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Water Quality in the Super-intensive Shrimp Ponds in Bac Lieu Province, Vietnam

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Abstract— *The study was conducted to assess the water quality in super-intensive shrimp ponds in Bac Lieu using water quality parameters such as pH, biochemical oxygen demand (BOD_5), and chemical oxygen demand (COD), total suspended solids (TSS), total nitrogen (TN), total phosphorus (TP), ammonium (NH_4^+-N), residual chlorine, total oil and grease and total coliform. Sixty water samples in super-intensive shrimp ponds were collected in 2019 Bac Lieu province. The results showed that the nutrients in the water samples include TN (0.54-36.12 mg/l), NH_4^+-N (0.016-1,246 mg/l) and TP (0.34-6.12 mg/l) did not exceed the limits of QCVN 40: 2011/BTNMT (column B). Residual chlorine (less than 0.5 mg/l), total oil and grease (<0.2 mg/l) and water pH (5.5-9.0) have not affected the water environment and the growth of shrimp. In water samples there were biodegradable organic substances (BOD_5/COD = 0.53> 0.4), BOD (4.43-55.19 mg/l) and TSS (6.1-320 mg/l) exceeding the limits of QCVN 40: 2011/BTNMT (column B) at some locations, while COD (10,21-90,12 mg/l) was below limit of QCVN 40: 2011/BTNMT (column B). Water in shrimp ponds is contaminated with microorganisms when the total coliform density ranged from 1,300 to 95,000 MPN/100ml and there were 40/60 locations having coliform density greater than 5,000 MPN/100ml. The current findings provide important information for shrimp pond management.*

Keywords— ***Bac Lieu, nutrients, organic matters, super-intensive shrimp farming, microbial pollution.***

I. INTRODUCTION

As a coastal province in the Mekong Delta with an area of over 40,000 squared kilometers, Bac Lieu province has rich and diverse resources to develop marine economy, agriculture - fishery, trade, services and tourism. The strength of the province is agriculture - fishery, especially fisheries development (the key economic sector of Bac Lieu province). In recent years, the fisheries sector has had a strong development (accounting for 58% of the product structure of agriculture, nearly 21% of the economic structure of the province), especially shrimp production **(Current report on environmental status of Bac Lieu province in the period 2016 - 2020 and 2020)**. Many effective production models have been replicated such as intensive shrimp farming, semi-intensive, extensive and improved extensive farming, in which high-tech super-intensive shrimp farming has contributed to increase productivity and production of farmed shrimp. Total aquaculture production in 2016 was 304,400 tons, increasing to 365,000 tons in 2019. In the first 6 months of 2020, aquaculture production reached 103,680 tons, of which shrimp reached 49,349 tons, fish and other seafood was 54,331 tons. In 2019, the province has over 140,510 hectares of land for aquaculture, of which 1,001 hectares for super-intensive white shrimp farming **(Department of Agriculture and Rural Development of Bac Lieu province, 2020)**.

The main types of shrimp farming in Bac Lieu province are mainly industrial and semi-industrial shrimp farming, typically high-tech super-intensive shrimp farming in nethouses. Compared to traditional farming methods, this model increases shrimp production from 10 to 15 times, bringing the average yield to 25-70 tons/ha of water surface/crop **(Current report on environmental**

status of Bac Lieu province in the period 2016 - 2020 and 2020). However, the super-intensive shrimp farming methods also cause significant impacts and pressures on the environment if the wastewater generated from the ponds is not well managed. Wastewater in super-intensive shrimp ponds contains many pathogenic microorganisms such as Vibrio, Aeromonas, E.coli, Pseudomonas, Proteus, Staphylococcus, ... and many fungi and protozoa if not treated completely, then discharge directly into the receiving water source causing water pollution, epidemic spread and crop failure. In addition, at the end of the crop, a large amount of sludge in the pond, about 1,800,000 tons/crop without treatment, was discharged **(Department of Natural Resources and Environment of Bac Lieu Province, 2018)**. This bottom sludge contains a large amount of pollutants, excess food, animal excretion products, bleaching by rainwater polluting the natural water environment or the water in shrimp ponds.

