



## Coastal Water Quality Assessment in Bac Lieu Province, Vietnam

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### Abstract

The study aims to assess surface water quality on canals in Bac Lieu Province in 2019 using water quality parameters including pH, dissolved oxygen (DO), chemical oxygen demand (COD), biochemical oxygen demand (BOD), total suspended solids (TSS), nitrite ( $\text{NO}_2^- \text{N}$ ), nitrate ( $\text{NO}_3^- \text{N}$ ), ammonium ( $\text{NH}_4^+ \text{N}$ ), orthophosphate ( $\text{PO}_4^{3-} \text{P}$ ), iron (Fe), chloride ( $\text{Cl}^-$ ) and coliform. Water samples were collected from the Department of Natural Resources and Environment, Bac Lieu Province, Vietnam, which including 9 locations during the dry and wet seasons. These parameters were compared with the national technical regulation on surface water quality (QCVN 08-MT:2015/BTNMT), column B<sub>1</sub>. The results showed that surface water quality in Bac Lieu province was polluted with organic matter (COD, BOD), nutrients ( $\text{NH}_4^+ \text{N}$ ,  $\text{NO}_2^- \text{N}$ ,  $\text{PO}_4^{3-} \text{P}$ ), total suspended solid and chloride. In addition, some places were also contaminated by iron and coliforms. The parameters DO, COD, BOD, TSS,  $\text{NO}_2^- \text{N}$ ,  $\text{NO}_3^- \text{N}$ ,  $\text{Cl}^-$  and coliform in the dry season were higher than the wet season. The parameters of pH,  $\text{NH}_4^+ \text{N}$ ,  $\text{PO}_4^{3-} \text{P}$  and Fe in the wet season were higher than in the dry season. The quality of surface water in this study area was influenced by domestic activities, agricultural cultivation and industrial activities. The future study should focus on investigating sources of coastal water pollution to propose appropriate measures for efficient water management in Bac Lieu province.

## 1. Introduction

Surface water resources play a very important role in life and production [1]. 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 only about 1.35%. However, population growth and socio-economic development have had a strong impact on surface water resources [2]. First of all, a rise in population will increase the demand about clean water for drinking and the amount of water needed for production. Anthropogenic activities, for examples activities from agriculture, husbandry, aquaculture without enough care of water resources could lead to adverse impact on quantity and quality of surface water. The risk of lack of clean water is more serious, especially in the dry season in areas with little rain. In addition, the climate change has been and will have a strong impact on water resources [3-4]. According to the initial assessment, around the year 2070, with the scenario of an increase in the air temperature of 2.5 - 4.50°C, the river flow will also change depending on the degree of rainfall change. If the rainfall decreases by 10%, the annual flow can decrease by 17-53% for the scenario of the temperature increase of 2.50°C and 26-90% decrease for the scenario of an increase of 4.50°C in the temperature scenario. On the other hand, global warming will cause the sea level to rise by 0.3-1.0 m. Thus, many low areas in the Mekong Delta, the North

Delta and the Central Coast will be submerged in seawater. It was predicted that there would have 40,000 km<sup>2</sup> of land would be flooded and 17 million people would suffer negative impacts from the flooding once the sea level rises 1 m.

Located at the end of the Mekong Delta and contiguous to the sea, Bac Lieu Province is a typical locality for the coastal ecology of the Mekong Delta that is seriously threatened. In which, the sea level rise and saline intrusion was contributing to negative impacts in the water quality in the province. Besides that, the uncontrolled urbanization and socio-economic development posed many challenges to the water resources [5-7]. Therefore, it is necessary to conduct research to assess surface water quality in salt water bodies in Bac Lieu province. The results of the study will provide information on water quality for surface water quality management.

## 2. Methodology

Surface water quality data in water bodies in Bac Lieu Province in 2019 were collected from the Department of Natural Resources and Environment of Bac Lieu Province. Monitoring parameters include pH, dissolved oxygen (DO), chemical oxygen demand (COD), biochemical oxygen demand (BOD), total suspended solids (TSS), nitrite (NO<sub>2</sub><sup>-</sup>-N), nitrate (NO<sub>3</sub><sup>-</sup>-N), ammonium (NH<sub>4</sub><sup>+</sup>-N), orthophosphate (PO<sub>4</sub><sup>3-</sup>-P), iron (Fe), chloride (Cl<sup>-</sup>) and coliform were used to evaluate the quality of surface water environment. Surface water samples were collected two times, including the first phase (dry season) and the second phase (wet season) at nine monitoring sites. The sampling sites are signed NM1 to NM9 and are described in detail as shown in Table 1. pH and DO parameters were measured directly in the field, while the remaining parameters were collected, stored, transported and analyzed by standard methods [8] at the Provincial Center for Natural Resources and Environment Monitoring Bac Lieu Province.

**Table 1. Water quality monitoring locations**

Sites	Location		Description of the monitoring sites
	X	Y	
NM1	1026202	0568587	Hoa Binh canal, Hoa Binh town, Hoa Binh district
NM2	1018413	0572170	30 April canal, Vinh Hau commune, Hoa Binh district
NM3	1024063	0560078	Xom Lung canal, Lang Tron ward, Gia Rai town
NM4	1022221	0549702	Outside Gia Rai sewer, ward 1, Gia Rai town
NM5	1011001	0563608	Cai Cung sewer, Long Dien Dong commune, Dong Hai district
NM6	1009834	0553726	Buu 2 canal
NM7	1009969	0553818	Cau so 4 canal, Dien Hai commune, Dong Hai district
NM8	1009615	0531006	Tac Van canal, Lung Sinh hamlet, Dinh Thanh commune, Dong Hai district
NM9	1017942	0581290	Cua Nha Mat, Bac Lieu City

The results of parameters of surface water quality were compared with the national technical regulation on surface water quality QCVN 08-MT:2015/BTNMT, column B<sub>1</sub>[9]. Limit values of the parameters are shown in Table 2.

