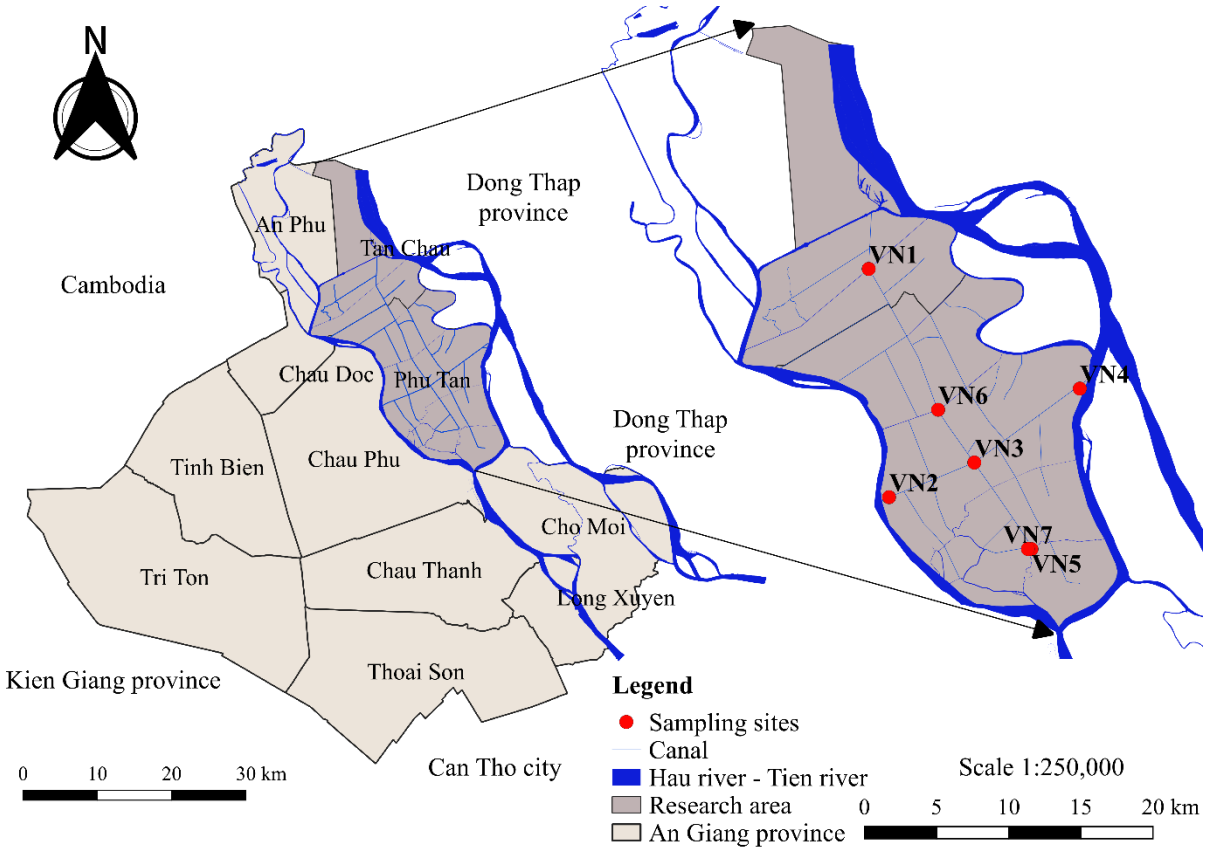

Figure 1. Map of the sampling sites in the flood control Bac Vam Nao, An Giang province

Table 1. Analytical methods and threshold levels of water quality parameters

Parameter	Description	Unit	Analytical methods	QCVN, A1
pH	pH	-	TCVN 6492:2011	6-8.5
Temp	Temperature	^oC	SMEWW 2550B:2012	-
DO	Dissolved oxygen	mg/l	TCVN 7325:2004	≥6
BOD	Biochemical oxygen demand	mg/l	TCVN 6001-1:2008	4
COD	Chemical oxygen demand	mg/l	TCVN 6491:1999	10
TSS	Total suspended solids	mg/l	TCVN 6625:2000	20
$N\text{-}NH_4^+$	Ammonium	mg/l	TCVN 6179:1996	0.3
$N\text{-}NO_3^-$	Nitrate	mg/l	TCVN 6180:1996	2
$P\text{-}PO_4^{3-}$	Orthophosphate	mg/l	SMEWW 4500-PO_4^{3-}.E:2012	0.1
Coliform	Coliform	MPN/100ml	TCVN 6187-2:1996	2500

3. Results and discussion

3.1 Evaluating water quality using national regulation

The average temperature measured at the monitoring points of the Bac Vam Nao flood control area ranges from 28.7-30.2 ^oC (Figure 2). The average temperature between the months of sampling is in the range of 29.3-29.8^oC. It can be seen that the temperature fluctuates with a low amplitude, is

relatively stable and ensures aquatic life in the area [4]. The temperature in the waters of the Mekong Delta is usually in the range of 19.9-32.2 ºC [8-9].

