

THE EFFECTS OF DOMESTIC AND INDUSTRIAL WASTEWATER ON MEKONG SURFACE WATER QUALITY IN AN GIANG PROVINCE, VIETNAM

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Abstract:

This study was conducted to assess the surface water quality of the Mekong River in the basins affected by urban areas (5 sampling points) and industrial parks/clusters (2 sampling points) in An Giang province by sampling surface water in June, 2021 (dry season), analyzing the parameters of temperature, pH, DO, TSS, COD, BOD₅, NO₃⁻, NH₄⁺, PO₄³⁻, Coliform, As, Pb, Hg, Benzene hexachloride, Dieldrin. The analytical results of water samples were compared with the National Technical Regulation on surface water quality of Vietnam. The water quality index was calculated according to the technical guidelines for calculation and publication of the water quality index of the Vietnam Environment Administration (VN_WQI). The results show that domestic and industrial wastewater have polluted the surface water of the Tien river and the Hau river - two important rivers of the downstream Mekong river - flowing through An Giang province. The pollution shows in parameters of TSS, DO, BOD₅, COD, NH₄⁺, Coliform that exceeds allowable limits. Other parameters such as temperature, pH, NO₃⁻, PO₄³⁻ are mostly at the acceptable range and within allowable limits. The water quality is lowest in Cai Dau urban area - Chau Phu district (on the Hau river). Based on the WQI, most of the water quality at the sampling points is poor – it is usable for water transport and similar purposes, requiring appropriate treatment before use for living purposes and need to have appropriate water quality management measures.

Keywords: water quality, Mekong surface water, domestic wastewater, industrial wastewater.

Introduction

An Giang is a province in the southwest of Vietnam and is located downstream of the Mekong River. An Giang occupies an important position in the Mekong Delta with the terrain of hills and plains lying along the Hau river and the Tien river - branches of the Mekong River. An Giang has potential for development of agriculture, commerce, services and tourism (Thang, 2003). In the context of international integration and economic development, the environment of An Giang province is under increasing pressure, especially water pollution, which has affected the supply of fresh water for agricultural irrigation, domestic use, industry... (Khanh, 2005; O. Shipin, 2005; Khanh, 2013; Report on results of environmental monitoring in An Giang province 2019, Phuong, 2020).

In 2020, the average population of An Giang province was 1,909,335 people and the density was 540 people/km². There is a high concentration of population in urban areas such as Long Xuyen city, Chau Doc city, Tan Chau town and Thoai Son district and low concentration in rural areas as Chau Phu district (An Giang Provincial Monitoring Center, 2020). The *migration of population from rural to urban areas* has a significant impact on the environment. The environment in the urban area is becoming more and more polluted with the progress of urbanization. In the cities, untreated or inadequately treated domestic wastewater has been discharged to the environment, domestic waste has not been collected and treated by suitable treatment solutions. There are still production facilities and factories located in residential areas. The total amount of domestic wastewater in the province is estimated at 176,000 m³/day.night, in which wastewater of the urban area is about 72,000 m³/day.night. The province includes 11 districts, towns and cities, but only 2 wastewater treatment systems. There are Chau Doc wastewater treatment system with a capacity of 5,000 m³/day.night and Long Xuyen wastewater treatment system with a capacity of 30,000 m³/day.night which is in trial operation (Report on environmental status of An Giang province in the period 2016-2020)

According to the report on environmental status of An Giang province in the period 2016-2020, An Giang province currently has 02 industrial Parks: Binh Long Industrial Park; Binh Hoa Industrial Park and 08 industrial clusters that are operating and new industrial zones and clusters will be constructed as planned. The centralized wastewater treatment system in Binh Hoa Industrial Park with the capacity of 2,000 m³/day.night is in operation and the centralized wastewater treatment system in Binh Long Industrial Park with a capacity of 4,000 m³/day is in building. Up to now, the province has invested in infrastructure for 8 industrial clusters and put them into operation but has not yet been invested in building a centralized wastewater collection and treatment system. Investment projects in these industrial clusters must have separate wastewater treatment systems if the activities generate wastewater. Industry of An Giang province mainly focuses on processing industries of foodstuffs, agricultural products, aquatic products, garment, leather shoes, construction materials...