**Table 2. Limited value of surface water quality parameters**

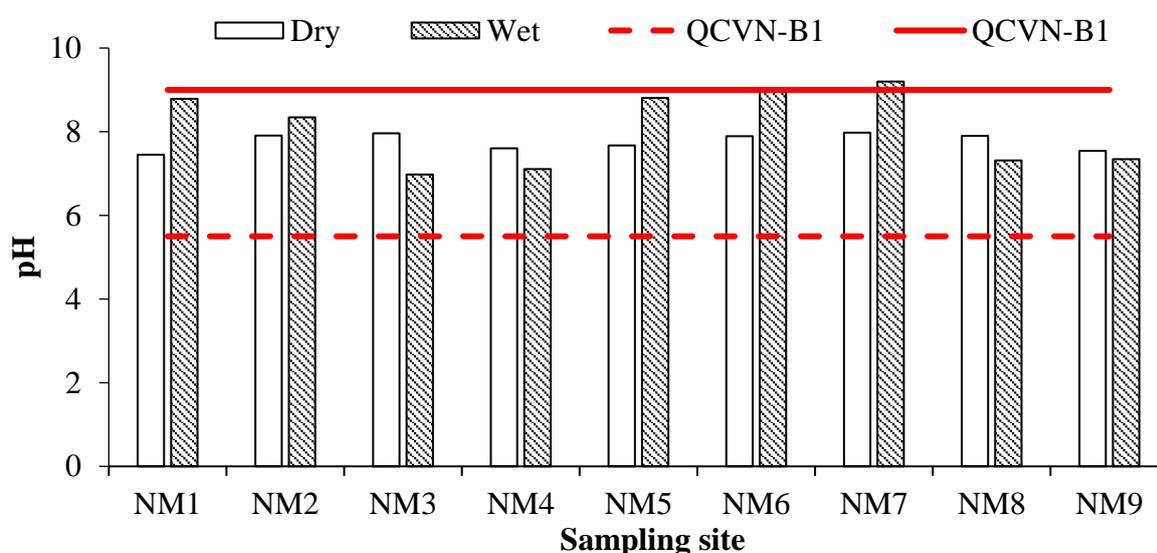
Parameter	Units	Limit value of QCVN*B1
pH		5,5-9
BOD	mg/l	15
COD	mg/l	30
DO	mg/l	≥ 4
TSS	mg/l	50
Ammonium	mg/l	0,9
Chloride	mg/l	350
Nitrite	mg/l	0,05
Nitrate	mg/l	10
Orthophosphate	mg/l	0,3
Fe	mg/l	1,5
Coliform	MPN or CFU /100 ml	7500

\*National technical regulation on surface water quality (QCVN 08-MT:2015/BTNMT); B1 means water quality used for irrigation or other uses with similar water quality requirements.

### 3. Results and discussion

#### 3.1 pH

pH value in water bodies in Bac Lieu Province was ranging from 6.98 to 9.2 (Figure 1). The first monitoring phase (dry season), pH value ranged from 7.45-7.98. The location with the highest pH value was Cau So 4 canal, Dien Hai commune, Dong Hai district (NM7). The location with the lowest pH value was Hoa Binh Canal, Hoa Binh town, Hoa Binh district (NM1). All 09 locations in the dry season were within the limit regulated by QCVN 08 MT:2015/BTNMT - National technical regulation on surface water quality in column B1 [9], while pH concentrations in the wet season exceeded the limit at NM7. pH value in the second phase (wet season) fluctuated within 6.98–9.2. The highest pH value was at Kenh Cau so 4, Dien Hai commune, Dong Hai district (NM7) and lowest in Xom Lung canal, Lang Tron ward, Gia Rai town (NM3). The monitoring results showed that pH value in the wet season tended to be higher during dry season.



**Figure 1. pH in water bodies in Bac Lieu province**

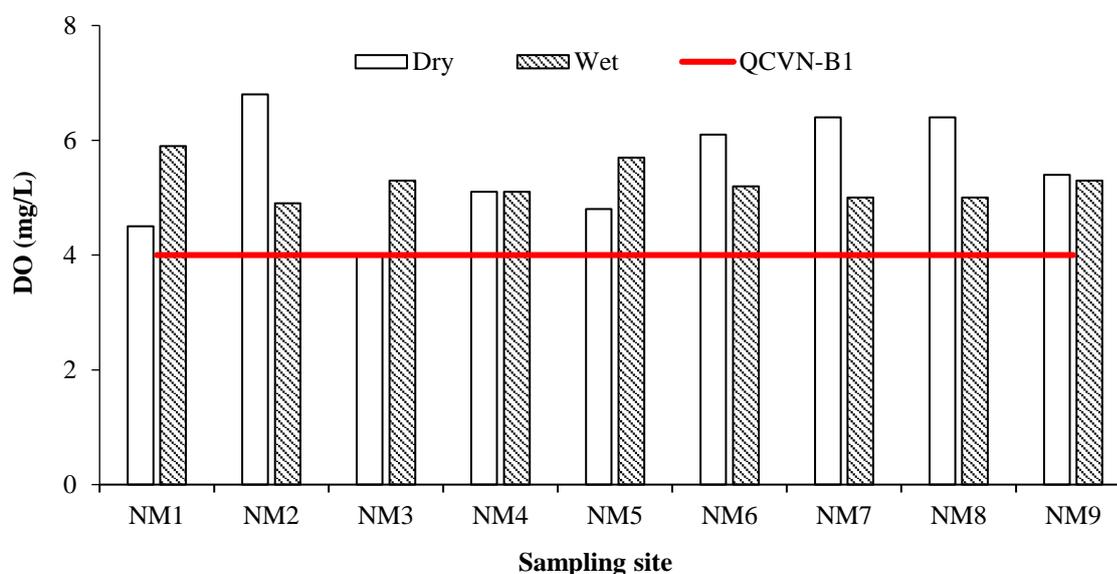
Compared with the study in Tien River flowing through Tan Chau, An Giang province [10], the range of pH in this study was higher than the pH in Tien River (ranged from 7.2-8.3). On the other hand, pH value in water bodies in Bac Lieu province was also higher than pH in Binh Thien lagoon

and in water bodies in Hau Giang Province, which varied from  $7.3 \pm 0.3$  to  $7.5 \pm 0.3$  and  $6.8 \pm 0.0$  to  $7.1 \pm 0.3$ , respectively [11-12].

### 3.2 Dissolved oxygen

DO value in the current study ranged from 4-6.8 mg/l (Figure 2), which was similar to that in the canals in An Giang and in Hau River. DO concentration in An Giang and Hau River varied from 4.9-5.5 mg/l and 4.9-6.3 mg/l, respectively [13-14]. Meanwhile, the mean of DO concentration in the canals of Soc Trang province ranged from 1.7-6.2 mg/l [15].

