



Quality and Sources of Water Pollution in Rivers Ninh Kieu District, Can Tho City, Vietnam

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Abstract

The study was conducted to assess the current state of surface water environment, the causes of surface water pollution and to recommend measures to manage surface water quality in Ninh Kieu district, Can Tho city, Vietnam. Surface water quality was assessed through the parameters of pH, temperature, turbidity, dissolved oxygen (DO), biochemical oxygen demand (BOD), suspended solids (TSS), and chemical oxygen demand (COD), ammonium ($\text{NH}_4^+\text{-N}$), nitrite ($\text{NO}_2^-\text{-N}$), nitrate ($\text{NO}_3^-\text{-N}$), orthophosphate ($\text{PO}_4^{3-}\text{-P}$), coliform. Surface water monitoring data was collected from Department of Natural Resources and Environment, Can Tho city in 2019. Causes of environmental pollution were investigated through surveyed the places and interviewed 40 households living near the water bodies in Ninh Kieu district, Can Tho city. The results showed that DO, BOD, COD, TSS, $\text{NH}_4^+\text{-N}$, $\text{PO}_4^{3-}\text{-P}$ exceeded the allowable limits of National Technical regulations on surface water quality (QCVN 08-MT: 2015/BTNMT, column A1) proving the surface water in the study area contaminated by suspended solids, organic matters and nutrients. The household interviewing findings revealed the main sources of water pollution were caused by solid wastes and domestic wastewater and wastes from the market area, business production and trading activities. To manage surface water effectively, it is necessary to have management solutions to strengthen law enforcement on environmental protection and at the same time to propagate and mobilize communities to participate in water quality management.

1. Introduction

Water is an extremely valuable resource that is an essential component of life and the environment, determining the existence and development of all living things on earth. Vietnam has a relatively rich surface water resource, accounting for about 2% of the total flow of rivers in the world while the land area accounts for about 1.35%. But the population growth and human activities increasingly strongly impact on the surface water environment with spontaneous, unplanned human activities that will cause very serious consequences for water resources. Lack of clean water is a danger to people in the future. The control, management and treatment of water quality is very necessary in the current context. According to the law on environmental protection, environmental protection of river water is one of the basic contents of planning and planning on exploitation and use of river water; waste sources entering river basins must be managed and treated in accordance with river assimilating capacity. In addition, river water quality must be monitored and evaluated.

Ninh Kieu District is a major central district of Can Tho City with a plentiful surface water resource due to the huge reserve of surface water provided by the Hau River which is very crucial for the people's livelihood and production. Ninh Kieu district is on the rise with the process of industrialization - modernization, is a crowded population with many hospitals, supermarkets, schools, restaurants, entertainment centers. As the place where the annual population density increases significantly as well as attracts the most tourists, the problem of environmental pollution in general and water pollution in particular is worthy of attention. Currently, the water environment in rivers and canals in Ninh Kieu district is suffering from domestic water sources, markets, some riverside houses, canals. The habits of direct discharge of wastewater, garbage disposal, dead animals in the river have made part of water increasingly polluted. There have been many studies on the quality of surface water [1-4], but there are no studies to determine the main cause of surface water pollution. Therefore, this study was conducted to assess the current state of water quality, survey the causes of pollution and recommend some solutions for water quality management.

2. Methodology

2.1 Study site description

Ninh Kieu district, Can Tho city is located in a tropical climate - monsoon, few storms, hot and humid all year round, with no cold season. The rainy season lasts from May to November, the dry season from December to April next year. The average temperature is about 28°C, the average number of sunny hours is about 2,249.2 hours, the average annual rainfall is 2000 mm. The annual average humidity ranges from 82%-87% [5]. Due to the influence of monsoon tropical climate, advantages in temperature background, heat radiation regime, high and stable sunshine regime according to two seasons of the year. Ninh Kieu District is located entirely on the land of alluvial origin of the Mekong River, which is deposited and regularly deposited through the alluvial water of the Hau River. Geology in the city is formed mainly through the sedimentation process of marine sediments and alluvium of the Mekong River. These advantages are very favorable for the growth and development of organisms, can create a high-yield tropical agricultural system, with many types of seedlings, creating diversity in production and in restructuring of production.