The development of residential areas in the trend of urbanization and the development of industrial parks and clusters has caused risks to reduce surface water quality of the Mekong River in An Giang province. Therefore, it is necessary to assess the effects of domestic and industrial wastewater on surface water quality of the Mekong River in An Giang province.

Significance Of The Study

In this study, water samples were collected in June 2021 (dry season), analyzed physio-chemical parameters, and calculated Water Quality Index to obtain information on levels and characteristics of pollution. Thereby, the study provides an overview of the surface water quality of the Mekong River affected by domestic and industrial wastewater in An Giang province, which has great significance for the control of the province's water quality. This is a new research with the most recent data and more parameters compared to previous studies. The results are the foundation for making recommendations to the citizens, proposing environmental solutions in the upcoming time. Data of the study are a useful source of information to help the local authority take positive actions of management, environmental protection and response to climate change in the current situation.

Review Of Related Studies

In 2006, Huong et al. conducted the assessment of water quality of the Tien river and the Hau river in some residential areas of Dong Thap province, Vinh Long province and Can Tho province. The analytical results of 40 water samples show that COD at low tide exceeds the allowable limit by 1.1 - 6 times, BOD₅ exceeds the allowable limit by 1.5 - 10 times. Coliform of the Hau river in Thot Not, Co Do and Binh Thuy district exceeds the allowable limit by 4.6 - 92 times. The pollution of surface water is largely due to domestic waste, human excrement and aquaculture waste.

In 2008, Nam et al. carried out a study to assess the pollution and eutrophication of surface water in some canals connecting the Tien river and the Hau river in Vinh Long province, Dong Thap province and Tien Giang province. The results show that the surface water quality in the 3 canals in the survey has pH, temperature, DO, BOD, COD within the allowable limits according to National technical regulation on surface water quality.

Nhan and Nhan researched the correlation between surface water quality of the Mekong river and some socio-economic indicators in Can Tho and Soc Trang from 2005 to 2009. The results shows that the increase in population density, the number of industrial establishments, the number of commercial and service establishments, the number of livestock and poultry are the main reasons for the increase of organic matter content in the surrounding surface water. Meanwhile, the increase of rice area, rice production, aquaculture area and aquaculture production are the main reasons for the increase of suspended solids, nitrogen and the decrease of pH in the surrounding surface water.

In 2016, Lien et al. conducted a study to assess the water quality of the mainstream and tributaries of the Hau river. The results show that the temperature and pH are suitable for aquatic life in most of the sampling locations, turbidity and TSS in the rainy season are higher than in the dry season. DO between areas fluctuates in the range of 1.76-7.96 mg/l, averages 4.9±1.4 mg/l. The content of nutrients and organic matter in the dry season is higher than in the rainy season. The mean values of TAN, N-NO₃⁻, TN, P-PO₄³⁻, TP, COD and TOM recorded were 0.26±0.26 mg/L, 0.11±0.07 mg/L, 1.17±0.6 mg/L, 0.1±0.07 mg/L, 0.29±0.25 mg/L, 14.3±6.3 mg/L and 5.7± 1.4%. The concentration of suspended matter reaches high value in the rainy season, while the content of nutrients and

organic matter reaches the highest value in the dry season. In general, the study shows that surface water of the Hau River is quite nutritious, especially in the areas affected by aquaculture and agricultural production.

In 2016, Dieu et al. conducted a research to assess the water quality of the Tien River. The results show that due to saline intrusion from the sea, the TDS is quite high (3,150 – 3,267 mg/l) in the Tien river estuary in the dry season; TSS, COD and BOD₅ ranges respectively from 9 - 475 mg/l; 2 - 13 mg/l and 2 - 16 mg/l; N-NH₄ and P-PO₄ are high, in the range of 0.02 - 0.60 mg/l and 0.06 - 0.47 mg/l, respectively; dissolved iron (Fe) and manganese (Mn) are quite high, in the range of 1,600 - 31,000 ppb and 50 - 1,000 ppb. Those parameters increase downstream and higher in the dry season. The concentration of toxic dissolved metals in the water is low.

In 2018, Truc et al. conducted a study to assess the surface water quality of the Tien River flowing through the Tan Chau river in Tan Chau town, An Giang province. The results show that PO₄³⁻, NH₄⁺ and NO₂⁻ exceed the allowable limits according to National Technical Regulation. Indicators of Br, As, F⁻, SiO₂⁻ are not detected in the study.