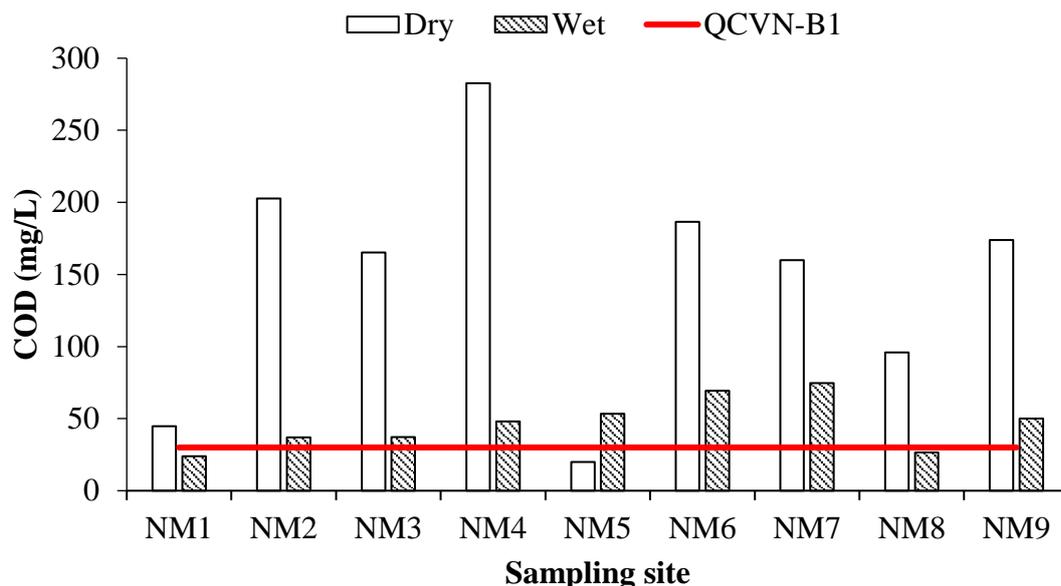
The mean of DO at nine sampling sites in both the dry and wet seasons were within limits regulated by QCVN 08-MT:2015/BTNMT, column B1 [9]. In the dry season, concentration of DO was in the ranges of 4.9-5.9 mg/l, which was less volatile than DO value measured in the wet season (ranged from 4-6.8 mg/l). DO value in the dry season was highest at Canal 30 April, Vinh Hau commune, Hoa Binh district (NM2) and lowest in Xom Lung canal, Lang Tron ward, Gia Rai town (NM3). In the wet season, the location with the highest DO value was Hoa Binh Canal, Hoa Binh town, Hoa Binh district (NM1) and Canal 30 April, Vinh Hau commune, Hoa Binh district (NM2) was the location with the lowest DO value. The cause of the fluctuation of DO value at the sampling locations can be aquatic respiration, decomposition of organic matters or water traffic leading to change in air diffusion into the water [10,16].



**Figure 2. DO in water bodies in Bac Lieu province**

### 3.3 Chemical oxygen demand

In the water bodies in Bac Lieu province, concentration of COD in the dry and wet season was in the ranges of 20-282.6 mg/l and 24-74.6 mg/l (Figure 3), respectively. In which, there were 08/09 monitoring sites with COD value in the dry season exceeded the limit value according to QCVN 08-MT:2015/BTNMT column B<sub>1</sub> (30 mg/l) [9]. The location of NM4 (outside Gia Rai sewer, ward 1, Gia Rai town) was the highest COD value and NM5 (Cai Cung sewer, Long Dien Dong commune, Dong Hai district) was the lowest COD value. COD concentration in the wet season were much lower than those in the dry season. The location with the highest COD value was NM7 (Cau so 4 canal, Dien Hai commune, Dong Hai district) and the location with the lowest COD was NM1 (Hoa Binh canal, Hoa Binh town, Hoa Binh district). There were 07/09 monitoring sites with COD values higher than permissible limit values in column B<sub>1</sub> of QCVN 08-MT:2015/BTNMT [9].

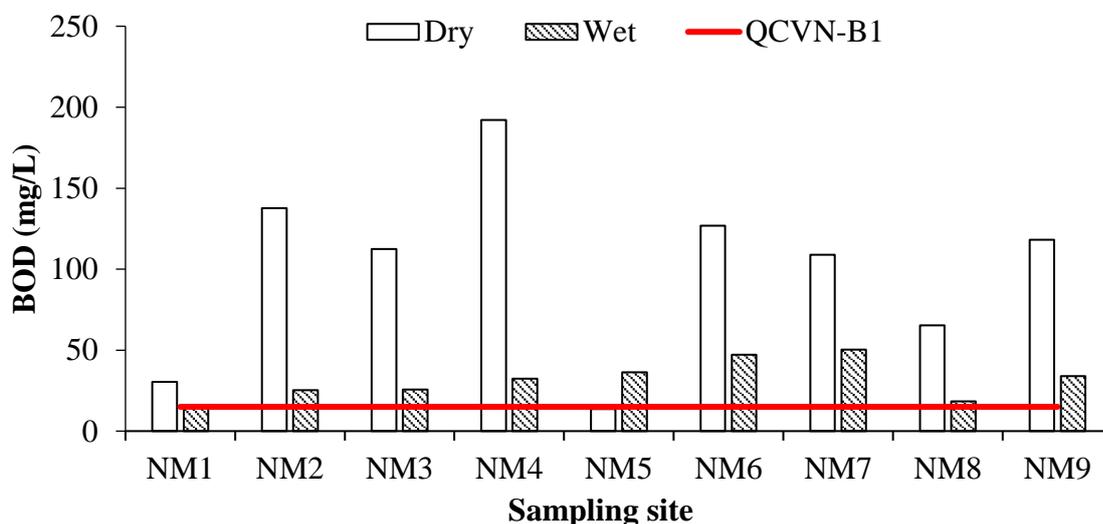


**Figure 3. COD in water bodies in Bac Lieu province**

The monitoring results showed that the COD values in Bac Lieu province were higher than other areas in the Mekong Delta. For example, COD value only ranged from 6.0 to 44.9 mg/l in the canals in Soc Trang [15] and was in the range of 10.4±1.2-16.5±4.1 mg/l on Hau River [14]. The high COD value can be mainly influenced by agricultural, industrial, service, residential and urban activities [17].

### 3.4 Biochemical oxygen demand

Biological oxygen demand is the amount of oxygen needed to oxidize organic substances in water by aerobic microorganisms, this is the criterion used to determine the level of organic pollution of water. The mean of BOD concentration in Bac Lieu province was ranging from 13.6-192.19 mg/l (Figure 4). Meanwhile, BOD value just ranged from 4.7±2.3-12.3±9.2 mg/l and 13.6-192.19 mg/l in canals in An Giang Province [13] and Soc Trang Province [15], respectively. Thus, BOD concentration in the surface water in Bac Lieu Province in 2019 was higher than that in previous studies. Similar to COD, the high BOD value can be explained by the influence of socio-economic activities such as industry, agriculture, residential and urban areas [17].