According to the report of the Department of Statistics in Can Tho city, the population of the district in 2018 was 269,541 people, the highest population density in the city was 9,202 people/km². In addition, due to the district's characteristics, there are 12 hospitals, 11 health care centers, 15 universities, colleges, and professional secondary schools that have attracted many people to study and medical treatment since then. For the number of temporary residents, living in the area is very crowded, this has put great pressure on the district when dealing with social security issues. Ethnic groups, mainly Kinh people account for about 96.3%, Hoa people about 2.6%, Khmer people account for 1% and the rest of some ethnic groups such as Tay, Thai, Cham. According to the socio-economic survey in June 2018, the percentage of males accounts for 47%, and females about 53%. Ninh Kieu District features a central district that is an urban area, so 100% is urban, all land is used for urban areas, economic development of the district focuses on industrial production, handicraft, business and more focused on commercial services. The current economic structure of the district is trade and services accounting for more than 70%, the rest is in industry, handicraft and agriculture. According to the economic development orientation at the XI Congress of the District Party Committee (term 2015 - 2020) has identified the general goal of promoting economic development in parallel with the good implementation of social security policies, improving people's life, economic shift towards service trade, industry, small industry, step by step building and developing Ninh Kieu district into a civilized city with large and most modern commercial centers Can Tho City. In terms of education, the district concentrates the biggest universities in the Mekong Delta such as Can Tho University, Can Tho University of Medicine and Pharmacy and many leading colleges in the city such as Can Tho College, College of Economics and Technology, College of Health. These educational facilities are places to train high-quality human resources not only for the city. Can Tho but for the whole Mekong Delta with the scale of thousands of students/year. In

terms of technology, there is also 1 Technology - Technology application center, 1 Software Technology center, 1 exhibition center, 2 television centers that have created the pioneering role of Ninh Kieu district, positively impacting the socio-economic development of Can Tho city, as well as of the whole Mekong Delta region. In terms of health, the district has many leading hospitals in the city and the region such as Can Tho Central General Hospital, City City General Hospital. Can Tho Central General Hospital was built on a total area of 61,664 m² located at Highway 91B, Binh An ward, Ninh Kieu district. The hospital was inaugurated on June 28, 2008. The hospital has 700 beds, including 35 departments (with 20 clinical departments, 9 subclinical departments, and 6 functional rooms). With the scale of being the largest central medical center in the Mekong Delta, the hospital is responsible for both treating the people and training regional medical staff.

2.2 Surface water quality data collection and investigation of polluting sources

Surface water samples were collected 12 times per year at 13 locations with 12 water quality indicators of pH, temperature, turbidity, suspended solids (TSS), dissolved oxygen (DO), biochemical oxygen demand (BOD), and chemical oxygen demand (COD), ammonia (NH₄⁺-N), nitrite (NO₂⁻- N), nitrate (NO₃⁻- N), orthophosphate (PO₄³⁻- P), coliform. The indicators of pH, temperature, DO were measured in the field by hand-held meters, the rest were collected, stored, transported and analyzed at the laboratory of the Center for Natural Resources and Environment Monitoring, Can Tho city using standard methods [6]. The environmental quality parameters of surface water were evaluated using QCVN 08-MT: 2015/BTNMT, column A1. Sampling locations and characteristics were shown in Table 1.

Table 1. Description of location to collect surface water quality assessment data in Ninh Kieu district

No.	Site	Code	Coordinates		Description
			Long	Lat	
1	Water plant 1 (30/4 street)	NM1	10°02'2.727"	105°7'74.051"	Assessing water quality of Can Tho river before supplying water for domestic use.
2	Vam Khai Luong canal	NM2	10°0'3.763"	105°7'89.799"	Assessment of water quality in Khai Luong canal before flowing to Hau river (due to domestic activities)
3	Vam Cai Khe canal	NM3	10°03'9.513"	105°7'89.247"	Assessment of water quality in Cai Khe canal before flowing to Hau river (due to domestic activities)
4	Vam Tham Tuong canal	TT1	10°0'2.545"	105°7'77.771"	Assess the water quality of Tham General canal before flowing into Can Tho river
5	Cong Tham Tuong- Mau Than	TT2	10°0'30.047"	105°7'76.358"	Assessment of water quality in Tham General canal is influenced by residential activities
6	Vam Cai Khe canal	CK1	10°04'3.058"	105°7'85.304"	Assess water quality in Cai Khe canal before flowing to Hau river
7	Nhi Kieu bridge	CK2	10°0'40.500"	105°7'77.259"	Assessment of water quality in Cai Khe canal influenced by residential activities