Currently, there are a number of studies conducted to assess water quality in the areas of intensive shrimp farming, improved extensive farming or wastewater treatment methods of these ponds **(Phuong et al., 2007; Menezes et al., 2017; Giang and Quyen, 2018)**. However, the effluent water quality of super-intensive shrimp ponds in Bac Lieu has not been paid much attention. Therefore, this study was conducted to evaluate characteristics of the water environment in the super-intensive shrimp pond in Bac Lieu. The results could provide useful information on water quality so the effective measures to manage and treat could be proposed for sustainable development of super-intensive shrimp farming.

II. MATERIALS AND METHODS

2.1 Water sampling and analysis

Wastewater samples were collected at the same time in 2019 in 60 super-intensive shrimp ponds in key shrimp farming areas in Bac Lieu city, Gia Rai town, Dong Hai district and Hoa Binh province of Bac Lieu province **(Figure 1)**. Wastewater from 60 shrimp ponds was collected and denoted from VT1 to VT60. Wastewater samples, after being transported to the laboratory, were analyzed for pH (measured in the field), BOD_5, COD, TSS, total nitrogen, total phosphorus, ammonium, residual chlorine, total oil and grease, and total coliforms. Wastewater samples were collected and preserved according to TCVN 6663-1: 2011, TCVN 6663-3: 2016, TCVN 5999: 1995 and analyzed by specialized methods based on **APHA (1998)**.

Fig.1: The sampling areas in Bac Lieu province

2.2 Data processing

The water quality data were compared among the sampling locations and were also compared with QCVN 40: 2011/BTNMT-National technical regulation on industrial wastewater to assess water quality in farming areas.

III. RESULTS AND DISCUSSION

3.1 pH

Unfavorable pH values in water will disturb the ion regulation in shrimp **(Morgan and McMahon, 1982; Allan and Maguire, 1992)**. In the wastewater from the surveyed super-intensive shrimp ponds, the pH value fluctuated with a small amplitude of between 7.03 - 8.73 and an average of 7.7. At the positions VT59 and VT16 had the highest and lowest pH respectively (**Figure 2**). The pH value of the water was relatively similar to the pH value (7.4 to 7.8) in intensive shrimp ponds in coastal Quang Tri province **(Giang and Quyen, 2018)** and improved extensive shrimp ponds in Bac Lieu **(Anh et al, 2017)** with pH ranges between 7.2 - 8.1 (morning) and 8.3 - 8.7 (afternoon). However, in the effluent of intensive shrimp ponds in Brazil **(Menezes et al., 2017)** the mean pH value was relatively higher than that in the super-intensive shrimp farming area in this study (8.23 > 7.7).

The pH range in water in the survey ponds was from neutral to alkaline in nature and was within the allowable limits of QCVN 40: 2011/BTNMT, column B (5,5-9). In general, the pH values in these areas were suitable for the growth of aquatic animals, especially shrimp growth **(Boyd, 1998; Hai and Phuong, 2009)**.