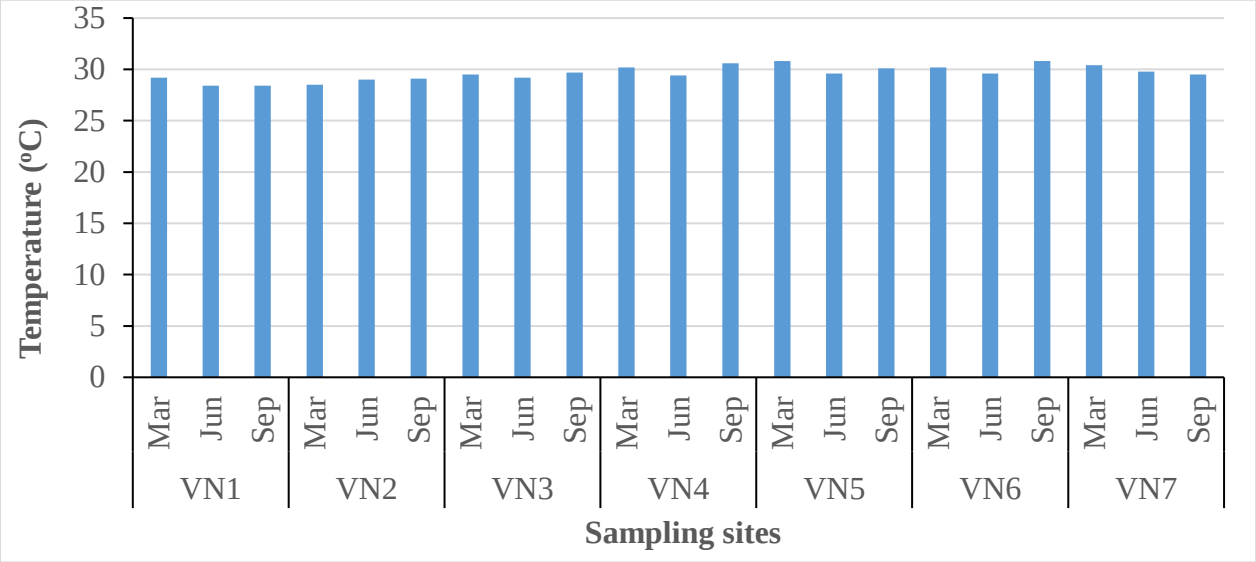

Figure 2. Temperature at the flood control area

The pH at the locations through 3 monitoring periods in 2020 ranged from 6.92 to 7.43 (Figure 3). The average pH value at the sampling sites was in the range of 7.0-7.3 while the average pH between samples was 7.1-7.3. The average pH value of pH is within the allowable range of QCVN 08-MT:2015/BTNMT, column A1 (6 - 8.5). Research results show that the pH in the area has little variation and is suitable for the growth of aquatic plants. Previous studies showed that pH in canals in An Giang province ranges from 6.9-7.1 [10], in Hau river ranges from 6.3-8.0 [11].

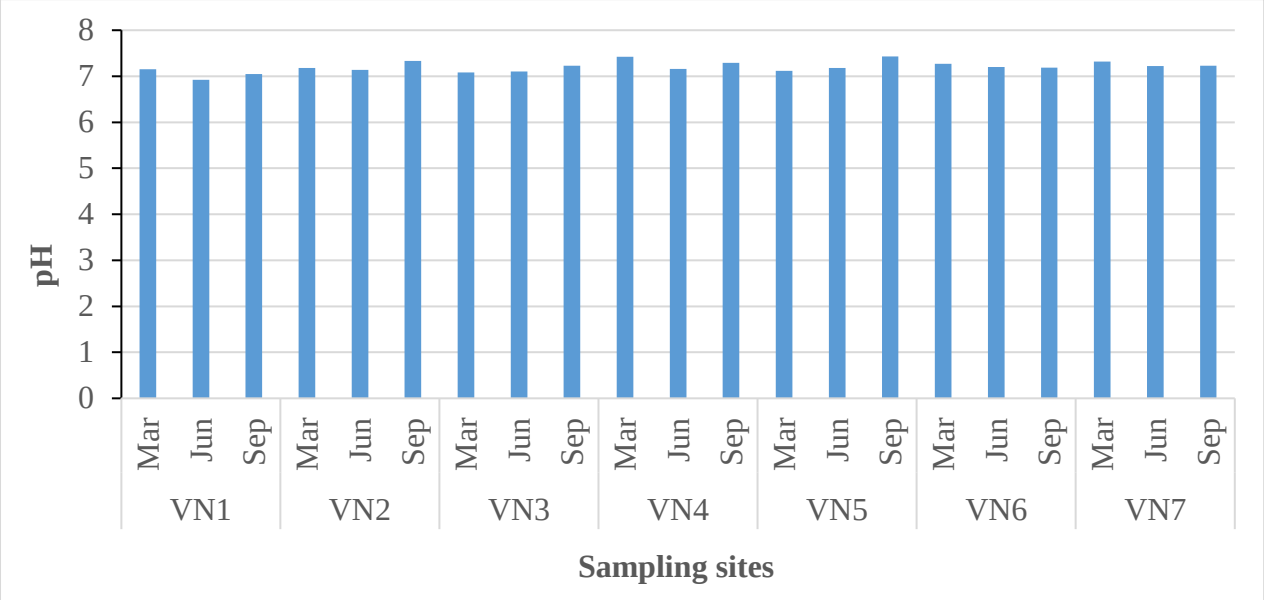

Figure 3. pH at the flood control area

The TSS concentration at the monitoring locations of the Bac Vam Nao flood control area in 2020 ranges from 41-78 mg/l (Figure 4), these values are 2.05 - 3.90 times higher than the norm. with QCVN 08-MT:2015/BTNMT, column A1 (20 mg/l), the highest pollution was at Cai Tac canal (VN7) in March. At the monitoring locations during the year, TSS concentration was in May. 6 (53.1 mg/L) and September (55.3 mg/L) tended to decrease lower than in March (65.7 mg/L). TSS

seasonal variation is very large, in which TSS in the rainy season is usually higher than that in the dry season [10-11]. TSS causes an increase in the cost of water treatment, affecting aquatic life [8-9].