8	Rach Ngong Bridge	CK3	10°03'9.332"	105°7'70.002"	Assessment of water quality in Cai Khe canal influenced by residential activities
9	Xang Thoi lake	CK4	10°03'8.018"	105°7'78.859"	Assessment of water quality of Xang Thoi lake affected by residential activities
10	Bun Xang lake	BX1	10°03'1.842"	105°7'62.849"	Assessment of water quality in Bun Xang lake affected by residential activities
11	The end point of Bung Xang lake intersects with Can Tho river	BX2	10°01'7.815"	105°7'51.064"	Assessing water quality in Bun Xang canal before flowing to Can Tho river
12	ection between Cai Son canal, Hang Bang (The area opposite companies such as Tan Hung Paper Company, Trung Viet Mechanical)	HB1	10°02'6.553"	105°7'42.078"	Water quality assessment in Cai Son Hang Bang canal is affected by industrial activities
13	Vam Cai Son canal, Hang Bang (the area adjacent to Can Tho river)	HB2	10°00'7.803"	105°7'46.926"	Assessing water quality in Cai Son Hang Bang canal before flowing to Can Tho river

The source of environmental pollution of surface water in Ninh Kieu district, Can Tho city was collected using semi-structured interview of 40 households living near the river were randomly selected for interviews to collect information about the current state of water quality and sources of pollution. Interview data was summarized, calculated average value and presented in the form of tables or pictures.

3. Results and discussion

3.1 Environmental quality of surface water in Ninh Kieu district, Can Tho city

pH at 13 sampling locations in the study area had a difference but not significantly, ranged from 7.1-7.3, on average 7.19 ± 0.22 (Table 2). At 2 points CK2 and CK4 had the lowest pH (pH = 7.1) and the highest at 2 points CK3 and CK1 (pH = 7.3), while at the remaining 9 points pH was at pH = 7.2. The former studies also showed that surface water usually has a pH of 6.4-7.3 [1-2]. The pH values in this study are still within the appropriate range for the growth of aquatic organisms [7]. The temperature of the monitoring locations in Ninh Kieu district in 2019 showed no difference, ranging from 26.9-27.2 °C, on average $27.05 \pm 0.43^\circ\text{C}$ (Table 2). According to the study of water quality on the main and tributary rivers of the Hau river [1], the water temperature in the sampling areas fluctuated in the range from 27.1-32°C. This temperature was suitable for the growth of aquatic organisms [7-8]. Turbidity had a large variation at the study locations from 17.38 to 63.92 NTU and the average value recorded is 39.03 ± 43.73 NTU. The location with the lowest turbidity was MN2-MN3, respectively 17.38-20.38 NTU and the highest position was in TT2 with 63.92 NTU (Table 2).

DO between sampling points ranged from 4.16-5.94 mg/l, average 5.45 ± 0.52 mg/l, all was lower than the allowable limit of QCVN 08-MT: 2015/BTNMT, column A1 showing signs of organic contamination in the water. Surface water quality of Can Tho river in the period 2010-2014 ranged

from 3.5-5.8 mg/l [8]. DO in Soc Trang canals ranged from 1.7 to 6.2 mg/L [3]; in inland canals of An Giang in the period 2009-2016 in the range of 4.9-5.5 mg/L [2] and on the Hau River in 2018, it was 4.9-6.3 mg/L [4]. Dissolved oxygen in the water environment depends on the diffusion of the air into the water, the disturbance of the river, the presence of biodegradable organic matter and the photosynthesis of phytoplankton [10]. The low DO content showed signs of organic pollution in the water environment.