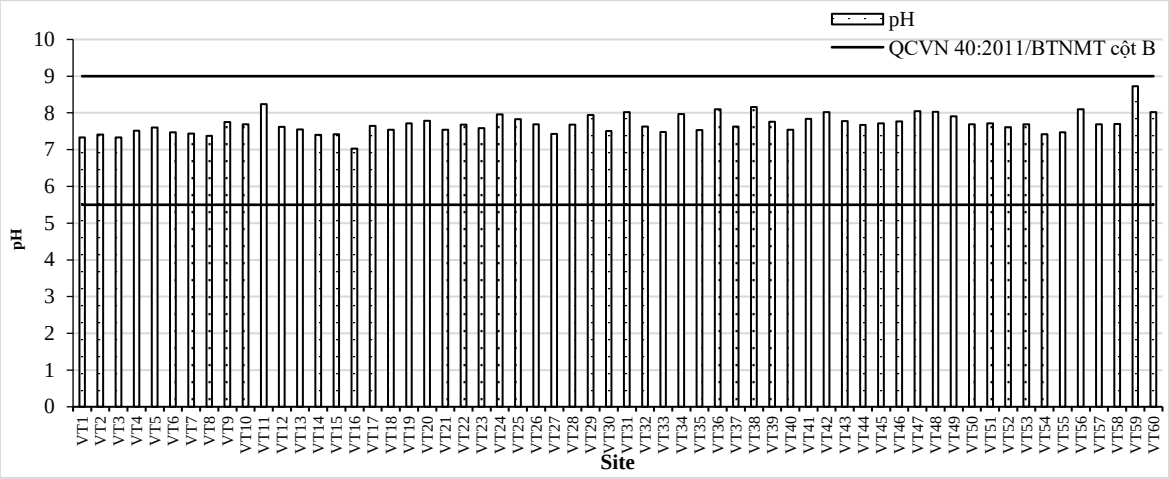

Fig.2: pH in the super-intensive shrimp ponds

3.2 Biochemical oxygen demand (BOD_5)

The biological oxygen demand is one of the parameters used to evaluate the pollution level of water bodies, reflecting the fast or slow rate of oxygen absorption in water of microorganisms **(Boyd, 1998)**. The average BOD at survey locations was 19.68 mg/L, ranging from 4.43 to 55.19 mg/l, the highest at VT10 and lowest in VT46. At most locations (except VT10 and VT17), BOD was below 50 mg/l and within the limit of QCVN 40: 2011/BTNMT, column B (**Figure 3**). According to **Boyd (1998)**, typical aquaculture ponds have BOD values of 5-20 mg/L and the higher BOD, the higher the level of organic matters. Water has a lot of organic matters due to accumulation of humus, excessive manure, excess food or the presence of a large number of algae. BOD in wastewater was relatively lower than the study of **Menezes et al. (2017)** in shrimp ponds in Brazil (19.68 <62.5 mg/l) but it was still consistent with the study of **Giang and Quyen (2018)** in shrimp ponds of coastal areas Quang Tri province with BOD ranging from 35 - 41.22 mg/l.

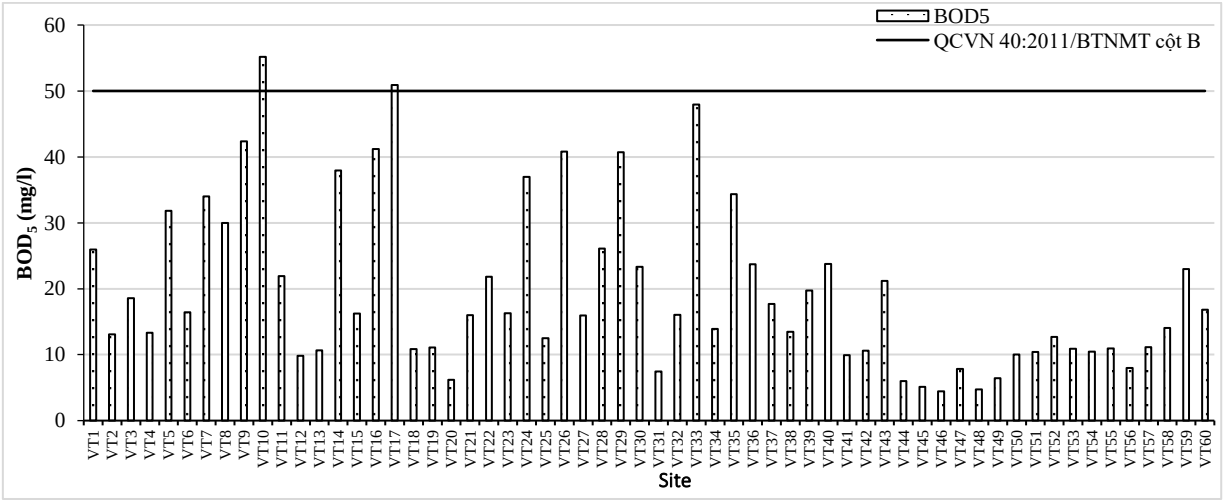

Fig.3: BOD_5 in the super-intensive shrimp ponds

The ratio of BOD/COD at the survey locations ranged from 0.35 to 0.66 mg/l and the average was 0.53 (**Figure 4**). Thus, wastewater in super-intensive shrimp ponds in Bac Lieu contains a lot of organic substances that are easily biodegradable when at most locations had BOD/COD ratios greater than 0.4 mg/l (except VT25, VT46 and VT49). However, this rate may change depending on the nature of the pollution source **(Thuong and Bach, 1999)**. The effects of the discharge of wastes from untreated shrimp ponds as well as the effect of

sedimentation from the sea contribute to the increase in the concentration of organic matters in the water.