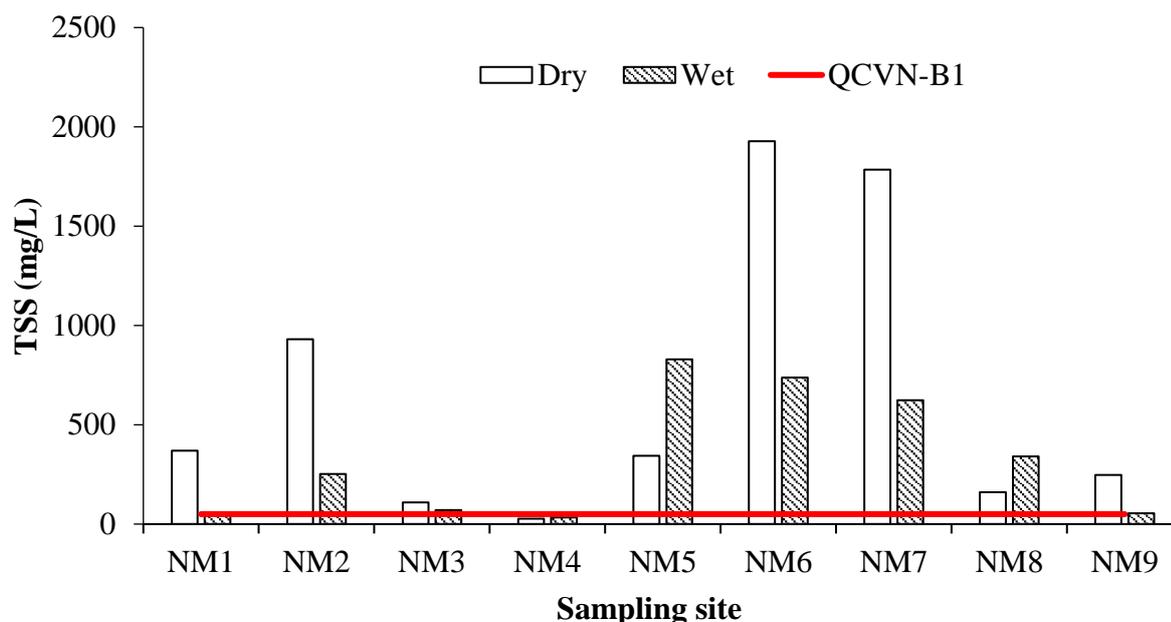


**Figure 4. BOD in water bodies in Bac Lieu province**

The value of BOD in the dry season ranged from 13.6-192.19 mg/l (Figure 4). In which, NM5 location (Cai Cung sewer, Long Dien Dong commune, Dong Hai district) was the lowest BOD value and NM4 location (Outside Gia Rai sewer, ward 1, Gia Rai town) was the highest BOD. Among 09 monitoring sites, 08 points were BOD value higher than the permitted limit in column B<sub>1</sub> of QCVN 08-MT:2015/BTNMT (15 mg/l) [9]. Although BOD value was lower than in the dry season, all 09 monitoring points in phase wet season exceeded QCVN 08-MT:2015/BTNMT, column B<sub>1</sub> [9]. NM1 location (Hoa Binh canal, Hoa Binh town, Hoa Binh district) was the lowest BOD value (16.2 mg/l). NM7 location (Cau so 4 canal, Dien Hai commune, Dong Hai district) was the highest BOD value (50.4 mg/l). The fluctuation of BOD in wet season tended to be lower than those in the dry season because in the wet season water is diluted by rainwater and the tide.

### 3.5 Total suspended solids

Content of the suspended solids in water depends on the amount of suspended matter, soil, sediment particles, planktons and these factors have a direct influence on the turbidity of the water. TSS formed by planktons are beneficial but formed from suspended clay particles are detrimental to aquatic organisms [18]. In this study, there were 08/09 positions in the dry season and 07/09 positions in the wet season exceeded the limit value according to QCVN 08-MT:2015/BTNMT column B<sub>1</sub> (50 mg/l) [9]. The first monitoring phase results showed that TSS value ranged from 27-1,928 mg/l (Figure 5), positions with higher TSS value than the second phase included NM1, NM2, NM3, NM6, NM7 and NM9. The lowest TSS value was recorded at the location outside Gia Rai sewer, ward 1, Gia Rai town (NM4). The highest TSS value at Kenh Buu 2 (NM6), which was 38.6 times higher than the limit of QCVN 08-MT:2015/BTNMT column B<sub>1</sub> [9]. The mean of TSS concentration in the second monitoring phase ranging from 33-830 mg/l (Figure 5). The location with the highest TSS value was Cai Cung sewer, Long Dien Dong commune, Dong Hai district (NM5), which exceeded the limit 16.6 times. The location with the lowest TSS value was Outside Gia Rai sewer, ward 1, Gia Rai town (NM4).



**Figure 5. TSS in water bodies in Bac Lieu province**

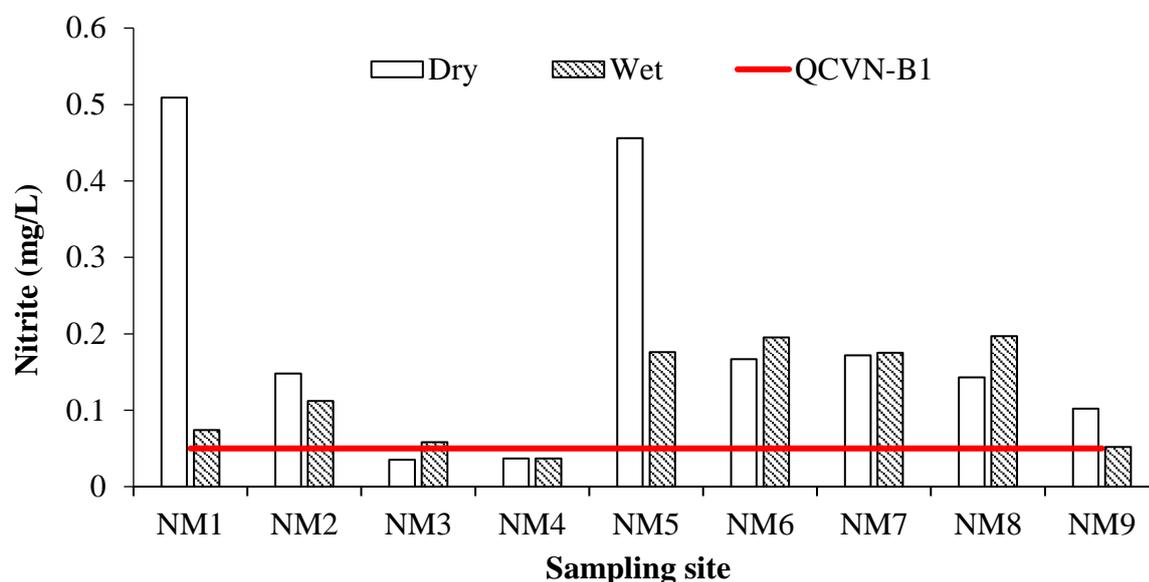
Compared with other studies in the Mekong Delta, TSS value in Bac Lieu was higher than that in the water bodies in the provinces of An Giang, Soc Trang, Hau Giang. This cause may be heavily influenced by mudflats and estuaries. According to research by Tuan *et al.* (2019) [15], the TSS value in Soc Trang fluctuated from 16 to 176 mg/l. Besides that, the mean of TSS concentration in

An Giang and Hau Giang province varied from 25.0 to 93.7 mg/l and  $32.8 \pm 6.4$  to  $101.8 \pm 40.9$  mg/l, respectively [13].