There are many studies conducted on Mekong river water quality in neighboring provinces of An Giang such as Huong et al (2006), Nam et al. (2008), Nhan and Nhan (2014), Dieu et al (2016). However, there are still no new and adequate studies in An Giang province. Some previous studies conducted in An Giang such as Lien et al. (2013) and Truc et al. (2018) did not focus on assessing the impact of residential areas and industrial zones/clusters on water resources and the indicators used in these surveys were still limited. Therefore, the study "The effects of domestic and industrial wastewater on Mekong surface water quality in An Giang Province" is necessary at this time.

Objectives Of The Study

The study focuses on assessment of surface water quality of the Mekong River basin affected by residential areas and industrial parks and clusters in An Giang province. Also, the study carries out comparison of pollution levels between two basins using the WQI.

Hypotheses Of The Study

Surface water of the Mekong River is polluted by domestic and industrial wastewater in An Giang province

Population And Sample

Statistical Techniques Used in the Present Study

Surface water samples were collected at 5 sampling points affected from urban areas and 2 surface water sampling points affected from industrial parks and clusters. Sample collection schedule is in June 2021 (dry season).



Figure 1: Location map of surface water sampling

Table 1: Location of sampling

No.	Code	Coordinate	Location	Feature	Reason of choosing
I. Basin affected by urban area					
1	MT1(TĐ-ĐT)-TC	554.699 1.194.414	Long Thanh Ward, Tan Chau town	The location is affected by wastewater from many production and business activities, residents...	This is the location affected by wastewater from Tan Chau urban area on the Tien River
2	MT2 (TĐ-ĐT)-CM	571.273 1.166.986	Cho Moi commune, Cho Moi district	The location is affected by wastewater from many production and business activities, residents...	This is the location affected by wastewater from Cho Moi urban area on the Tien River
3	MT3 (TĐ-ĐT)-CM	581.029 1.162.307	My Luong commune, Cho Moi district	The location is affected by wastewater from many production and business activities, residents...	This is the location affected by wastewater from My Luong urban area on the Tien River
4	MH3 (TĐ-ĐT)-LX	576.273 1.147.845	My Long ward, Long Xuyen city	The location is affected by wastewater from many production and business activities, residents...	This is the location affected by wastewater from Long Xuyen urban area on the Hau River
5	MH2 (TĐ-ĐT)-CP	553.659 1.168.368	Cai Dau commune, Chau Phu district	The location is affected by wastewater from many production and business activities, residents...	This is the location affected by wastewater from Cai Dau urban area on the Hau River (Primary canal)
II. Basin affected by industrial parks and industrial clusters					
1	MH1(TĐ-CN)-CP	554.720 1.168.808	Binh Long Industrial Park, Binh Chanh Hamlet, Binh Long Commune, Chau Phu District	The location affected by industrial wastewater	This is the location affected by wastewater from Binh Long industrial area on the Hau River
2	MH2(TĐ-CN)-LX	577.294 1.146.119	My Qui Industrial Cluster, Long Xuyen city	The location affected by industrial wastewater	This is the location affected by wastewater from My Qui Industrial Cluster on the Hau River

The parameters for assessment included: Temperature, pH, Dissolved Oxygen (DO), Total Suspended Solids (TSS), Chemical oxygen demand (COD), Biological oxygen demand (BOD₅) Nitrate (NO₃⁻ calculated by N), Phosphate (PO₄³⁻ calculated by P), Ammonium (NH₄⁺ calculated by N), Coliform, Arsenic (As), Lead (Pb), Mercury (Hg), Benzene hexachloride, Dieldrin.

Table 2: Method of measuring parameters at the location

No.	Parameter	Methods of measuring	Measuring range
1	Temperature	SMEWW 2550B:2012	4 ÷ 50°C
2	pH	TCVN 6492:2011	2 ÷ 12
3	DO	TCVN 7325:2016	0 ÷ 20 mg/l

The order and methods of environmental monitoring are implemented in accordance with Circular 24/2017/TT-BTNMT dated September 1, 2017 of the Vietnamese Ministry of Natural Resources and Environment on promulgation of technical regulations on environmental monitoring and current Vietnamese standards and regulations. Methods of sampling, preservation and analysis of samples are shown as follows:

Table 3: Methods of sampling, preservation of samples

No.	Parameter	Methods of sampling	Methods of sample preservation
1	Surface water sample	TCVN 6663-1:2011; TCVN 5994:1995; TCVN 6663-6:2008.	TCVN 6663-3:2008