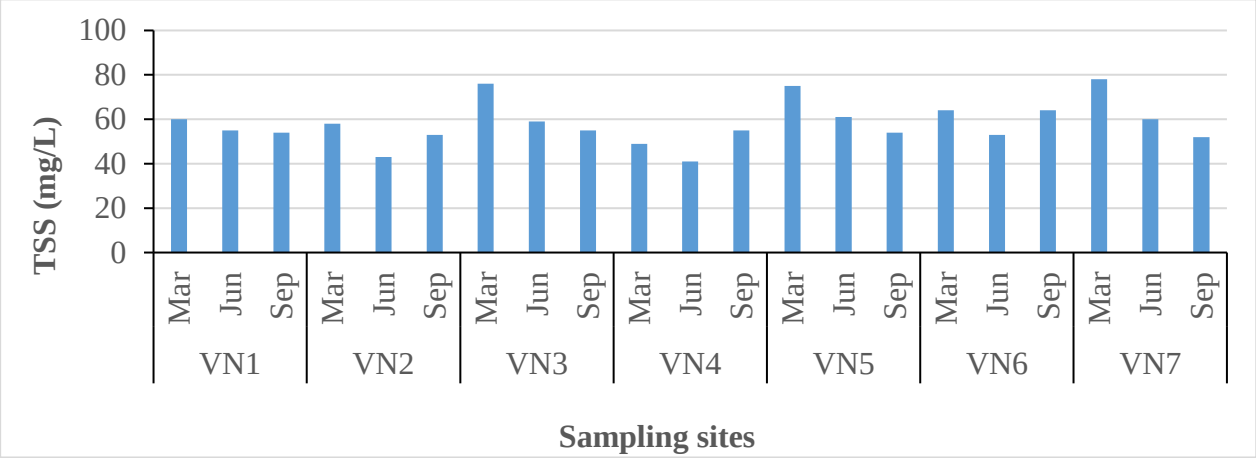

Figure 4. TSS at the flood control area

The DO concentration at the locations of the Bac Vam Nao flood control area through 3 monitoring periods in 2020 ranged from 3.08 to 5.18 mg/l (Figure 5). The average DO at the sampling sites ranged from 3.8 to 4.5 mg/L. The average DO in the months ranged from 3.5 to 4.8 mg/L, in which the DO concentration in March and September was higher than that in June at all monitoring locations. DO in the flood control area are lower than the allowed standards according to QCVN 08-MT:2015/BTNMT, column A1 (≥6 mg/l). This proves that the water already shows signs of organic pollution. In water bodies such as Tien and Hau rivers, DO should be 5 mg/L or higher to be suitable for aquatic life [8]. Previous studies also showed that DO in canals and canals of the Mekong Delta is lower than the allowable limit [10-11].

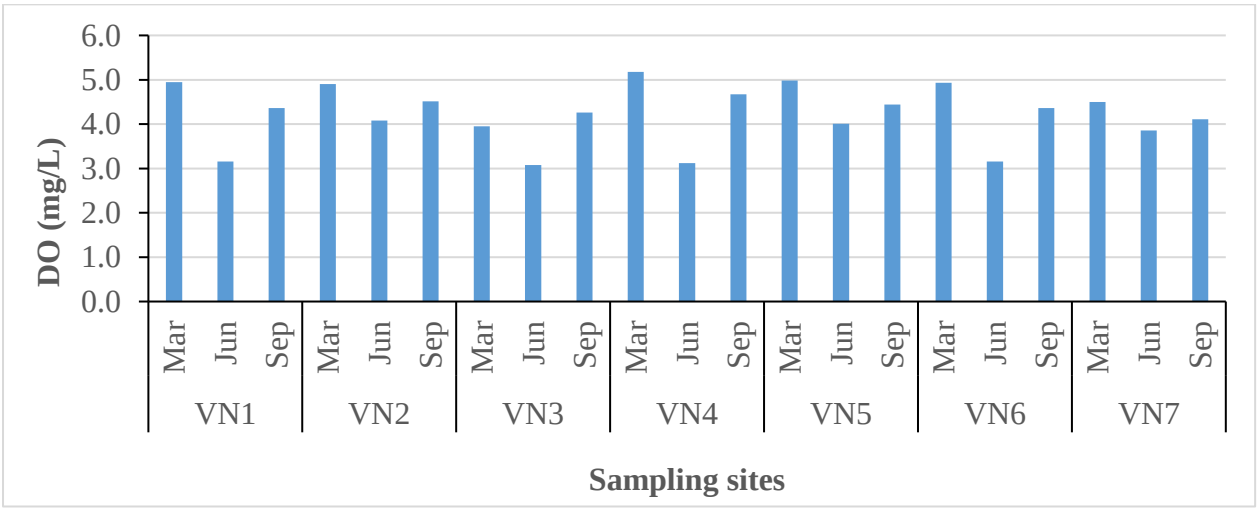

Figure 5. DO at the flood control area

The average BOD concentration at the sampling sites in the Bac Vam Nao flood control area in 2020 ranged from 13.7 to 24.3 mg/L (Figure 6). The highest BOD was found at the midpoint of Than Nong canal (VN3), adjacent to K26 canal in June. BOD in March, June and September was 19.7, 17.0, 20.7 mg/L, respectively. BOD at all locations in the sampling months exceeded QCVN 08-MT:2015/BTNMT, column A1 (4 mg/l) by 2.2-7.8 times. Surface water in the study area has organic pollution. River water with a BOD concentration exceeding QCVN 08-MT:2015/BTNMT poses many risks when used as feed water because carbon compounds can combine with chlorine

during the disinfection phase to produce hazardous compounds. health effects when exposed to the community through the process of using water [4]. Like TSS, organic pollution due to high BOD concentration is a common problem of water bodies in the Mekong Delta [9-12].