### 3.6 Nitrite

Nitrite is intermediate products in the nitrogen cycle, and it is very toxic to fish and aquatic animals. Therefore, in QCVN 08-MT:2015/BTNMT [9] specified nitrite concentration at very low level with the limit value is 0.05 mg/l for all water use purposes. However, the results in Bac Lieu province showed that the nitrite value was recorded with a rather high level. This indicated that the water environment was lacking of oxygen and this could be toxic to aquatic life [12]. In the dry season, the nitrite value ranged from 0.035 to 0.509 mg/l (Figure 6), the location with the highest and lowest nitrite value were NM1 (Hoa Binh canal, Hoa Binh town, Hoa Binh district) and NM3 (Xom Lung canal, Lang Tron ward, Gia Rai town), respectively. There were 07/09 locations with nitrite value exceeded the limit in QCVN 08-MT:2015/BTNMT, especially NM1 and NM5 exceeded 10 times. The mean of nitrite in the wet season ranged from 0.037-0.197 mg/l (Figure 6), with 08/09 sites exceeded QCVN 08-MT:2015/BTNMT [9]. NM8 location (Tac Van canal, Lung Sinh hamlet, Dinh Thanh commune, Dong Hai district) was the highest nitrite value and NM4 location (outside Gia Rai sewer, ward 1, Gia Rai town) was the lowest value.

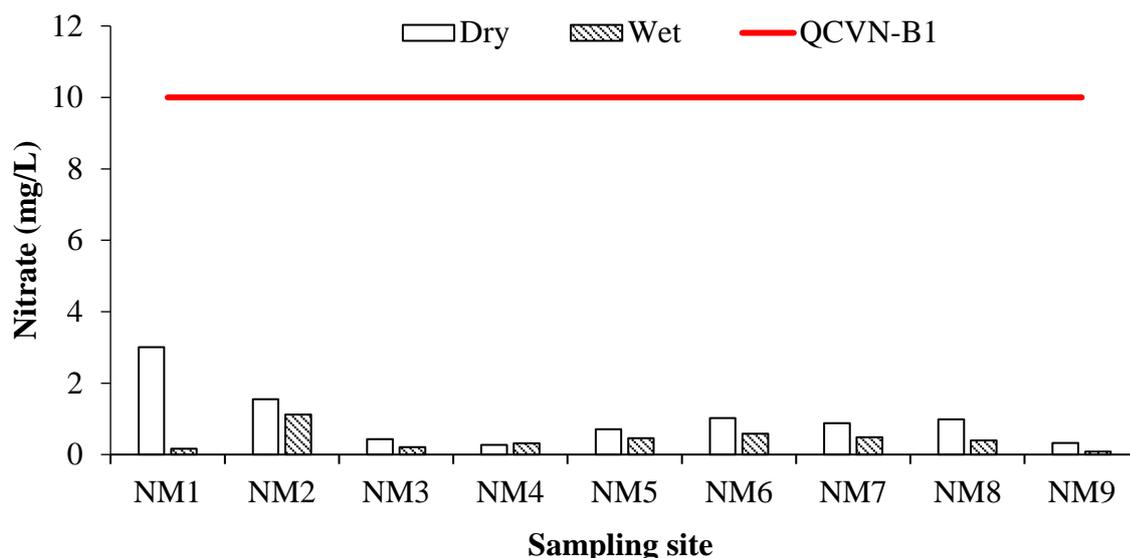
The canals in Soc Trang Province also recorded similar nitrite concentration in the dry season of current study, the nitrite value ranged from 0.001-0.56 mg/l [15]. Meanwhile, nitrite concentration was in the range of  $0.011 \pm 0.0006$ - $0.066 \pm 0.049$  mg/l in-field canals and  $0.011 \pm 0.007$ - $0.017 \pm 0.009$  mg/l on Hau River [12]. Besides that, the nitrite value in Binh Thien lagoon, An Giang was only  $0.01 \pm 0.01$  mg/l [11].



**Figure 6. Nitrite in water bodies in Bac Lieu province**

### 3.7 Nitrate

Nitrate are products of nitrification. Although nitrate is not toxic to shrimp and fish, they can cause phytoplankton bloom, affecting water quality. In previous studies, nitrate value in Hau river ranged from 0.002 to 0.395 mg/l [19]; the canals in An Giang and Soc Trang were  $0.31 \pm 0.3$ - $0.58 \pm 0.64$  mg/l and 0.05-0.14 mg/l, respectively [13, 15]. Figure 7 showed that nitrate value in surface water in salt water bodies of Bac Lieu province in 2019 ranged from 0.085 to 3.004 mg/l, much higher than previous studies. However, nitrate values at all sampling sites in the two monitoring phases were within the limits regulated by QCVN 08-MT:2015/BTNMT, column B<sub>1</sub> [9].