BOD at 13 monitoring positions ranged from 5.84 - 17.18 mg/l, average 8.95 ± 2.78 mg/l (Table 2). The highest BOD was found at Cong Tham General - Mau Than (17.18 mg/l) and the lowest was in Vam Cai Khe (5.84 mg/l). BOD at all survey locations exceeded the permitted limit QCVN 08-MT: 2015/BTNMT, column A1 (4mg/l) indicating that the water environment was polluted with organic matters [11-12]. BOD on Can Tho River for the period 2010-2014 was in the range of 5.5-31.6 mg/l [9]. BOD in canals in the inner field of An Giang province in the period 2009-2016 ranged from 4.7 ± 2.3 - 12.3 ± 9.2 mg/L [2]; BOD and COD in Soc Trang canal are 2.2-22.4 mg/L and 6.0-44.9 mg/L, respectively [3]; and COD on Hau river 10.4 ± 1.2 - 16.5 ± 4.1 mg/L [4]. The high concentrations of BOD and COD in river water are mainly due to the influence of socio-economic activities such as agriculture, industry, services, residential and urban areas [13-14]. The COD ranged from 11.79 to 32.60 mg/l, with the mean value being 18.4 ± 4.59 mg/l (Table 2). It can be seen that COD at the monitoring positions in the water bodies of Ninh Kieu district all exceeded the allowable limits of QCVN 08-MT: 2015/BTNMT, column A1. The highest COD was found at Xang Thoi Lake (22.43 mg/l) Rach Ngong Bridge (22.95 mg/l), Cong Tham Tuong - Mau Than (32.60 mg/l) and lowest at Vam Rach Cai Khe (11.79 mg/l). High COD is caused by organic polluted water environment [10-11] and is affected by waste disposal during socio-economic development [13-14]. TSS at the monitoring positions ranged from 27.75 to 62.75 mg/l, averaging 46.45 ± 23.8 mg/l (Table 2). Previous research showed that on the Hau river in 2016, the average was 51.5 ± 31.37 mg/L [1], TSS in 2018 ranged from 41.16-48.67 mg/L [4]. In inland canals of An Giang province, TSS reached 25-93.7 mg/L between 2009 and 2016 [2]. Whereas in canals in Soc Trang province, TSS ranged from 16-176 mg/L [3]. TSS at 13 monitoring locations all exceeded the standard QCVN 08-MT: 2015/BTNMT, column A1. The causes of high TSS are from storm water runoff, erosion, and the presence of phytoplankton [10, 13].

N-NH₄⁺ fluctuated in the range of 0.16 - 1.44 mg/l, most of the survey locations exceeded the permissible limit QCVN 08-MT: 2015/BTNMT, column A1. Ammonium was highest at Cong Tham Tuong - Mau Than (over 4.79 times), at Nhi Kieu Bridge (3.7 times higher) and Rach Ngong Bridge (exceeding 3.42 times) compared to QCVN 08-MT: 2015/BTNMT. Ammonia in surface water in Soc Trang ranged from 0.02-4.15 mg/L [3], Hau Giang ranged 0.04 ± 0.017 mg/L [4]. The presence with high concentrations of ammonium poses a risk of poisoning to aquatic organisms and eutrophication. Ammonium is derived from wastes from socio-economic development activities of Ninh Kieu district, Can Tho city. Nitrite and nitrate ranged from 0.016 to 0.043 mg/L and 0.46 to 1.09 mg/l, respectively (Table 2). At all points nitrite and nitrate were lower than the limits of QCVN 08-MT: 2015/BTNMT. PO₄³⁻-P ranged from 0.06 to 0.19 mg/l, averaging 0.11 ± 0.07 mg/l (Table 2). Orthophosphate at 9/13 positions exceeded the permitted limit of QCVN 08-MT: 2015/BTNMT column A1 (0.1 mg/l). Orthophosphate values in inland canals and Hau river in An Giang province ranged from 0.02 to 0.47 mg/L [2], on Hau river An Giang-Hau Giang section 0.04-0.11 mg/L [4], canals of Soc Trang province 0.05-0.9 mg/L [3] shows that PO₄³⁻-P in surface water environment in the Mekong Delta has exceeded QCVN 08-MT: 2015/BTNMT, column A1. The results showed that PO₄³⁻-P may be an environmental problem with water bodies of Ninh Kieu district, Can Tho city.