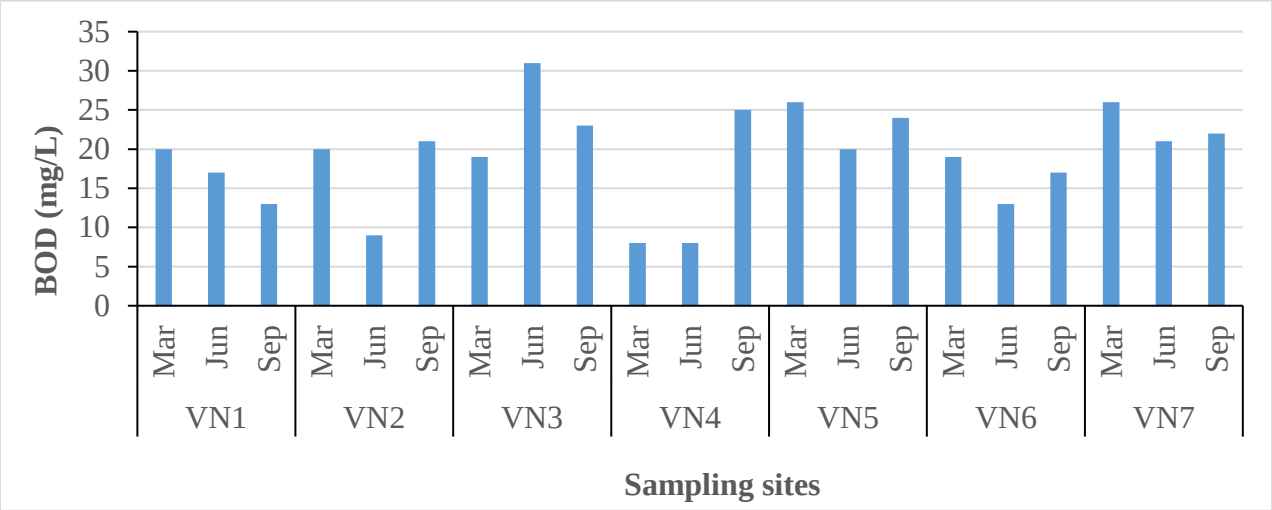

Figure 6. BOD at the flood control area

The COD concentration through 3 monitoring periods in 2020 in the Bac Vam Nao flood control area has values ranging from 13 - 48 mg/l (Figure 7), exceeding the allowable limit of QCVN 08-MT:2015/BTNMT, column A1 (10 mg/l) from 1.3 to 4.8 times. COD at the midpoint of Than Nong canal (VN3) adjacent to K26 in June is the highest. The average COD between monitoring sites is in the range of 21.7-37.7 mg/L. The mean values of COD in March, June, and September were 30.4, 26.3, and 32.1 mg/L, respectively. The research results showed that the BOD and COD concentrations in September were higher than those of the other months, showing the seasonal variation of organic matter in the studied watershed. Previous studies have shown that water quality in large rivers such as Tien and Hau rivers has COD exceeding the allowable limit [10-12].

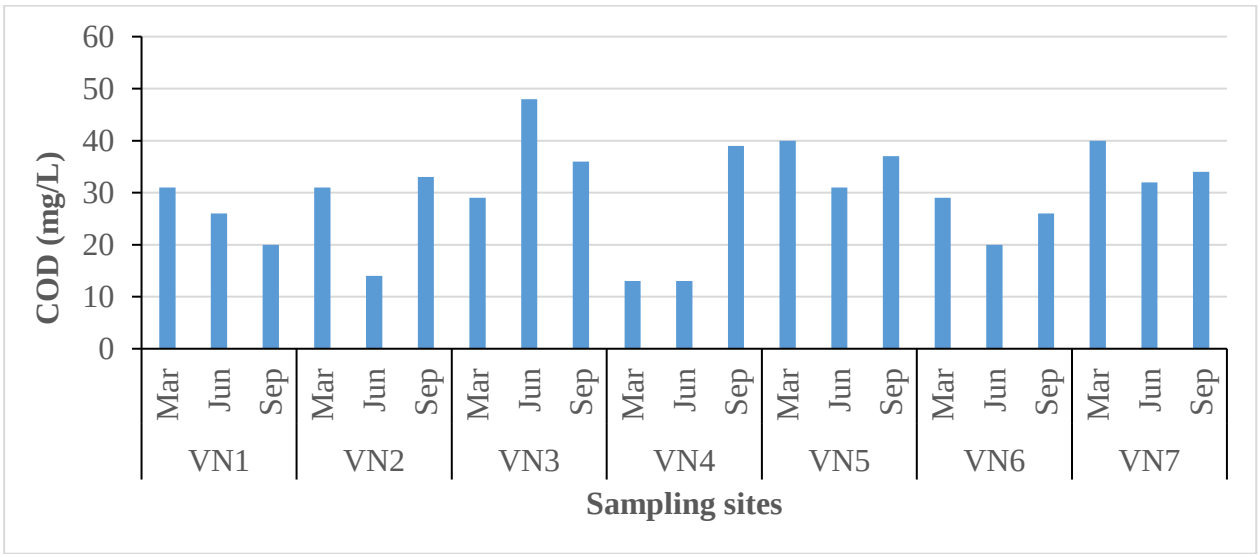

Figure 7. COD at the flood control area

The ammonium concentration ($N\text{-}NH_4^+$) in the Bac Vam Nao flood control area through 3 monitoring periods in 2020 ranges from 0 to 1.82 mg/l (Figure 8). The $N\text{-}NH_4^+$ concentration in March was lower than QCVN 08-MT:2015/BTNMT, column A1 (0.3 mg/l). The $N\text{-}NH_4^+$ concentration in the June samples had 3/7 locations exceeding the standard limit of 4.06; 1.53; 1.59 times at the midpoint of Than Nong canal (VN3) adjacent to K26; end of Than Nong canal (VN5)

adjacent to Cai Tac canal and Cai Tac canal (VN7). $N\text{-}NH_4^+$ concentration in 7 research sites during the September sample collection exceeded the allowable limit from 1.73 to 6.07 times. The $N\text{-}NH_4^+$ concentration in the flask in March, June, and September was 0.07, respectively; 0.38; and 1.31 mg/L, indicating seasonal variation in $N\text{-}NH_4^+$, in which $N\text{-}NH_4^+$ in rainy season tends to be higher than rainy season. The concentration of $N\text{-}NH_4^+$ fluctuates according to the seasons in which the rainy season is often higher than the dry season, which has also been reported in previous studies [12-13].