Table 4: Method of analyzing water samples in a laboratory

No.	Parameter	Method	Measuring range
1	Chemical oxygen demand (COD)	SMEWW 5220C:2012	3 mg/l
2	Biological oxygen demand (BOD ₅)	SMEWW 5210B:2012	1 mg/l
3	Total Suspended Solids (TSS)	SMEWW 2540D:2012	10 mg/l
4	Nitrate (NO ₃ ⁻ calculated by N)	SMEWW 4500-NO3-.E:2012	0.01 mg/l
5	Phosphate (PO ₄ ³⁻ calculated by P)	SMEWW 4500-P.E:2012	0.03 mg/l
6	Coliform	TCVN 6187-2:1996	3 MPN/100ml
7	Arsenic (As)	SMEWW 3114B:2012	0.0006 mg/l
8	Lead (Pb)	TCVN 6665:2011	0.004mg/l
9	Mercury (Hg)	SMEWW 3112B:2012	0.0003 mg/l
10	Ammonium (NH ₄ ⁺ calculated by N)	SMEWW 4500 -NH3.B&F:2012	0.03 mg/l
11	Benzene hexachloride	US.EPA Method 3510C + US.EPA Method 3630C US.EPA Method 8081B	0.005 µg/l
12	Dieldrin		0.005 µg/l

Machines and equipment used to analyze water samples include: Meter to measure temperature, DO, pH - PCD 650/ pH 600 Eutech; Satellite navigation device - GPS map 76CSX Garmin; Incubator - LI20 - Shellab; Digester block- Merck TR420; Microbiology cabinet cabin- AC2-4E1 Esco; Drying cabinet - ED105 Binder; UV-vis - 2700 Labomed; Atomic absorption spectrophotometric - AAS 400 Perkin Elmer; Digital analytical balance -CPA224S Satorius brand. These machines and equipments are calibrated once a year.

The analytical results of water samples are compared with surface water quality parameters according to Vietnam's National Technical Regulation on Surface Water Quality - QCVN 08-MT:2015/BTNMT.

The Water quality index (WQI) is calculated based on the Decision 1460/QĐ-TCMT dated November 12, 2019 of the Vietnam Environment Administration on promulgating technical guidelines for calculation and Vietnam water quality index (VN_WQI). Parameters used to calculate WQI in this study include: Temperature, pH, DO, BOD₅, COD, N-NO₃⁻, N-NH₄⁺, P-PO₄³⁻, Coliform.

The calculation formulas are as follows:

* For parameters BOD₅, COD, TOC, N-NO₃⁻, N-NH₄⁺, P-PO₄³⁻, Coliform, WQI are calculated according to the following formula:

$$WQI_{SI} = \frac{q_i - q_{i+1}}{BP_{i+1} - BP_i} (BP_{i+1} - C_p) + q_{i+1} \quad (\text{formula 1})$$

In particular:

BP_i: lower limit concentration of monitoring parameters corresponding to level i;

BP_{i+1}: upper limit concentration of monitoring parameters corresponding to level i+1;

q_i: WQI at level i given corresponds to BP_i;

q_{i+1}: WQI at level i+1 corresponds to BP_{i+1};

C_p: Monitoring parameters are taken into account.

Calculating WQI_{DO}:

$$WQI_{SI} = \frac{q_{i+1} - q_i}{BP_{i+1} - BP_i} (C_p - BP_i) + q_i \quad (\text{formula 2})$$

In particular:

C_p: Saturated DO%;

BP_i, BP_{i+1}, q_i, q_{i+1} are the values corresponding to the level i, i+1

Calculating WQI_{pH} :

If pH < 5.5 or pH > 9, WQI_{pH} = 10.

If 5.5 < pH < 6, use formula 2 to calculate WQI_{pH}

If 6 ≤ pH ≤ 8.5, WQI_{pH} bằng 100.