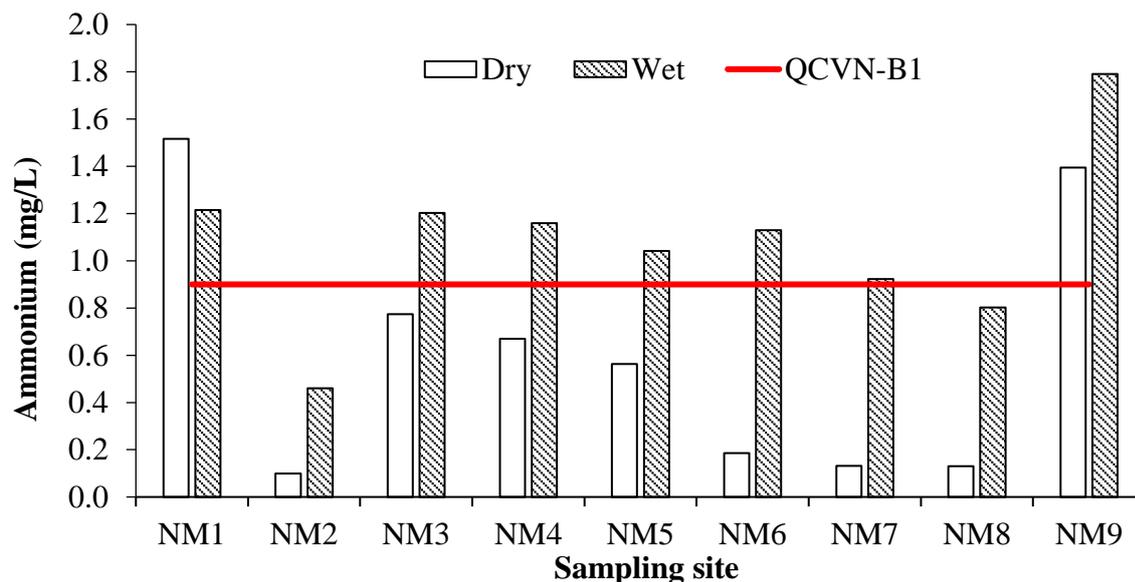


**Figure 7. Nitrate in water bodies in Bac Lieu province**

The first monitoring results (dry season) showed that NM4 location (outside Gia Rai sewer, ward 1, Gia Rai town) was the lowest nitrate value with 0.273 mg/l. Meanwhile, the highest nitrate value of 3.004 mg/l was recorded at NM1 location (Hoa Binh canal, Hoa Binh town, Hoa Binh district). In the second monitoring phase (wet season), the highest nitrate value was only 1.123 mg/l at NM6 position (Kenh Buu 2, Long Dien Dong commune, Dong Hai district) and the lowest was 0.085 mg/l at NM9 (Cua Nha Mat, Bac Lieu City). Analysis results showed that nitrate values were lower in the wet season due to increased water flow to rivers, diluting pollutants [10].

### 3.8 Ammonium

The concentration of ammonium in the dry and wet season in Bac Lieu province were 0.099-1.516 mg/l and 0.46-1.79 mg/l, respectively (Figure 8). The location with the lowest ammonium value in both monitoring phases was NM2 (30 April canal, Vinh Hau commune, Hoa Binh district). The site highest ammonium value in the dry season was Hoa Binh Canal, Hoa Binh town, Hoa Binh district (NM10) and in the wet season was Cua Nha Mat, Bac Lieu city (NM9). The means of ammonium in the wet season tended to be higher than that in the dry season, excepted at NM1 (Hoa Binh canal, Hoa Binh town, Hoa Binh district). The water quality in current study was less polluted by ammonium than that in the canals in Soc Trang province [15]. However, this concentration tended to be higher than the concentration of ammonium in water bodies in Hau Giang province and in Hau River fluctuated from  $0 \pm 0$ - $0.92 \pm 0.56$  mg/l and  $0.1 \pm 0$  mg/l, respectively [12,14]. Cause of the difference between the research results can be a result of oxidation of organic debris, human and animal wastes [20].



**Figure 8. Ammonium in water bodies in Bac Lieu province**

Compared with QCVN 08-MT: 2015/BTNMT (column B<sub>1</sub>) [9], there were 02/09 monitoring locations in the dry season and 07/09 locations in the wet season had ammonium values exceeded the standard. The reason for the high values of nitrite, nitrate and ammonium in surface water is the influence of agricultural cultivation and daily activities of the people [10,17].

### 3.9 Orthophosphate

The results of study did not record the orthophosphate value at Cua Nha Mat, Bac Lieu city (NM9). In the first phase, the orthophosphate value ranged from 0.11 to 0.718 mg/l (Figure 9) and there were 02/08 sampling sites with orthophosphate value higher than the permissible limit value in column B<sub>1</sub> of QCVN 08-MT:2015/BTNMT (0.3 mg/l) [9]. The location with the highest and lowest orthophosphate value were 30 April canal, Vinh Hau commune, Hoa Binh district (NM2) and outside Gia Rai sewer, ward 1, Gia Rai town (NM4), respectively. The orthophosphate value ranged from 0.092-0.852 mg/l in the second monitoring phase (Figure 9), with 04/08 sites had the orthophosphate value exceeded the limit value of QCVN 08-MT:2015/BTNMT column B<sub>1</sub>[9]. The location at 30 April canal, Vinh Hau commune, Hoa Binh district (NM2) was the highest orthophosphate value and Buu 2 canal, Long Dien Dong commune, Dong Hai district (NM6) was the place with the lowest value.

Orthophosphate concentration in Bac Lieu province was similar to that in Soc Trang province, which ranged from 0.05-0.9 mg/l [15]. Meanwhile, the orthophosphate value in the canals was reported in An Giang Province ranging from 0.16±0.12 mg/l [13] and the mean concentration of 0.13±0.05 in Hau River [14], which were the lower than that in this current study. Besides that, the average concentrations of orthophosphate in the Binh Thien lagoon in An Giang Province was 0.1±0.1 mg/l [11]. In addition to nitrate, orthophosphate is also an indicator of the human impact on the water environment due to domestic and industrial wastewater (excretion, detergent) and fertilizers from agricultural cultivation [10].

