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WATER QUALITY STATUS OF WHITE LEG SHRIMP FARMING AREAS IN BINH DAI DISTRICT, BEN TRE PROVINCE, VIETNAM

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Abstract – *This study focused on water quality assessment of farmed shrimp ponds in Binh Dai District, Ben Tre Province. The goals of the study were to provide chemical parameters of pond water for farmers, to identify problems and causes in farmed shrimp related to water quality and disease, and to help managers find appropriate solutions to minimize damage to local shrimp farming. Water samples were collected monthly from January to June 2021 from 90 vannamei farmers in six different areas, including Vang Quoi Dong, Dinh Trung Binh Thoi, Phu Long, Phu Vang, and Binh Thang of Binh Dai District. Parameters investigated in this study included pH, alkalinity, NH_4+, NH_3, NO_2- and three other minerals. Water quality parameters were analyzed based on APHA standard analysis methods. The results showed that the water quality of shrimp farming areas in Binh Dai fluctuated from time to time, and water quality parameters were suitable for vannamei shrimp farming. However, the concentration of NO_2- was always higher than the permitted threshold. The results from cluster analysis and MANOVA testing showed that water quality of the shrimp farming areas in Binh Dai was significantly different ($p < 0.05$), especially NO_2-, Ca, Mg and alkalinity. These findings suggest that farmers must apply proper solutions for water quality management in each farming area to maximize crop production.*

Keywords: Ben Tre Province, shrimp farming, water parameters, water quality.

I. INTRODUCTION

Ben Tre is a province in the Mekong Delta region with a coastline of 65km and an interlaced river system. Ben Tre has a high potential for aquaculture development, with aquaculture areas concentrated mainly in the three coastal Districts of Binh Dai, Ba Tri, and Thanh Phu. In 2010, the total aquaculture area of the three districts was 37,343 hectares, accounting for 88.06% of the province's aquaculture area, and the total output reached 69,906 tons, accounting for 41.42% of the province's total output [1]. Separately, Binh Dai has a total area of 18,000 hectares for aquaculture (accounting for 48.2% of the province's total output), of which the intensive Vannamei shrimp farming area occupies over 1,619 ha in 2020 [1]. Before 2012, shrimp farming in the District developed very strongly, and the income of shrimp farmers after each shrimp harvest was relatively high.

During shrimp farming, water quality is considered one of the essential factors that directly affect shrimp growth, as poor water quality causes stress and leads to disease outbreaks. Due to climate change and environmental pollution in recent years, shrimp farming in Binh Dai District has faced many difficulties, typically severe saline intrusion. In 2019–2020, the saline intrusion in Dinh Trung Commune was up to 17–20‰ and in Binh Thoi Commune 20–22‰, affecting the production of rice, vegetables, fruit trees, and aquatic products, causing 70% all agriculture damage [2]. Therefore, it is necessary to analyze and assess the water quality in shrimp farming areas to mitigate the impacts of environmental and climate change in a timely manner. This study investigates the current state of water quality in six Vannamei shrimp farming areas of Binh Dai District, Ben Tre Province, including Vam Quoi Dong, Dinh Trung, Binh Thoi, Phu Long, Phu Vang, and Binh Thang. The results illustrate the importance of water quality for Vennamei shrimp culturing, and the study

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proposes solutions to reduce water pollution and improve water quality for shrimp farming.

II. LITERATURE REVIEW

Previously, there were a few studies researching water quality for aquaculture areas in Ben Tre. The research of Le Thi Hong Van and Tran Ngoc Diem My [3] studied surface water quality fluctuations at some points around the aquaculture area in Ben Tre Province. In their research, the physical and chemical parameters of the water included temperatures ranging from 27.6–34.0^{o}C, pH from 7.6–9.3, salinity from 2–40 ppt, TDS (Total Dissolved Solids) from 1.28–42.2, DO from 5.3–6.9 mg/L, NO_3- from 0–0.19 mg/L, NH_4+ from 0–2.17 mg/L, and $PO_4$3- from 0–0.21 mg/L [3]. This study showed that most of the water quality factors in Ben Tre in the surveyed areas were within the allowable limits for aquaculture farming, conservation of aquatic plants and animals, and useability for domestic purposes.

When studying water quality in Ham Luong and Ba Lai rivers (Ben Tre Province), Yen et al. [4] noted that water quality in the two rivers tends to decrease gradually from points outside the estuary towards upstream areas. Correlation analysis showed that the hydrological system in Ham Luong river and Ba Lai river (Binh Dai District side) has been affected by several factors such as pH, DO, and salinity. The study conducted monitoring of several chemical indicators on both rivers, consisting of pH, DO, and TSS. Both criteria were within the allowable limit following QCVN 08-MT: 2015 / BTNMT (National Technical Regulation on surface water suitable for shrimp and fish farming) [4]. In particular, in the Ba Lai river basin, where the section flows through the sampling points in Binh Dai District, the results of a one-factor analysis of variance showed that parameters such as pH, DO, TDS, salinity and NO_3- had a significant difference between the dry season and the rainy season. The values of DO, TDS and salinity in the dry season were higher than in the rainy season; in contrast, the concentration of NO_3- in the rainy season was higher than in the dry season [4]. These findings prove that the concentration of substances in ponds can change with the weather and season. From there, shrimp farmers have a basis to take suitable adjustment measures to the water environment for farmed shrimp to thrive.