If 8.5 < pH < 9, use formula 1 to calculate WQI_{pH}

After calculating WQI for each of the above parameters, the WQI calculation is applied according to the following formula:

$$WQI = \frac{WQI_I}{100} \left(\frac{\prod_{i=1}^n WQI_{II}}{100} \right)^{\frac{1}{n}} \left(\frac{\prod_{i=1}^m WQI_{III}}{100} \right)^{\frac{1}{m}} \left[\frac{1}{k} (\sum_{i=1}^k WQI_{IV})^2 \frac{1}{l} (\sum_{i=1}^l WQI_V) \right]^{\frac{1}{3}}$$

In particular:

WQ_I: Calculation results for pH

WQ_{II}: Calculation results for the group of pesticides parameters

WQ_{III}: Calculation results for the group of heavy metal parameters

WQ_{IV}: Calculation results for the group of organic and nutritional parameters

WQ_V: Calculation results for microbiological parameters

Table 5: Water Quality Rating and recommendation of usage according to the technical of the Vietnam Environment Administration

Water quality Index Range	Water Quality Rating	Color	Intended use
91 - 100	Excellent		Good for water supply
76 - 90	Good		For water supply but needs appropriate treatment measures
51 - 75	Medium		For irrigation and other similar purposes
26 - 50	Poor		For water transport and other similar purposes
10 - 25	Polluted		Water is heavily polluted, needs future treatment
<10	Serious polluted		Water is poisoned, needs treatment

6.2. Data Analysis and Interpretation**Table 6: Analytical results of surface water affected by urban area**

Parameters	Location										Column A1 - Regulation
	MT1(TĐ-ĐT)-TC		MT2 (TĐ-ĐT)-CM		MT3 (TĐ-ĐT)-CM		MH3 (TĐ-ĐT)-LX		MH2 (TĐ-ĐT)-CP		
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	
Temperature (°C)	30.7		29.5		30.3		32.1		30.2		
pH	7.63		7.40		7.41		7.46		7.22		6-8.5
DO (mg/l)	6.05	0.07	4.98	0.10	5.15	0.09	5.59	0.14	2.81	0.12	≥6
TSS (mg/l)	54.33	2.08	51.00	2.65	45.00	2.00	48.67	2.08	59.00	4.36	20
COD (mg/l)	29.67	4.04	23.67	2.52	25.00	1.00	18.67	2.08	91.00	3.00	10
BOD ₅ (mg/l)	19.00	2.65	13.67	2.08	14.33	1.16	12.67	1.53	63.00	2.65	4
Nitrate (mg/l)	0.10	0.01	0.13	0.00	0.19	0.01	0.07	0.00	0.02	0.01	2
Phosphate (mg/l)	0.17	0.02	0.06	0.01	0.06	0.01	0.07	0.01	0.25	0.02	0.1
Ammonium (mg/l)	1.09	0.06	0.90	0.05	0.90	0.05	0.95	0.04	2.78	0.10	0.3
Coliform MPN/100 ml	17,000	3,464	30,000	13,892	11,633	8,445	2,967	1,155	215,333	211,888	2,500
As	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	
Pb	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	
Hg	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	
Benzene hexachloride	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	
Dieldrin	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	

Note: ND- Not detected

Table 7: Analytical results of surface water affected by industrial parks and industrial clusters

Parameters	Location				Column A1 - Regulation
	MH1(TD-CN)-CP		MH2(TD-CN)-LX		
	Mean	SD	Mean	SD	
Temperature	31.7		32.3		
pH	7.12		7.26		6-8.5
DO (mg/l)	5.98	0.06	4.95	0.03	≥6
TSS (mg/l)	47.67	1.53	52.00	2.65	20
COD (mg/l)	27.00	1.00	20.00	1.73	10
BOD ₅ (mg/l)	16.00	1.73	12.67	0.58	4
Nitrate (mg/l)	0.19	0.00	0.06	0.00	2
Phosphate (mg/l)	0.09	0.01	0.03	0.00	0.1
Ammonium (mg/l)	1.81	0.09	0.46	0.04	0.3
Coliform (MPN/100 ml)	13,667	6,429	4,800	2,606	2,500
As	ND	ND	ND	ND	
Pb	ND	ND	ND	ND	
Hg	ND	ND	ND	ND	
Benzene hexachloride	ND	ND	ND	ND	
Dieldrin	ND	ND	ND	ND	

Note: ND- Not detected

Interpretation of table 6 and table 7

The water temperature at the sampling locations ranges from 29.5 to 32.1 °C in the area affected by domestic wastewater and ranges from 31.7 to 32.3°C in the area affected by industrial wastewater. In general, the results are consistent with the general temperature of the area, and do not affect the aquatic life of the area.