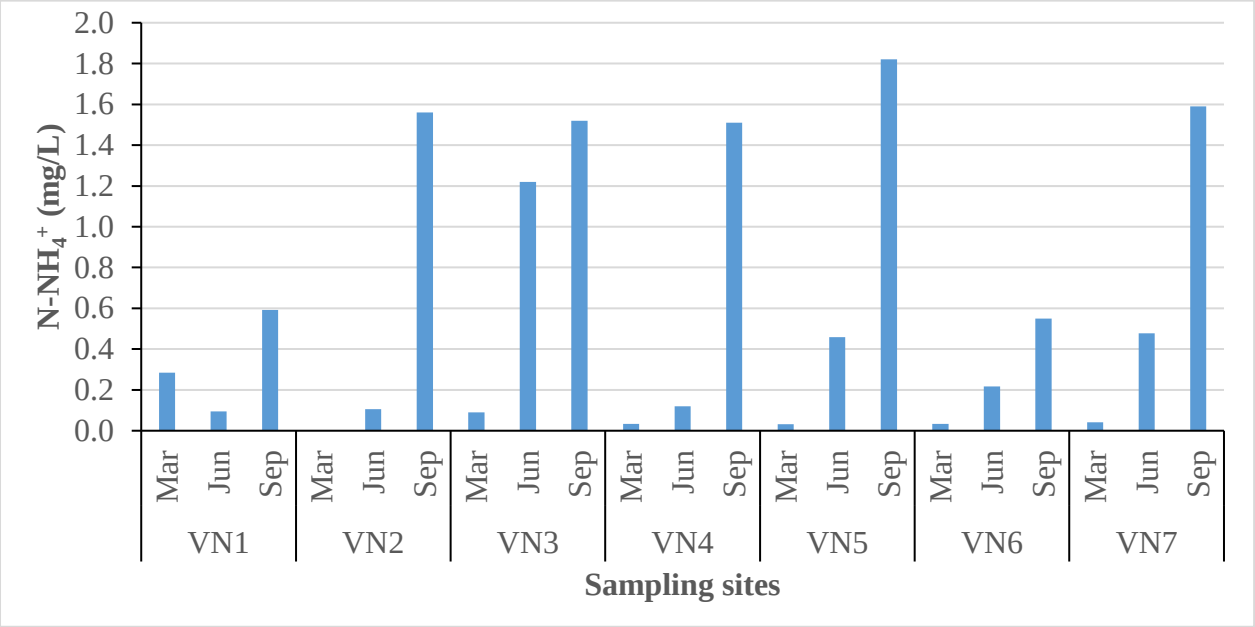

Figure 8. $N\text{-}NH_4^+$ at the flood control area

The nitrate ($N\text{-}NO_3^-$) concentration at the monitoring locations of the Bac Vam Nao flood control area in 2020 ranges from 0.024 to 1.66 mg/l (Figure 9), all of which meet the standards QCVN 08-MT:2015/BTNMT, column A1 (2 mg/l). The $N\text{-}NO_3^-$ concentration between sampling sites ranged from 0.07 to 0.61 mg/L. Nitrate in March, June and September were 0.85, 0.24 and 0.05 mg/L, respectively. The results show that nitrate in the dry season tends to be higher than that in the dry season. Previous research showed that $N\text{-}NO_3^-$ concentration in Hau river ranged from 0.002-0.395 mg/L [11], An Giang canals ranged from 0.31 ± 0.3 to 0.58 ± 0.64 mg/L [10], canals in Soc Trang province 0.05-0.14 mg/L [14], but still within the allowable limit of QCVN 08-MT:2015/BTNMT, column A1(2 mg/L) [4].

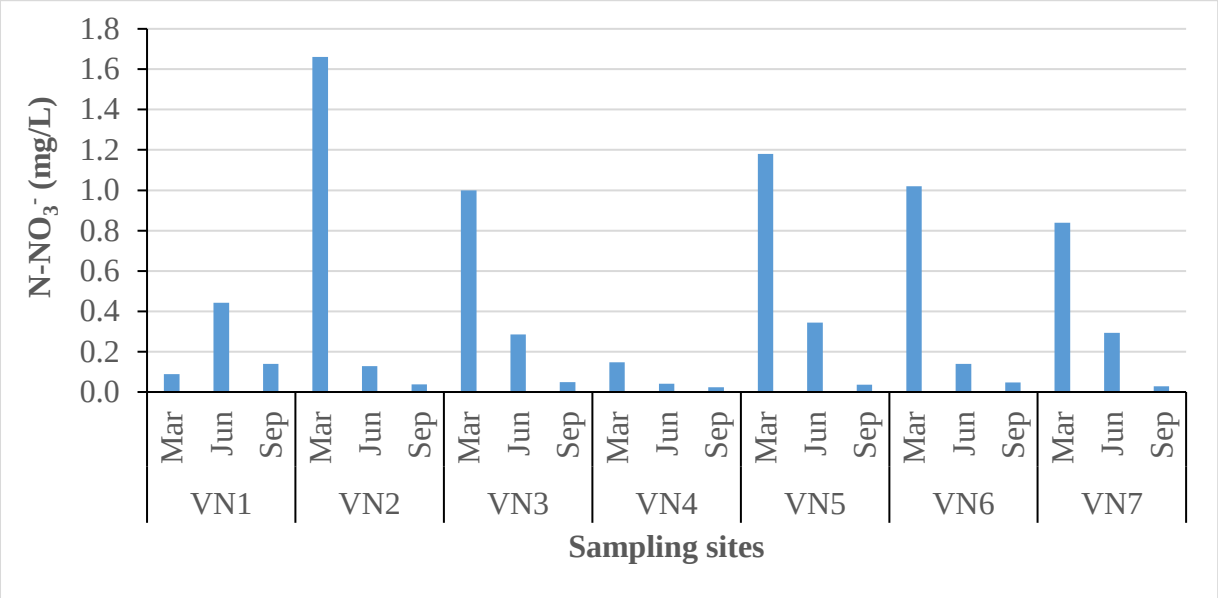

Figure 9. N-NO_3^- at the flood control area

Orthophosphate (P-PO_4^{3-}) in the Bac Vam Nao flood control area ranges from 0 to 0.34 mg/l (Figure 10). The mean value of P-PO_4^{3-} between sampling sites was in the range of 0.12-0.19 mg/L. The average value of P-PO_4^{3-} at the sampling locations exceeded the allowable limit of QCVN 08-MT:2015/BTNMT, column A1 (0.1 mg/l). Meanwhile, P-PO_4^{3-} in March, June, and September was 0.06, 0.10, and 0.33 mg/L, respectively, showing that P-PO_4^{3-} fluctuates over time in which P-PO_4^{3-} in the rainy season tends to higher than the dry season. Normally, in natural surface water, P-PO_4^{3-} concentrations exist from 0.005-0.02 mg/L. In water bodies, the concentration of P-PO_4^{3-} in water is usually very low, around 5-20 µg/L and rarely exceeds 200 µg/L even in nutrient-rich water bodies. The total phosphorus (TP) concentration also rarely exceeds 1000 µg/L [15]. The origin of phosphorus can be from fertilizers, detergents due to farming, livestock and industrial activities [16].