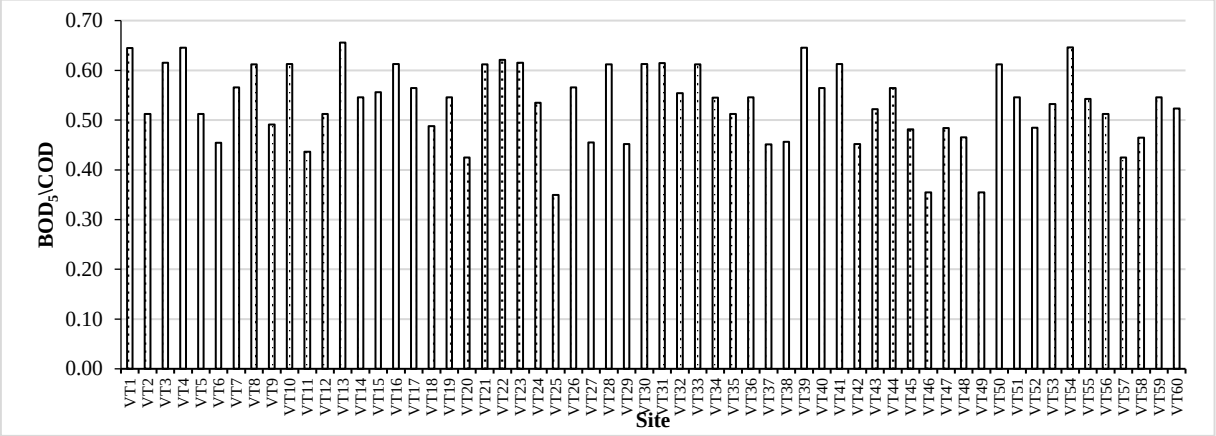

Fig.4: BOD/COD in the super-intensive shrimp ponds

3.3 Chemical oxygen demand (COD)

Chemical oxygen demand (COD) is an important measure of water pollution. The results showed that the difference in COD in wastewater in super-intensive shrimp ponds when the highest concentration was 90.12 mg/l (VT29), the lowest was 10.21 mg/l (VT48) and mean 36.5 mg/l (**Figure 5**). COD concentrations in wastewater from intensive shrimp ponds along the coast of Quang Tri (59.8 - 120.7 mg/l), Thua Thien Hue (130 - 200 mg/l) and Brazil (average 564 mg/l) were all higher than that found in the study area because water sources in surveyed ponds were mainly affected by shrimp farming activities **(Giang and Quyen, 2018; Ngan and Can, 2012; Menezes et al., 2017)**. In fact, the effects from the supply of food and fertilizers to different ponds lead to the difference in COD and BOD concentrations in water in the shrimp ponds **(Figure 3, Figure 4 and Figure 5)**.