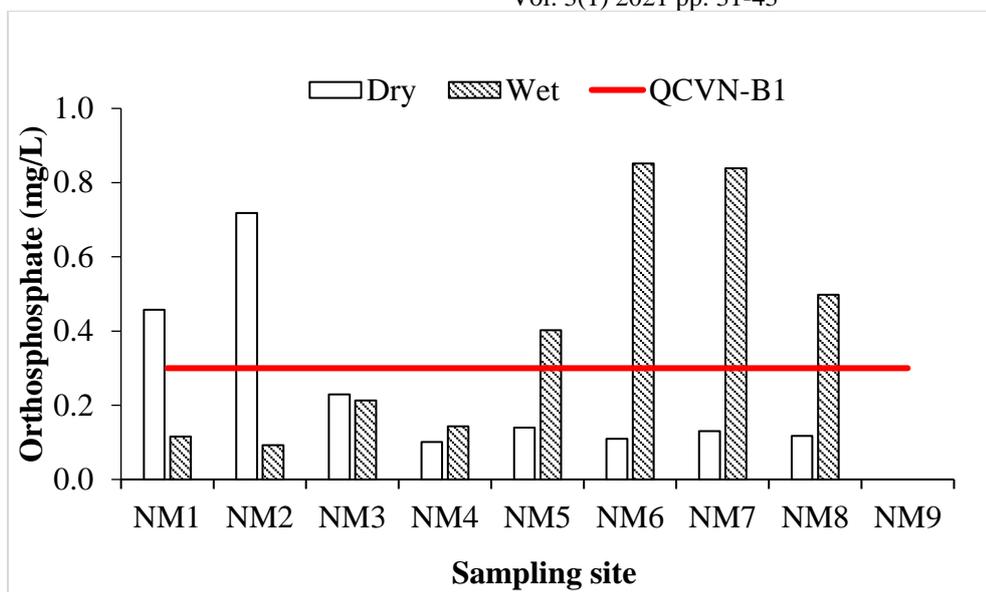


Figure 9. Orthophosphate in water bodies in Bac Lieu province

### 3.10 Iron

The value of iron in surface water in Bac Lieu province ranges from 0.11 to 4,842 mg/l (Figure 10). The first monitoring results showed that the iron concentration ranged from 0.11-2.083 mg/l, the location with the lowest value was NM5 (Cai Cung sewer, Long Dien Dong commune, Dong Hai district). The location with the highest iron value was NM2 (30 April canal, Vinh Hau commune, Hoa Binh district), this was also the only location exceeded the limit of QCVN 08-MT:2015/BTNMT (column B<sub>1</sub>) [9]. In the second phase, the mean of iron ranged from 0.188-4,842 mg/l, there were 04/09 monitoring positions with the iron value higher than the permitted limit value in standard. The location with the highest iron value was Buu 2 canal, Long Dien Dong Commune, Dong Hai District (NM6) and the lowest is Cua Nha Mat, Bac Lieu City (NM9). The presence of iron in surface water leading to degrade water quality, aesthetic issues, treatment costs and poses a health risk to humans.

The value of iron in the wet season of this study was higher than the range of value 0.30-3.75 mg/l in Soc Trang Province [15]. Besides that, the average iron concentration was  $1.2 \pm 0.6$  mg/l in 2019 ranging from  $0.5 \pm 0.2$ - $2.26 \pm 0.5$  mg/l in-field canals and  $0.3 \pm 0.1$ - $0.47 \pm 0.2$  mg/l in Hau River. Geographical conditions and human activities such as intensive agricultural production, washing acidic soil are the causes of the generation of iron in surface water [12-15].

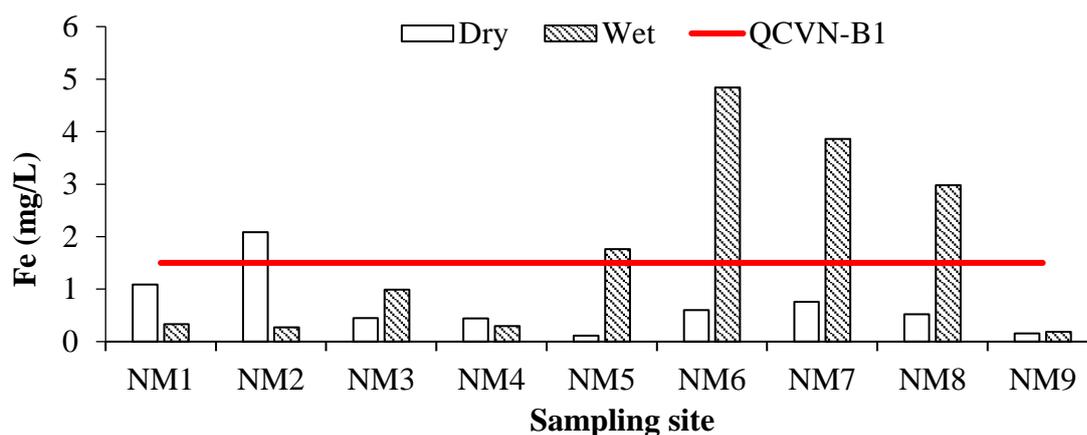
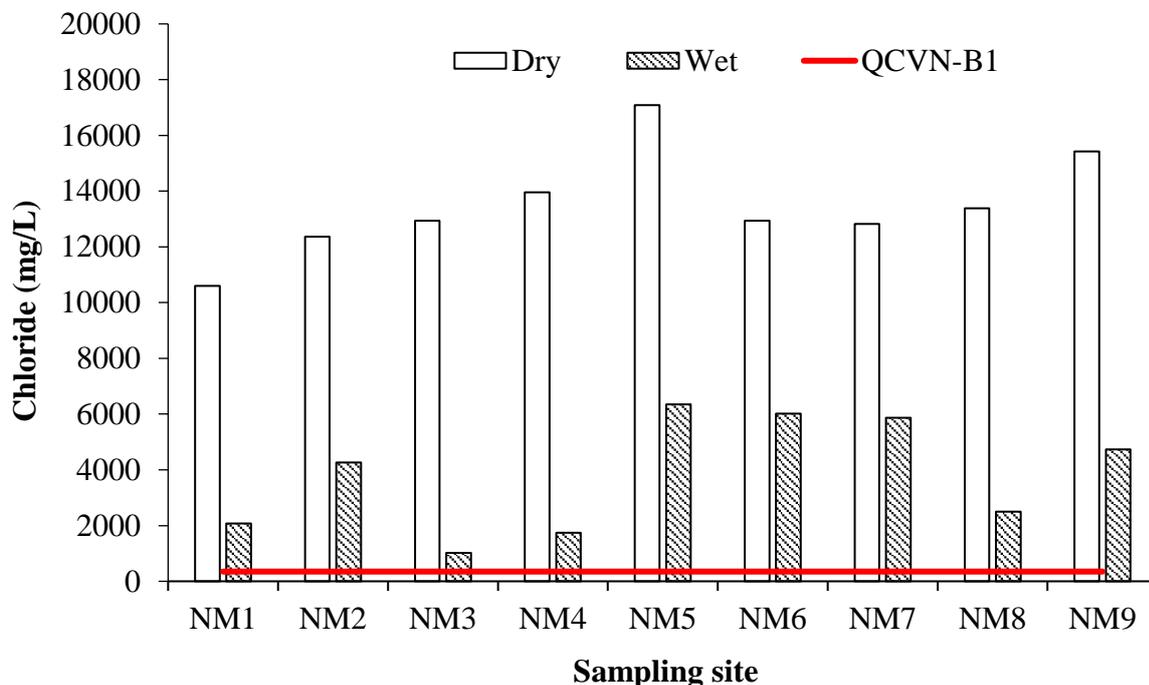


Figure 10. Fe in water bodies in Bac Lieu province

### 3.11 Chloride

While  $\text{Cl}^-$  value recorded in Tien River flowing through Tan Chau, An Giang only fluctuated in the range of 2.1-9.4 mg/l [10], the monitoring result in salt water areas of Bac Lieu province was up to 1,021 - 17,087 mg/l (Figure 11). All positions in both two monitoring phases exceeded the permitted limit of QCVN 08-MT:2015/BTNMT in column B<sub>1</sub> [9].