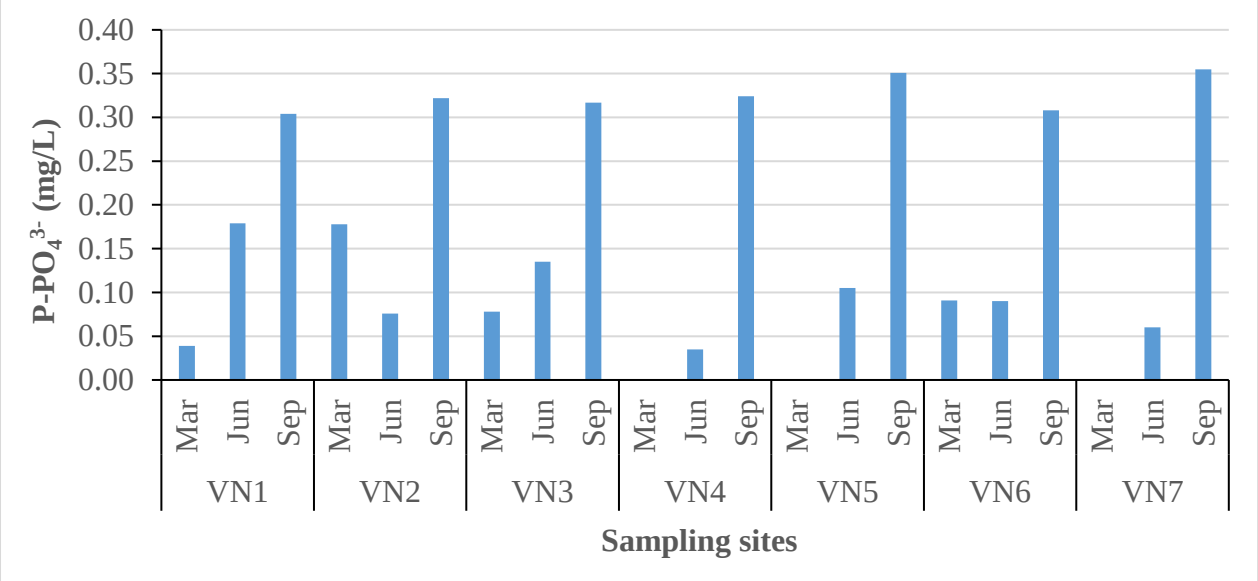

Figure 10. P-PO_4^{3-} at the flood control area

The evolution of Coliform density through 3 monitoring periods in 2020 in the Bac Vam Nao flood control area ranged from 2,300 to 110,000 MPN/100 ml (Figure 11), 1.12 to 44 times higher

than the standard QCVN 08-MT:2015/BTNMT, column A1 (2,500 MPN/100 ml) (except at the beginning of Phu Binh - Hiep Xuong canal adjacent to Hau river (VN2) in September; beginning of K26 canal, adjacent to Tien river- (VN4) in June and September). In which, the level of coliform pollution reached the highest level in September at Cai Tac canal (VN7), 44 times, followed by the end of Than Nong canal adjacent to Cai Tac canal (VN5) in June and at the midpoint of the Than Nong canal adjacent to K16 (VN6) in September, it exceeded 18.40 times. The coliform counts in March, June, and September were 14200, 17414, and 25286 MPN/100 mL, respectively. The results showed that coliform population in the rainy season tends to be higher than that in the dry season. Research by [10] showed that coliform in surface water of An Giang province exceeded the allowable limit 2.14-7.02 times. In canals of Soc Trang province, coliform exceeded from 1 to 36 times [14]. The sources of coliform contamination are from human and animal wastes, especially the fecal materials [17-18].