Table 2. Summary of water quality in Ninh Kieu district, Can Tho city

Cod e	Stat s	pH	Tem p	Tüb c	DO	BOD s	CO D	TSS	N- NH ₄ ⁺	N- NO ₂ ⁻	N- NO ₃ ⁻	P- PO ₄ ³⁻	Coli- form	
NM 1	Mea n	7.20	26.95	23.2	5	5.83	6.58	9	4	0.16	0.02	0.74	0.06	2500
	SD	0.04	0.05	0.11	0.13	0.24	0.22	0.27	0.34	0.25	0.33	0.33	0.30	
NM 2	Mea n	7.18	32.50	17.3	8	5.91	7.10	5	5	0.19	0.04	0.63	0.06	1750
	SD	0.47	11.40	0.41	0.24	0.28	0.31	0.41	0.47	0.47	0.60	0.60	0.60	0.70
NM 3	Mea n	7.20	26.91	20.3	8	5.94	5.84	9	40.1	0.19	0.02	1.09	0.08	1645
	SD	9.54	3.40	9.36	9	34.1	24.6	7	29.8	54.92	52.00	51.63	67.91	50.70
TT1	Mea n	7.18	27.03	37.3	1	5.81	7.20	9	4	0.33	0.03	0.51	0.09	2091.6
	SD	0.36	0.23	0.35	0.47	0.72	0.32	0.77	0.74	0.51	0.54	0.46	0.35	7
TT2	Mea n	7.24	27.05	63.9	2	4.16	17.18	0	5	1.11	0.03	0.69	0.19	3216.6
	SD	1.47	1.99	1.17	3.15	4.67	2.25	3.25	3.73	3.51	3.48	2.08	1.73	7
CK1	Mea n	7.27	27.00	26.2	5	5.89	6.58	9	0	0.42	0.04	0.70	0.12	1501.6
	SD	1.77	0.86	2.57	5.59	9.09	4.10	6.16	5.43	6.31	4.34	2.60	3.41	7
CK2	Mea n	7.11	27.04	35.3	3	5.14	9.66	3	3	1.11	0.03	0.80	0.13	2008.3
	SD	4.67	2.25	7.04	0	14.9	45.90	3	7	32.79	31.75	31.37	32.30	13.7
CK3	Mea n	7.28	27.20	44.4	2	4.87	12.23	5	3	1.03	0.04	0.74	0.12	2021.6
	SD	0.06	0.10	0.08	0.33	1.03	0.45	0.66	0.68	0.32	0.32	0.20	0.19	7
CK4	Mea n	7.11	27.14	42.8	3	4.98	10.77	3	8	0.81	0.03	0.86	0.14	2454.1
	SD	0.06	0.07	0.04	0.08	0.17	0.12	0.14	0.16	0.13	0.08	0.12	0.13	7
BX1	Mea n	7.15	27.11	51.7	5	5.33	8.74	5	5	0.58	0.04	0.73	0.11	2438.3
	SD	0.00	0.044	0.00	0.05	0.05	0.05	0.05	0.05	0.052	0.053	0.055	0.056	0.054
BX2	Mea n	7.18	27.08	48.8	3	5.61	8.48	7	8	0.54	0.04	0.59	0.13	1985.8
	SD	0.30	0.13	0.40	0.37	0.36	0.47	0.39	0.52	0.32	0.26	0.28	0.40	3
HB1	Mea n	7.23	27.15	51.1	7	5.63	7.82	0	2	0.51	0.04	0.60	0.13	2337.5
	SD	0.01	0.02	0.02	0.05	0.16	0.12	0.04	0.05	0.06	0.11	0.10	0.07	0
HB2	Mea n	7.19	27.08	44.5	8	5.68	8.17	3	7	0.44	0.04	0.73	0.12	2257.5
	SD	1577	568.6	975.	396.	1008	788.	729	995.41	1349.	1357.	773.7	5	893.96