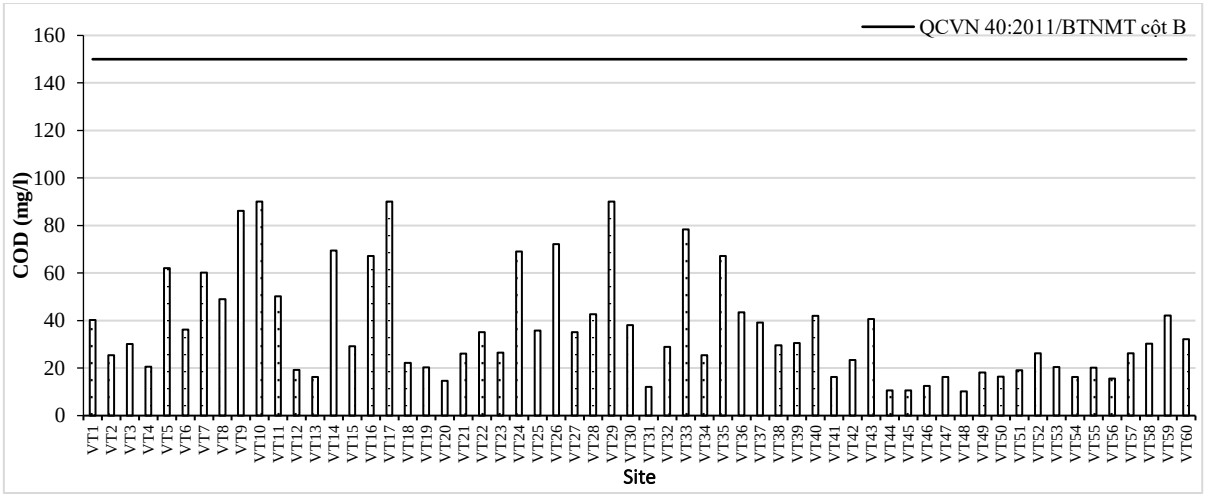

Fig.5: COD in the super-intensive shrimp ponds

In general, COD concentrations in the surveyed shrimp ponds were within the permitted limits of QCVN 40: 2011/BTNMT column B (150 mg/l). According to **Boyd (1998)**, COD is an indicator of the organic richness of pond water. COD of the pond water can range from 10 - 20 mg/L, usually ranges from 40-80 mg/L and COD suitable for aquaculture in the range of 15-20 mg/L. Thus, at the sites VT12, VT13, VT41, VT50, VT51, VT54 and VT56, COD valueswere more suitable for shrimp culture than other pond areas **(Figure 5)**.

3.4 Total suspended solids (TSS)

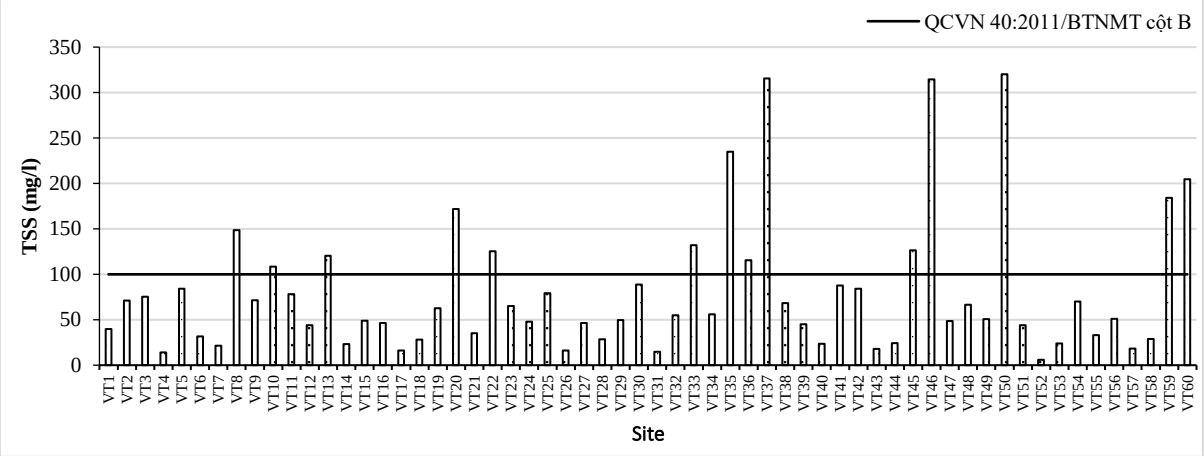

Fig.6: TSS in the super-intensive shrimp ponds

According to **Boyd (1998)**, total suspended solids (TSS) is very closely related to the particle size and the settling rate of suspended particles in water. Pollutants and microorganisms can cling to suspended matters further contributing to the spread of pollutants into the environment **(Ty et al., 2018)**. The TSS concentration in wastewater at the survey sites ranged from 6.1 to 320 mg/l, averaging 79.25 mg/l, the highest at VT50 and lowest in VT52 **(Figure 6)**. The results of the study were more variation than that in the intensive black tiger shrimp ponds in Quang Tri when the TSS concentration in this area ranged from 48.4 to 208.9 mg/l **(Giang and Quyen, 2018)**. The findings showed that 14/60 survey locations had TSS exceeded the permitted limit of the National Technical Regulation on industrial wastewater, column B (100mg/l) from 1.15 – 3.2 times. This proves that at these locations there was organic pollution.