The pH of surface water affected by urban areas ranges from 7.22 to 7.63, and pH of surface water affected by industrial parks and clusters ranges from 7.12 to 7.26. These values are all within the allowable limits according to the National Technical Regulation on Surface Water Quality of Vietnam, column A1 (6 – 8.5).

Dissolved oxygen (DO) at the sampling locations affected by urban areas ranges from 2.81 to 6.05 mg/l. According to the national technical regulation on surface water quality of Vietnam, only the DO in the locations of Tan Chau residential area, Tan Chau town (6.05 mg/l) is still within the allowable limit (≥6 mg/l), the remaining locations are lower than the allowable value from 1.07 to 2.81 times. DO at sampling locations affected by industrial zones and clusters ranges from 4.95 to 5.98 mg/l, lower than the allowable limit from 0.83 to 0.99 times. This result is consistent with the result of Lien et al. (2013), DO in the mainstream and tributaries of the Hau river route ranges from 1.76-7.96 mg/l.

Total suspended solids (TSS) of surface water at 5 locations affected by domestic wastewater ranges from 45.00 to 59.00 mg/l that are 2.25 to 2.95 times higher than the allowable limits in National technical regulation on surface water quality of Vietnam (20 mg/l). TSS at 02 locations affected by industrial wastewater has values ranging from 47.67 to 52.00 mg/l that are 2.38 to 2.60 times higher than the allowable limits. This result is consistent with the result in the study of Dieu et al. (2016), TSS ranges from 9 to 475 mg/l in the Tien river.

The Chemical Oxygen Demand (COD) at 5 sampling locations in urban areas values from 18.67 to 91 mg/l, these values exceed 1.87 to 9.10 times compared to the limits in National Technical Regulations (10 mg/l). The COD at sampling locations in industrial parks and clusters ranges from 20 to 27 mg/l that exceeds the

permissible limits from 2.00 to 2.70 times. The COD in this study is higher than data in the previous studies by Lien et al. (2013) and Dieu et al. (2016).

Biological oxygen demand (BOD₅) of surface water affected by urban areas ranges from 12.67 to 63.00 mg/l that exceeds the allowable limit (4 mg/l) from 3.17 to 15.75 times according to the National Technical Regulation on surface water quality of Vietnam. BOD₅ of the surface water affected by the industrial parks has values ranging from 12.67 to 16.00 mg/l that exceeds the permissible limits from 3.17 - 4.00 times. These values are higher than the results in the study of Dieu et al. (2016), BOD₅ of the Tien river ranges from 2-16 mg/l.

Nitrate (NO₃⁻) at sampling locations ranges from 0.02-0.19 mg/l for locations affected by urban areas and ranges from 0.06 - 0.19 mg/l for locations affected by industrial parks and clusters. These values are within the allowable limits according to the National Technical Regulation on surface water quality of Vietnam (2 mg/l). This result is consistent with the study of Lien et al. (2013), N-NO₃ on the mainstream and tributaries of the Hau river is 0.11±0.07 mg/l.

Phosphate (PO₄³⁻) at the sampling locations affected by urban areas ranges from 0.06 - 0.25 mg/l. The values of Phosphate at the sampling point of Tan Chau residential area - Tan Chau town and Cai Dau residential area - Chau Phu district exceeds the permissible value (0.1 mg/l) according to the National Technical Regulation on surface water quality of Vietnam, the remaining sampling points are still within the allowable limits. In the sampling points affected by industrial parks and industrial clusters, the Phosphate ranges from 0.03 to 0.09 mg/l and is within the allowable limits. These values are lower than the results in the study of Dieu et al. (2016), Phosphate of the Tien river ranges from 0.06-0.47 mg/l.

Ammonium (NH₄⁺) at sampling locations affected by urban wastewater ranges from 0.90 to 2.78 mg/l. According to the National Technical Regulation on surface water quality of Vietnam, ammonium value at all locations exceeds permissible value (0.3 mg/l) from 3.00 – 9.27 times. Ammonium (NH₄⁺ calculated by N) at sampling points affected by industrial parks and clusters ranges from 0.46 to 1.81 mg/l exceeding the allowable limits from 1.53 to 6.03 times. These value are higher than the results in the study of Dieu et al. (2016), the Tien river water has Ammonium ranging from 0.02-0.6 mg/l.