The coliform density ranged from 1502 to 2872 MPN/100 ml (Table 2). Former study by Ly and Giao (2018) [2] showed that coliforms in surface water of An Giang province in the period 2009-2016 exceeded the permitted limit by 2.14-7.02 times. In canals in Soc Trang province, coliform exceeded 1 to 36 times [3]. Coliform on Tien river exceeded the permitted standard by 2.2-5.7 times [4]. In the study area, coliform was still within the allowable level of QCVN 08-MT: 2015/BTNMT, column A1 (2500 MPN/100 ml) excepting the position MN. The study area had the signs of

microbiological contamination. The origin of coliform can be from human and animal feces [15-16], indicating that the sanitation conditions in the study area are very poor.

3.2 Sources of surface water pollution

The present study results showed that the causes of water pollution were the wastes and wastewaters from residential areas (42% of respondents), and from markets (24%). Manufacturing and trading activities contributed 16% to surface water pollution. Only 6% of households believed that water quality was affected by wastewaters from industrial zones and factories. In addition, 6% of households considered that medical waste and wastewater also contributed to surface water quality and 5% was due to other reasons. The interview results also showed that 19% of the surface water was not polluted, 48% responded that there was little pollution, 26% said that water was medium pollution, 23% thought that surface water was heavily polluted and 13% supposed that that water was seriously polluted. Most of the people's comments were consistent with the results of the water quality assessment discussed in the above sections that the water source was polluted with suspended solids, organic matters, nutrients and microorganisms.

Water is essential for life. Therefore, protection of water resources is essential. Some measures to protect surface water quality in Ninh Kieu district, Can Tho city including strengthening law enforcement on environmental protection, especially water environment. Violations need to be detected and handled according to the provisions of Decree No. 155/2016/ND-CP dated November 18, 2016, the regulations on sanctioning of administrative violations in the field of environmental protection. Regularly propaganda to raise people's awareness of environmental protection through state management agencies and the social organizations such as Women's Union, Youth Union, local Trade Union is needed. It is possible to combine programs such as World Environment Day, National Clean Water Week, International Day of Action for Rivers, World Water Day with the form of mass media propaganda by newspapers, radio, posters, flyers. Organization of the friendly meeting in densely populated places to raise people's awareness about environmental protection. Appropriate measures should be taken to collect wastewater and have a centralized wastewater treatment plant before discharging it into rivers, canals and ditches. Organizing teams to collect domestic waste, garbage on rivers, canals and ditches. Regularly renovate and dredge canals and ditches to increase self-cleaning capacity of water sources. Clear decentralization of environmental management to enable effective environmental management.

Table 3. Decentralization of water environment management

Management level	Responsibility
City	Promulgating legal documents
	Allocation of the budget for the environmental protection
	Environmental monitoring, periodic results announcement
District	Organizing waste collection system
	Monitoring environmental quality
	Implementing and enforcing the environmental laws and policies
Ward	Propagating and rising community's awareness on environmental protection
	Guiding, mobilizing and propagating people to participate in environmental protection actions
	Supervising the environmental protection actions
Community	Implementing waste collection
	Supporting each other to practice properly environmental protection actions.
	Complying with the instructions from the environmental authority.

4. Conclusion

Surface water quality in canals in Ninh Kieu district, Can Tho city in 2019 was polluted. DO, BOD, COD, TSS, NH_4^+ -N, PO_4^{3-} -P, coliform exceeded the permitted limits of QCVN 08-MT: 2015/BTNMT (column A1) showing that the water source has been polluted by suspended solids, organic matters, nutrients and microorganisms. Most of the people living near the canals perceived that the water was polluted. The findings on the causes of water pollution showed that waste and wastewater from residential areas accounting for 42%, and from markets accounting for 24%. Manufacturing and trading activities contributed by 16% to surface water pollution. Only 6% of households believed that water quality was affected by wastewater from industrial zones and factories. In addition, 6% of households considered that medical waste and wastewater also contributed to surface water quality and 5% was due to other reasons. To solve the problem of surface water pollution, solid waste and wastewater must be collected and treated thoroughly. It is necessary to strengthen law enforcement on environmental protection and regularly propagate and mobilize communities to participate in protecting surface water environment.

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