3.5 Total nitrogen (TN)

The total nitrogen in wastewater were large difference between the survey locations. The lowestwas found at VT47 (0.54 mg/l), and the highest was at VT17 (36.12 mg/l) and the mean value was 6.21 mg/l **(Figure 7)**. At the locations of VT10, VT17, VT27, VT29 and VT35, the total nitrogen were quite high and were all greater than 20 mg/l due to the addition of fresh feed, leftovers, and decomposition of food. Compared to QCVN 40: 2011/BTNMT, the total nitrogen at all locations was below the allowable limit of industrial wastewater when discharged into water sources which is not used for domestic water supply purposes (column B, 40 mg/l). In intensive black tiger shrimp ponds in Soc Trang, the total nitrogen in the water ranged from 1.39 to 2.90 mg/L, with an average of 2.31 - 0.58 mg/L**(Phuong et al., 2007)** and TN in the water in the shrimp ponds in the coastal province of Quang Tri was from 10.25 to 18.42 mg/l **(Giang and Quyen, 2018)**. Thus, the results of TN measured in the shrimp ponds in the former studies were much higher than the current study posing a potential risks of eutrophication and water pollution in the farming areas.

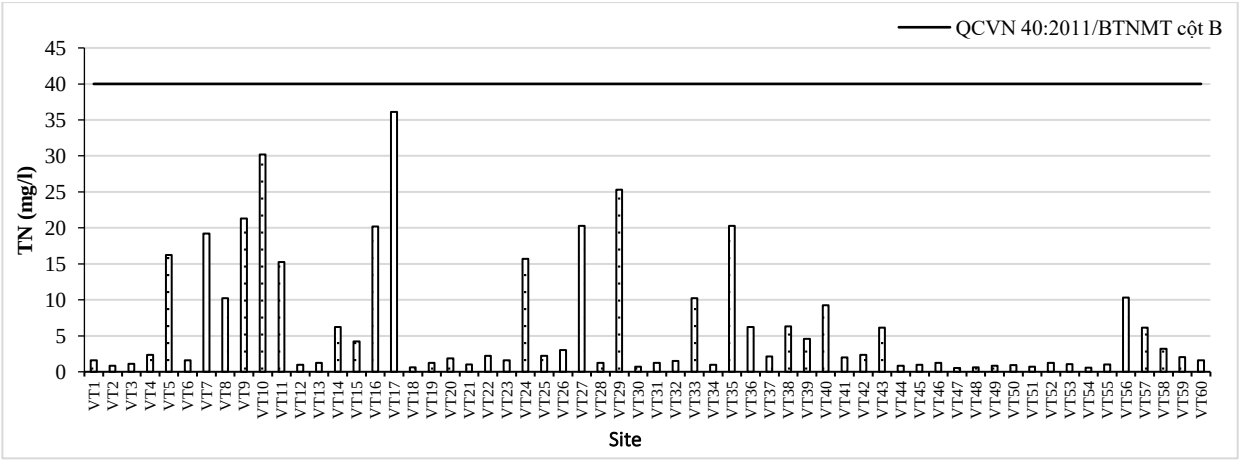

Fig.7: TN in the super-intensive shrimp ponds

3.6 Amoni (NH_4^+-N)

Ammonium values in the super-intensive shrimp ponds ranged from 0.016 to 1.246 mg/l, the highest was at VT7, the lowest was at VT19 and the average was 0.212 mg/l **(Figure 8)**. Ammonium values were lower than the maximum allowable limit of QCVN 40: 2011/BTNMT, column B at all sampling locations (10mg/l). However, the ammonium at most locations (37/60) was greater than 0.13 mg/l, not suitable for the growth of shrimp. However, this ammonium concentration has not greatly harmed the development of cultured shrimp, because in the pond pH was often at neutral values **(Figure 2)**, so ammonium cannot be toxic **(Dat et al., 2012)**. In the improved extensive shrimp ponds in Ca Mau, this concentration ranged from 0.06 - 0.1 mg/l **(Loc et al., 2008)** and in intensive shrimp ponds in Brazil was 0.07 mg/l **(Menezes et al., 2017)**. The results indicated that the water environment of super-intensive shrimp ponds was relatively high ammonium compared to other farming models due to the influence of excess feed, fertilizer and wastes of shrimp.