Parameters of Coliform at sampling locations affect by domestic wastewater value from 2,967 to 215,333 MPN/100 ml that exceed the permissible limit from 1.19 to 86.13 times compared to the National Technical Regulations on surface water quality in Vietnam (2,500 MPN/100 ml). Parameters of coliform at sampling points in industrial parks and clusters range from 4,800 – 13,667 MPN/100 ml, all values exceeding the allowable limits from 1.92 – 5.47 times. This result is higher than the value of Coliform in the study to assess the water quality of Tien and the Hau river in some residential areas conducted by Huong et al (2006).

Analytical results of all surface water samples show that As, Pb, Hg, Benzene hexachloride, Dieldrin are not detected in water samples. These results are similar to the results in the research of Dieu et al. (2016), which also do not detect As in the Tien River.

Therefore, most of the water samples exceed the allowable limits of TSS, DO, BOD₅, COD, NH₄⁺, Coliform according to the National Technical Regulation on surface water quality of Vietnam. Temperature, pH, NO₃⁻, PO₄³⁻ are mostly at suitable levels and within allowable limits. As, Pb, Hg, Benzene hexachloride, Dieldrin are not detected at all sampling points.

For surface water sources affected by domestic wastewater, the main cause of water pollution is that most of the domestic wastewater discharged into the river is untreated. A large amount of waste water and solid waste from trading, production and business activities in markets, residential areas, densely populated urban centers located along the Tien river and the Hau river is discharged into water sources. The surface water affected by Cai Dau urban area is the most polluted location with highest values of parameters, because this location is the primary canal connected to the mainstream with a narrow surface, not strong flow, and low capacity of dispersion and low self-cleaning. High concentration of pollutants dispersed into the environment causes local pollution. For surface water sources affected by industrial wastewater, the main reason for pollution is that the wastewater has not been thoroughly treated and has not met the standards for discharge into water sources.

The level of water pollution due to the impact of urban areas, industrial parks and industrial clusters calculated by the WQI index is shown in Figure 1.

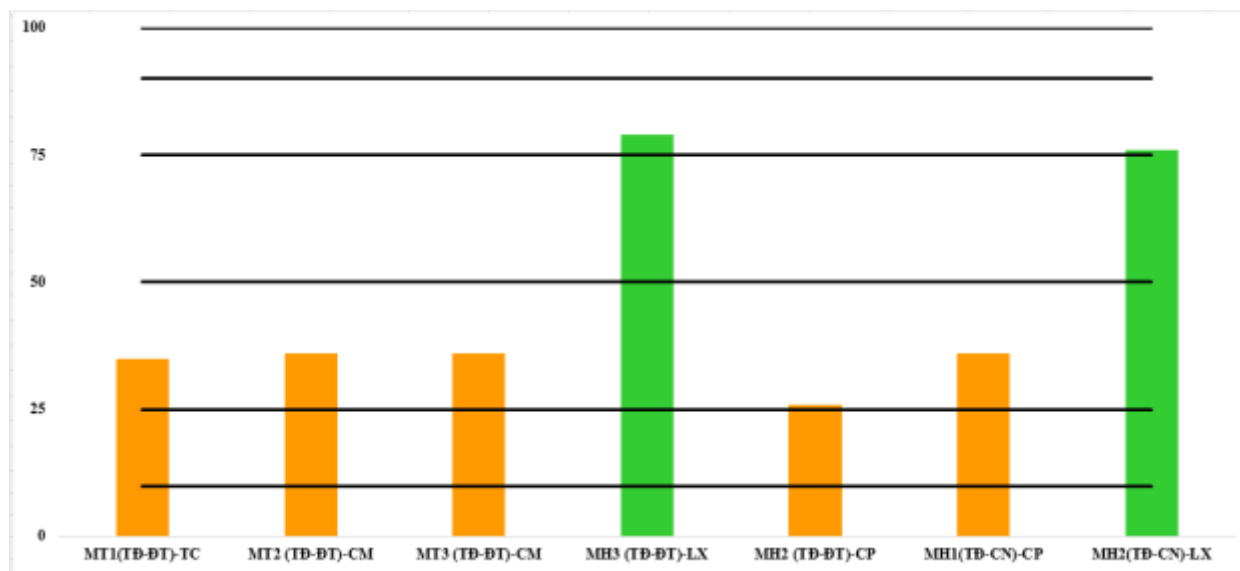


Figure 2: Water Quality Index of sampling points

Interpretation of Figure 2

WQI of location affected by urban areas and industrial parks, industrial clusters range from poor level (able to be used for water transport and other similar purposes) to good level – (able to use for water supply but needs appropriate treatment measures).