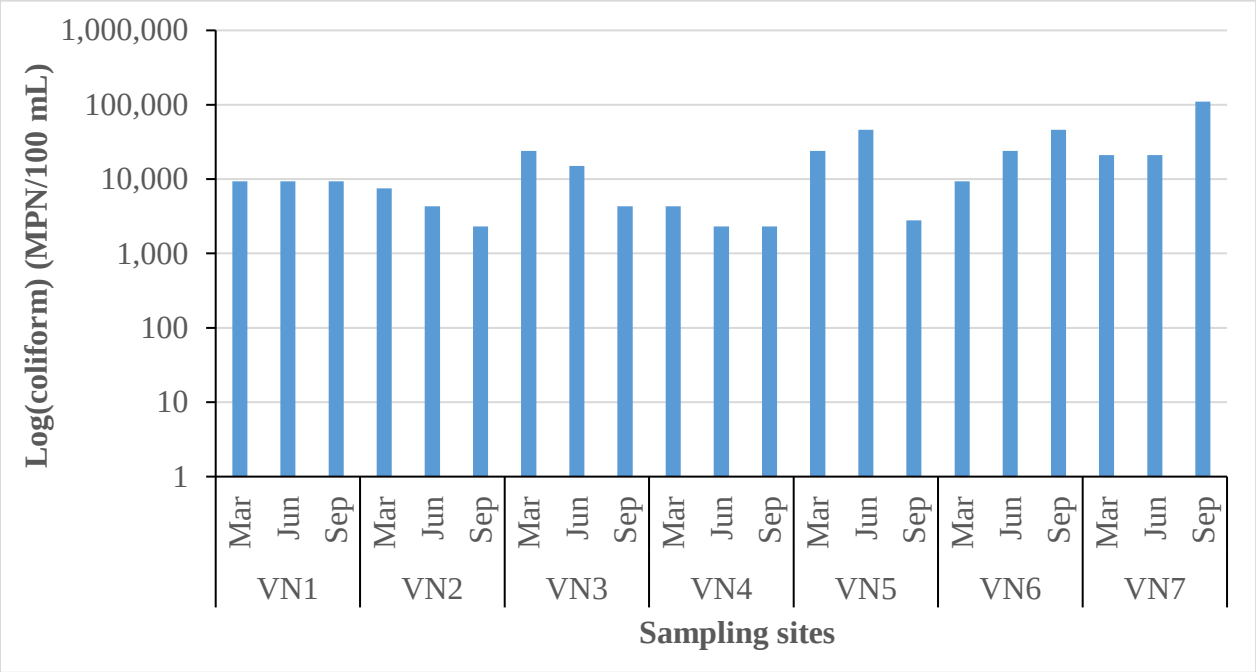

Figure 11. Coliform at the flood control area

3.2 Evaluating water quality using water quality index

Surface water quality in the Bac Vam Nao flood control area according to the WQI index over time in 2020 ranges from the level of use for navigation to the level of use for domestic water supply but needs to be treated. suitable reason. In general, at the beginning of the Phu Binh - Hiep Xuong canal adjacent to the Hau river (VN2) and the beginning of the K26 canal, adjacent to the Tien river (VN4), the water quality according to the WQI index is better than the rest of the areas. ranges from irrigation use to domestic water use but needs appropriate treatment measures, preferably in June. Most of the remaining sites ranged from use to navigation to the extent of irrigation use. Particularly, the location of Cai Tac canal (VN7) has poorer water quality, suitable only for navigation purposes. The mean value of WQI at the sampling sites ranges from 32-75. WQI in March, June, and September are 49, 52, 51 respectively. Research results show that overall water quality has little seasonal variation. Therefore, it is necessary to continue monitoring to promptly warn people, depending on the purpose of use, and take appropriate measures to treat water. Due to the characteristics of the Bac Vam Nao flood control area, the water flow is controlled and not circulated regularly, in addition, this area is mainly located in the canals, in-field canals with small area, self-cleaning ability. of the canals and canals are poor, which partly causes the water quality to be

reduced. Therefore, it is necessary to strengthen control of agricultural activities and dredging of canals to limit the entry of pollutants from these activities into water sources.

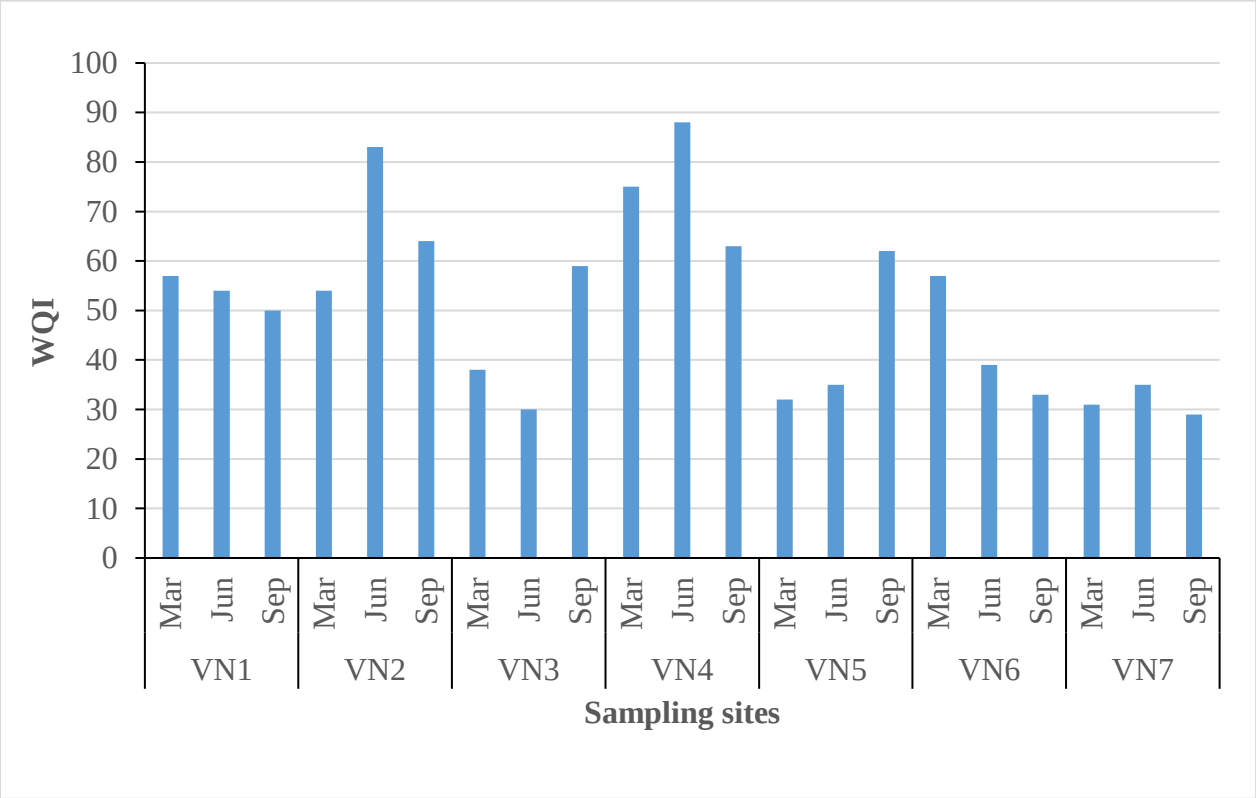

Figure 12. WQI at the flood control area

3.3 Key variables influencing on water quality at the flood control area

The results of the main component analysis are presented in Table 3. Water quality in the Bac Vam Nao flood control area is affected by four main sources, PC1-PC4, which explain 84.8% of the variation in water quality. Sources from PC5-PC7 are secondary sources that explain only 15.2% of the variation in surface water quality in the flood control area. PC1 had a weak effect on TSS, BOD, COD and coliform parameters. PC2 has a weak to moderate impact on temperature, pH and DO parameters. Meanwhile, PC3 had a weak to moderate correlation with temperature, DO, N-NH_4^+, N-NO_3^- and coliform. In particular, PC4 is strongly correlated with P-PO_4^{3-}. Similar to PC3, PC5 has a weak correlation with DO N-NH_4^+, N-NO_3^- and coliform. PC6 has a weak to moderate correlation with temperature, pH and coliform whereas PC7 has a moderate correlation with DO and N-NO_3^-. In the study area, temperature is affected by 3 sources (PC2, PC3, PC6), pH is affected by 2 sources (PC2, PC6), TSS is affected by 1 source PC1, DO is affected by 4 sources (PC2, PC3, PC5, PC7), BOD and COD are affected by PC1, N-NH_4^+ is affected by source PC3, PC5, N-NO_3^- is affected by PC3, PC5, PC6, P-PO_4^{3-} affected by PC4. Coliform is affected by 4 sources including PC1, PC3, PC5, PC6. Research results show that there are many factors affecting surface water quality in the study area. The parameters of temperature, pH, N-NH_4^+, N-NO_3^-, P-PO_4^{3-}, DO, and coliform have major impacts on water quality and need to be continuously monitored.