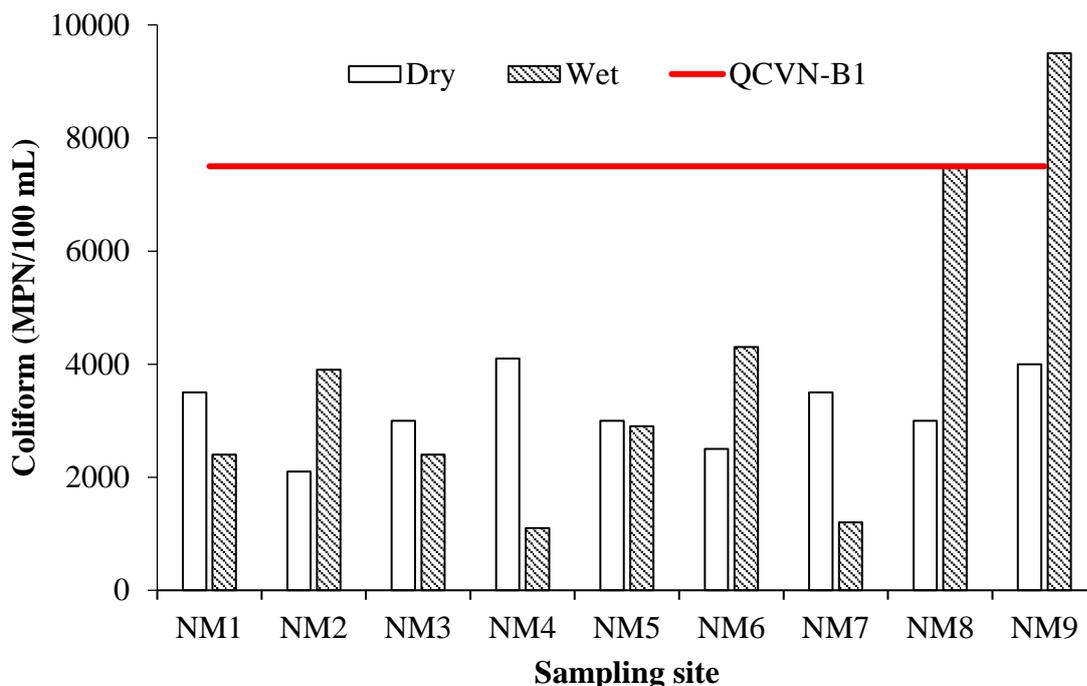
**Figure 11. Chloride in water bodies in Bac Lieu province**

According to Vu *et al.* (2016) [7], changes in rainfall and sea level rise have made saline intrusion deeply penetrate in-fields, so the  $\text{Cl}^-$  value observed in the dry season was many times higher than in the wet season. In which, the first monitoring results was the  $\text{Cl}^-$  value ranging from 10,603 - 17,087 mg/l, exceeded QCVN 08-MT:2015/BTNMT (column B<sub>1</sub>) [9] from 30-48 times. The location with the highest  $\text{Cl}^-$  value is Cai Cung sewer, Long Dien Dong commune, Dong Hai district (NM5) and the lowest position was Hoa Binh canal, Hoa Binh town, Hoa Binh district (NM1). In the second monitoring phase, the  $\text{Cl}^-$  value ranged from 1,021-6,353 mg/l, exceeded the allowable value in column B<sub>1</sub> of QCVN 08-MT:2015/BTNMT [9] by 3-18 times. In which, the location with the highest  $\text{Cl}^-$  value was Cai Cung sewer, Long Dien Dong commune, Dong Hai district (NM5) and the lowest was Kenh Xom Lung, Lang Tron ward, Gia Rai town (NM3).

### 3.12 Coliform

Coliform is a group of bacteria commonly found in the intestines of warm-blooded animals; their presence indicates that the source of water has shown sign of organic pollution [11]. According to QCVN 08-MT:2015/BTNMT [9], the coliform value specified in column B<sub>1</sub> is 7,500 MPN/100ml. The first monitoring results in salt water area of Bac Lieu province showed that the coliform values at 09 locations were within the permissible limit of the standard, this value ranged from 2,100-4,100 MPN/100ml (Figure 12). In which, the highest value was measured at NM4 location (outside Gia Rai sewer, ward 1, Gia Rai town) and the lowest value was at NM2 location (30 April canal, Vinh Hau commune, Hoa Binh district). In the second monitoring phase, the mean of coliform ranged from 1,100-9,500 MPN/100ml. There was 01 site with value equal to the limit specified in column B<sub>1</sub> of QCVN 08-MT:2015/BTNMT [9] which was Tac Van canal, Lung Sinh hamlet, Dinh Thanh commune, Dong Hai district (NM8) and 01 site at Cua Nha Mat, Bac Lieu City (NM9) exceeded

the limit by 1.3 times. The location with the lowest coliform value in the second phase was NM4 (outside Gia Rai sewer, ward 1, Gia Rai town).



**Figure 12. Coliform in water bodies in Bac Lieu province**

Human and animal feces can be source of coliforms [21-22]. Coliform density in this study compared to other studies in Soc Trang, An Giang and Hau Giang was relatively lower value. The coliform values in these three areas were ranges from 2,300-89,000 MPN/100ml; 2,260-155,000 MPN/100ml and 3,225±1,913.8-15,275±15,244.8 MPN/100ml, respectively [13-15]. This showed that the study area was less polluted by fecal materials than other areas.

#### 4. Conclusion

The results showed that surface water quality in Bac Lieu province was polluted with organic matters (COD, BOD), nutrients ( $\text{NH}_4^+ \text{N}$ ,  $\text{NO}_2^- \text{N}$ ,  $\text{PO}_4^{3-} \text{P}$ ), total suspended solid (TSS) and chloride. In addition, water in some places were also contaminated by iron and coliform, especially in the wet season. Coastal water in the study area was seasonally varied. The parameters DO, COD, BOD, TSS,  $\text{NO}_2^- \text{N}$ ,  $\text{NO}_3^- \text{N}$ ,  $\text{Cl}^-$  and coliform in the dry season were higher than those in the wet season. In contrast, the water quality variables including pH,  $\text{NH}_4^+ \text{N}$ ,  $\text{PO}_4^{3-} \text{P}$  and Fe in the wet season were higher than those in the dry season. The potential sources of coastal water pollution could be from runoff water, river bank erosion, solid wastes and from domestic, agricultural and industrial activities. To improve surface water quality, these polluting sources should be well controlled.

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