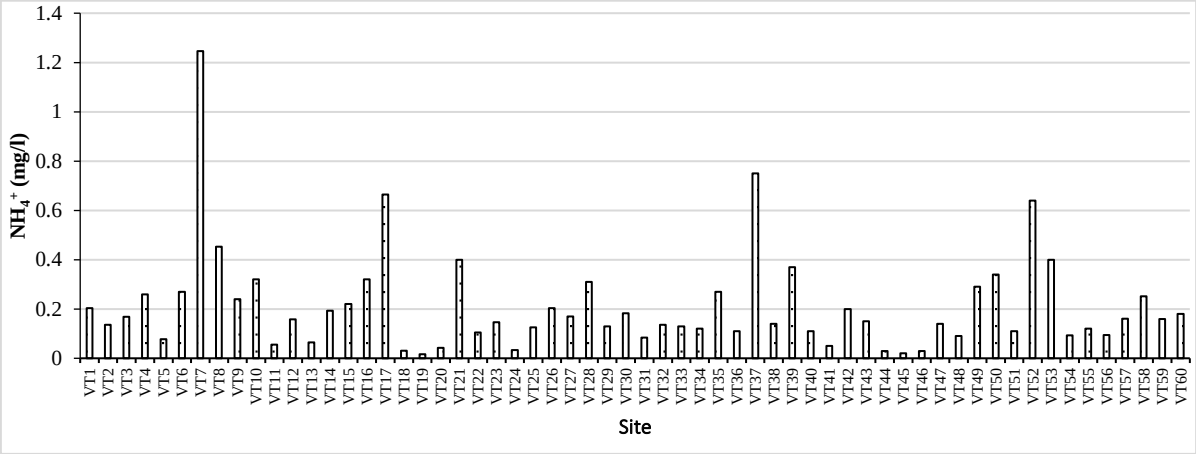

Fig.8: Amoni in the super-intensive shrimp ponds

3.7 Total phosphorus

In culture ponds, phosphorus is periodically supplied through fertilizers to maintain the desired density of phytoplankton. In feeding ponds, some phosphorus is also accumulated by decomposition of uneaten feed and animal manure **(Boyd, 1990)**. The analytical results showed that the total phosphorus fluctuated between the survey locations, reaching from 0.34 to 6.12 mg/l and the average was 1.27 mg/l **(Figure 9)**. At all locations (except VT44), the total phosphorus in wastewater was lower than QCVN 40: 2011/BTNMT column B (6 mg/l). The locations VT5, VT23, VT28, VT30, VT31 and VT44 had relatively high phosphorus and higher than the study in improved extensive shrimp ponds in Bac Lieu **(Anh et al., 2017)** with the phosphate in ponds reached from 0.1 to 1.5 mg/l and an average of 0.4 to 0.5 mg/l. In intensive tiger shrimp ponds in Soc Trang, this concentration ranged from 0.13 to 1.08 mg/l, with an average of 0.567 mg/l **(Phuong et al., 2007)**. Thus, the impact from the addition of food sources for super-intensive shrimp ponds contributes to increasing nutrient levels in the water environment. Therefore, when using this water source, it is necessary to have specific treatment measures for each use purpose.