Table 3. Key variables influencing on water quality at the flood control area

	PC1	PC2	PC3	PC4	PC5	PC6	PC7
Temp	0.160	0.526	0.342	0.000	0.181	0.632	0.196
pH	0.050	0.670	-0.007	0.000	0.237	-0.395	0.102
TSS	0.447	-0.120	0.242	0.000	-0.265	0.243	0.050
DO	-0.151	0.405	-0.427	0.000	-0.460	0.270	-0.583
BOD	0.484	-0.127	-0.047	0.000	0.075	0.053	-0.265
COD	0.482	-0.125	-0.059	0.000	0.110	0.065	-0.271
$N\text{-}NH_4^+$	0.290	0.065	-0.500	0.000	0.554	-0.069	-0.080
$N\text{-}NO_3^-$	0.271	0.057	-0.533	0.000	-0.403	0.028	0.665
$P\text{-}PO_4^{3-}$	0.000	0.000	0.000	-1.000	0.000	0.000	0.000
Coliform	0.353	0.237	0.321	0.000	-0.376	-0.548	-0.126
Eig. V	4.00	1.97	1.51	1.00	0.90	0.34	0.28
%Var.	40.0	19.7	15.1	10.0	9.0	3.4	2.8
C.%Var.	40.0	59.7	74.8	84.8	93.8	97.2	100.0

4. Conclusion

From the monitoring results, surface water quality affected by the flood control area of Bac Vam Nao in 2020 is not guaranteed well according to QCVN 08-MT:2015/BTNMT, column A1 - National Technical Regulation on surface water quality. In which, the DO concentration in the water is lower than the standard and the parameters TSS, COD, BOD, $P\text{-}PO_4^{3-}$, $N\text{-}NH_4^+$ and Coliform exceed the permissible limits. Surface water quality in the Bac Vam Nao flood control area according to the WQI index over time in 2020 ranges from the level of use for navigation to the level of use for domestic water supply but needs to be treated. suitable reason. The results show that temperature and pH have little seasonal variation. DO, TSS, $N\text{-}NO_3^-$ in the dry season were higher than that in the rainy season while BOD, COD, $N\text{-}NH_4^+$, $P\text{-}PO_4^{3-}$, coliform in the rainy season were higher than that in the dry season. Water quality in the Bac Vam Nao flood control area is influenced by four main sources, PC1-PC4, which explain 84.8% of the variation in water quality. The parameters of temperature, pH, $N\text{-}NH_4^+$, $N\text{-}NO_3^-$, $P\text{-}PO_4^{3-}$, DO, and coliform have the main impact on water quality and need to be continuously monitored. The research results show that the water quality in the flood control area has been polluted, it is necessary to have solutions to improve the water quality.

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References

[1] People's Committees of An Giang province. (2015). Environment State Report for the period of 2015-2020.
[2] Ministry of Natural Resources and Environment (MONRE). (2015). State of the National Environment for the period 2011-2015.
[3] Ministry of Natural Resources and Environment (MONRE). (2018). State of the National Environment in 2018-Water environment of river basins.
[4] Vietnam Environmental Protection Agency. (2015) National technical regulation on surface water quality (QCVN 08-2015/BTNMT). Vietnam Environmental Protection Agency: Hanoi, Vietnam, 2015.
[5] American Public Health Association, American Water Works Association, Water Environment Federation. (1998). Standard Methods for the Examination of Water and Wastewater, 20th Ed. American Public Health Association: Washington, D.C.
[6] Vietnam Environment Administration. (2019). Decision No. 1460/QD-TCMT dated on 12/11/2019 on the guidance of water quality index (WQI) calculation.

[7] Chounlamany, V., Tanchuling, M.A., Inoue, T. (2017). Spatial and temporal variation of water quality of a segment of Marikina River using multivariate statistical methods. *Water Science and Technology*, 76: 1510–1522.
[8] Ongley. E.D. (2009). Chapter 12: Water Quality of the Lower Mekong River. In: Campbell, I.C. (ed.): *The Mekong: Biophysical Environment of an International*.
[9] Mekong River Commission (MRC). (2015). Lower Mekong regional water quality monitoring report. ISSN: 1683-1489. *MRC Technical Paper No.51*.
[10] Ly, N.H.T., Giao, N.T. (2018). Surface water quality in canals in An Giang province, Viet Nam, from 2009 to 2016. *J. Vietnamese Environment*, 10, 113–119.
[11] Lien, N.T.K., Huy, L.Q., Oanh, D.T.H., Phu, T.Q., Ut, V.N. (2016). Water quality in mainstream and tributaries of Hau River. *Can Tho University Journal of Science*, 43, 68–79.
[12] Giao, N.T., Minh, V.Q. (2021). Evaluating surface water quality and water monitoring variables in Tien River, Vietnamese Mekong Delta. *Journal Teknologi*, 83(3), 29-36.
[13] Giao, N.T., Nhien, H.T.H., Anh, P.K. and Ni, D. V. (2021). Classification of Water Quality in Low Lying Area in Vietnamese Mekong Delta Using Set Pair Analysis Method and Vietnamese Water Quality Index. *Environmental Monitoring and Assessment*, 193(6):1-16.
[14] Tuan, D.D.A., Thu, B.A., and Trung, NH. (2019). Assessing quality of surface water for urban water supply source for Soc Trang City. *Can Tho Scientific Journal of Science*, 4A:61-70.
[15] Boyd, C.E., Green, B.W. Water quality monitoring in shrimp farming areas: an example from Honduras, Shrimp Farming and the Environment. The World Bank, NACA, WWF and FAO Consortium Program on Shrimp Farming and the Environment; Auburn: USA, 2002.
[16] Ojok, W., Wasswa, J. and Ntambi, E. (2017) Assessment of Seasonal Variation in Water Quality in River Rwizi Using Multivariate Statistical Techniques, Mbarara Municipality, Uganda. *Journal of Water Resource and Protection*, 9, 83-97.
[17] United Nations Children's Fund (UNICEF). Handbook on Water Quality. UNICEF, New York, 2008.
[18] World Health Organization (WHO). Guidelines for drinking-water quality - Volume 1: Recommendations Third edition, incorporating first and second addenda. Geneva: World Health Organization, 2008.