The two sampling points with the highest WQI - reaching a good water level are the location affected by the urban area of Long Xuyen city (WQI = 79) and the location affected by the My Qui industrial cluster in Long Xuyen city (WQI = 76) on the Hau River, water on this level can be used for domestic water supply purposes but needs appropriate treatment measures. Next, the locations affected by Tan Chau urban area-Tan Chau town (WQI=35), Cho Moi urban area - Cho Moi district (WQI=36), My Luong urban area - Cho Moi district (WQI=36), on the Tien river and Binh Long industrial park - Chau Phu district on the Hau river (WQI=36) are rated poor water level, water on this level can be used for water transport and other similar purposes. WQI is the lowest in the surface water area affected by Cai Dau urban area - Chau Phu district on the Hau River (WQI = 26) which is at a poor level. The causes of the poor water quality – low WQI ($26 \leq \text{WQI} \leq 50$) are high value of Coliform in the water and high value of other parameters participating in the calculation of WQI such as: DO, COD, BOD₅ and Ammonium that are exceeds the allowable limits.

Recommendations

Based on the results of this study, it is recommended that people should not directly use water of the Tien river and Hau river in An Giang for drinking, domestic purposes to ensure their health in long-term. It is necessary to apply appropriate water treatment measures if people want to use this water source for drinking, domestic purposes. In the coming time, authorities need to monitor and take measures to treat wastewater in markets, commercial centers and urban areas to ensure the quality of wastewater before discharging into the river based on regulations on discharge. In addition, authorities need to monitor the surface water quality affected by waste sources in industrial zones and clusters to take the most appropriate and strict management measures, and promptly warn people in using water for domestic purposes.

Conclusion

In summary, surface water in the Mekong River, An Giang province affected by domestic wastewater has the temperature ranging from 29.5 to 32.1⁰C, pH ranging from 7.22 to 7.63, NO₃⁻ ranging from 0.02 to 0.19 mg/l, PO₄³⁻ ranging from 0.06 to 0.25 mg/l, TSS ranging from 45.00 – 59.00 mg/l, DO ranges from 2.81 to 6.05 mg/l, COD ranging from 18.67- 91 mg/l, BOD₅ ranging from 13.67 – 63.00 mg/l; NH₄⁺ ranging from 0.90 to 2.78 mg/l, Coliform ranging from 2,967 to 215,333 MPN/100 ml. Surface water in the Mekong River, An Giang province affected by industrial wastewater has temperature ranging from 31.7⁰C to 32.3⁰C, pH ranging from 7.12 to 7.26; NO₃⁻ ranging from 0.06 - 0.19 mg/l; PO₄³⁻ ranging from 0.03 to 0.09 mg/l, TSS ranging from 47.67 - 52.00 mg/l, DO ranging from 4.95 to 5.98 mg/l; COD ranging from 20 to 27 mg/l; BOD₅ ranging from 12.67 – 16.00 mg/l; NH₄⁺ ranging from 0.46 to 1.81 mg/l, Coliform ranging from 4,800 to 13,667 MPN/100 ml. Domestic and industrial wastewater have polluted surface water of the Tien river and

the Hau river - two important rivers of the lower Mekong - flowing through An Giang province, mainly for parameters of TSS, DO, BOD₅, COD, NH₄⁺, Coliform. Other parameters of temperature, pH, NO₃⁻, PO₄³⁻ are mostly at suitable levels and within the allowable limits compared with the National Technical Regulation on surface water quality of Vietnam. As, Pb, Hg, Benzene hexachloride, Dieldrin are not detected at all sampling points. In general, most sampling locations have the water quality index at a poor level – can be used for water transport, requires appropriate treatment before being used for domestic purposes and needs to have appropriate water quality management measures in place. Sampling location in the urban area of Long Xuyen city has the highest water quality (highest WQI), at a good level. Cai Dau urban area - Chau Phu district has the lowest water quality (lowest WQI), at the poor level.

Acknowledgements

This research is funded by Vietnam National University Ho Chi Minh City (VNU-HCM) under grant number “B2021-16-03”.

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