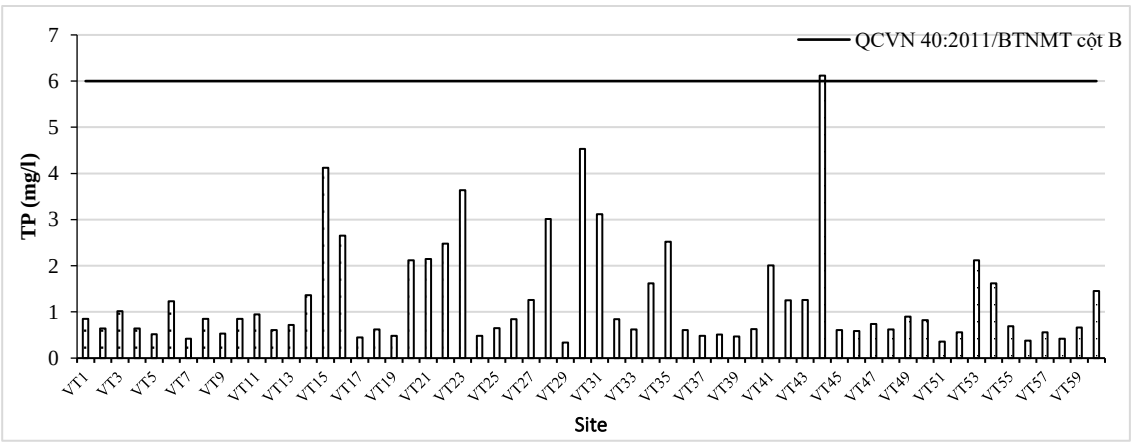

Fig.9: TP in the super-intensive shrimp ponds

3.8 Coliform

The density of coliform at the sampling sites was quite high, ranging from 1,300 - 95,000 MPN/100ml, the lowest at VT12, the highest at VT5 and an average of 16,355 MPN/100ml **(Figure 10)**. Coliform density in this area was relatively higher than the study of **Giang and Quyen (2018)** in coastal Quang Tri province and **Menezes et al. (2017)** in Bazil with the average density of coliform in intensive shrimp ponds were 1,900-3,000 MPN/100ml and 16,000 MPN/100 ml, respectively. The results presented that the water quality in shrimp ponds was showing signs of serious microbiological pollution when there were 40/60 locations exceeding the permitted limit of QCVN 40: 2011/BTNMT, column B (5,000 MPN/100ml) with an excess of 1.01 - 19 times. Waste generated from shrimp farming was the main cause of high density of coliforms in water because coliform is derived mainly from human and animal feces **(Bolstad and Swank, 1997; UNICEF, 2008)**. Therefore, it is necessary to strengthen the management of the pond, regularly apply lime and properly adjust the amount of daily food to limit disease spread in the pond.

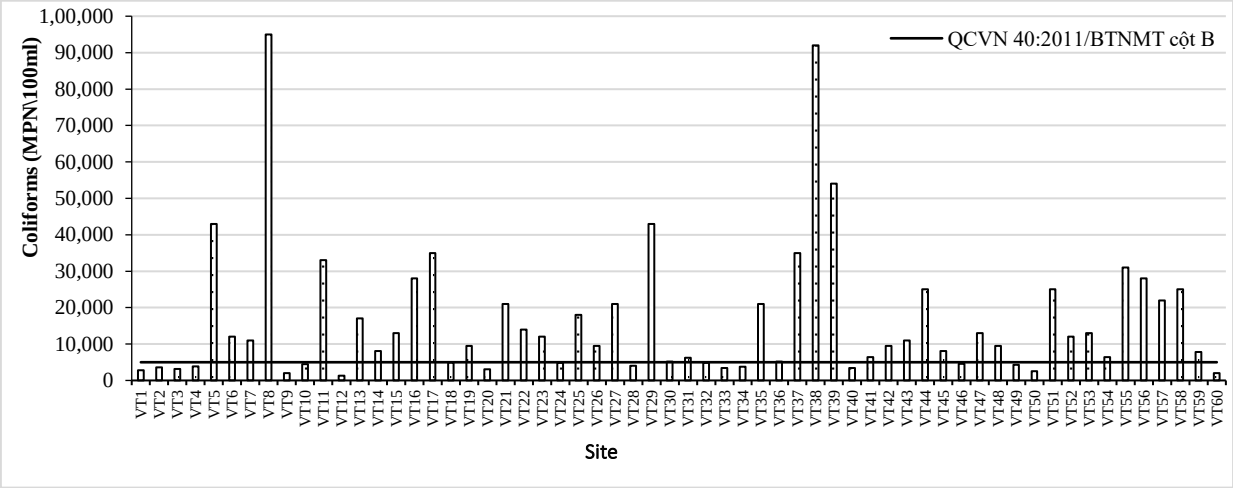

Fig.10: Coliforms in the super-intensive shrimp ponds

IV. CONCLUSION

In the wastewater from the super-intensive shrimp ponds, pH (5.5-9), COD (10.21-90.12 mg/l), total nitrogen (0.54 - 36.12 mg/l), ammonium (0.016-1.246 mg/l) and total phosphorus (0.34-6.12 mg/l) (except VT44) were all within the permissible limits of QCVN 40: 2011/BTNMT, column B. In all ponds, there were residual chlorine below 0.5 mg/l. However, in some ponds there were signs of organic and microbiological pollution since the BOD (4.43 - 55.19 mg/l), TSS (6.1-320 mg/l), total coliforms (1,300 - 95,000 MPN/100ml) in water were quite high, exceeding the allowable limit of QCVN 40: 2011/BTNMT, column B, especially at location VT10 and VT17. The average BOD/COD ratio was 0.53, which showed that the wastewater contained a lot of biodegradable organic matters. The use of fertilizers, excess feed and shrimp waste had a negative impact on the quality of the water source, so it is necessary to fine tune and control these activities.

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