Several studies on water quality assessment in water bodies in Ben Tre Province were published in the period 2018–2019. When studying water quality in major rivers and canals in Ben Tre, Nguyen et al. [5] stated that the water quality of many areas originating from the main rivers and canals of Ben Tre in April and October of 2015 and 2016 was tarnished by TSS values at 75–304 mg/L, BOD_5 from 7–25 mg/L and coliform from $1.1x10^3$ to $2.3x10^3$ CFU/mL. In Binh Dai District, factors affecting water quality at clam farms such as pH, NO_2-, NH_3 and H_2S were suitable for clam culture and showed no difference between the rainy and the dry season. In terms of factors such as temperature and salinity, there was a difference between the two seasons [5]. On large rivers, the direction from the upstream is to the estuary, the water quality in the rainy season was more disturbed than those in the dry season. In particular, for Ba Lai river basin, in the sampling points of Binh Dai District near Ba Lai dam, the water quality was the worst compared to other areas [6, 7].

Most studies of water quality survey and evaluate the water volume fluctuations in natural water bodies like rivers and canals, including studies in Ben Tre Province. Although there is a partial application to aquaculture activities (such as shrimp farming and clam farming), there has not been a study that evaluates water quality fluctuations in aquaculture systems in general and the region of white leg shrimp farming in Binh Dai District in particular. Therefore, the study aims to study and evaluate the water quality in shrimp farming areas and then suggests feasible solutions for improving shrimp yield in Binh Dai District, Ben Tre Province.

III. RESEARCH METHODS

A. Time and place of study

Time of study: The study was conducted from January to June, 2021.

Sample collection location: Samples were collected at six shrimp farming communes of Binh

Dai District, Ben Tre Province, including Vang Quoi Dong, Dinh Trung, Binh Thoi, Phu Long, Phu Vang, and Binh Thang.

Sample analysis location: General laboratory, Faculty of Agriculture and Food Technology, Tien Giang University.

B. Water sampling

Water samples were taken in Vannamei shrimp ponds (from 25 to 45 days old) at 15 farms/communes (six communes in all). The pond water from each farming household was collected once a week. The pond water was collected in clean plastic bottles and then sealed. The author collected water from five different areas including the middle and four corners of the pond at a depth between 0.3–0.4m from the bottom. The samples were then mixed and 1000 mL was extracted to be brought to the analytical laboratory.

C. Water sample analysis methods

The pH was measured directly in the pond by a pH meter. Alkaline is measured in the field by titration with bromine and sulfuric acid with phenolphthalein parameter. The remaining parameters, such as NH_4+, NH_3, NO_2-, Fe, Ca, and Mg, were analyzed at the laboratory according to APHA's analysis methods system [8].

D. Data statistical methods

SPSS 16.0 software was used to analyze the collected data. The study calculated the mean (average) values and standard errors of the water quality parameters for comparison and evaluation. Then, the conclusion was made if the water sample quality was suitable for shrimp growth. Three main analysis methods were applied to analyze water quality in six sampling areas of Binh Dai District. The research used ANOVA one-way analysis to compare and assess water quality factors among the six samplings, MANOVA analysis method for the overall water quality in six sampling areas of Binh Dai District, and the cluster analysis method for the similarity of water quality among six sampling areas.

IV. RESULTS AND DISCUSSION

A. Results of water quality in Binh Dai District

Results of water quality parameters of 90 ponds in 6 communes of Binh Dai are shown in Table 1.

In shrimp farming, pH is one of the important factors that reflects the hydrological and biological conditions of the pond environment and the health of farmed shrimp. pH directly affects shrimp growth, survival, nutrition, digestion, and molting. Besides pH, alkalinity is also an important parameter of shrimp pond water. Alkalinity helps the pond water stabilize the buffer system and balance the hydration to create a favorable environment for molting and growth of shrimp. In shrimp ponds, alkalinity directly affects pH fluctuation in ponds, affecting the molting and hardening process of farmed shrimp [9]. Since water is highly alkaline, the pH of the water resists changes because alkalinity is a pH buffer and provides CO_2 for the photosynthesis of algae and domestic plants. In terms of alkalinity in water, Table 1 shows that the average alkalinity of Binh Dai District is 127 mg/L. According to Nguyen Dinh Trung [10], the alkalinity value in Binh Dai is good for Vannamei growth because Vannamei grows well at alkalinity in the range of 70 to 180 mg/L. Therefore, farmers need to concentrate and manage pond water quality closely to maintain proper alkalinity and pH for their ponds.

In addition to pH and alkalinity, iron (Fe) is also an important factor in shrimp ponds. Iron deficiency will retard growth, and iron will become toxic for shrimp and adversely affect pond water quality in excessive concentration. Ammonia, a toxin accumulated and generated from shrimp waste during culture, from dead shrimp and from bottom algae is one of the causes of contaminated water. Ammonium exists in two forms, ammonia NH_3 and NH_4+ ammonium ion. In particular, NH_4+ is essential for the growth of plankton in the shrimp pond. The long-lasting residues in the pond bottom create a large amount of waste, generating massive amounts of toxic NH_3 gas. The excess amount of toxic NH_3 gas in the water causes the shrimps to be lethargic, have red bodies, stop eating, slow

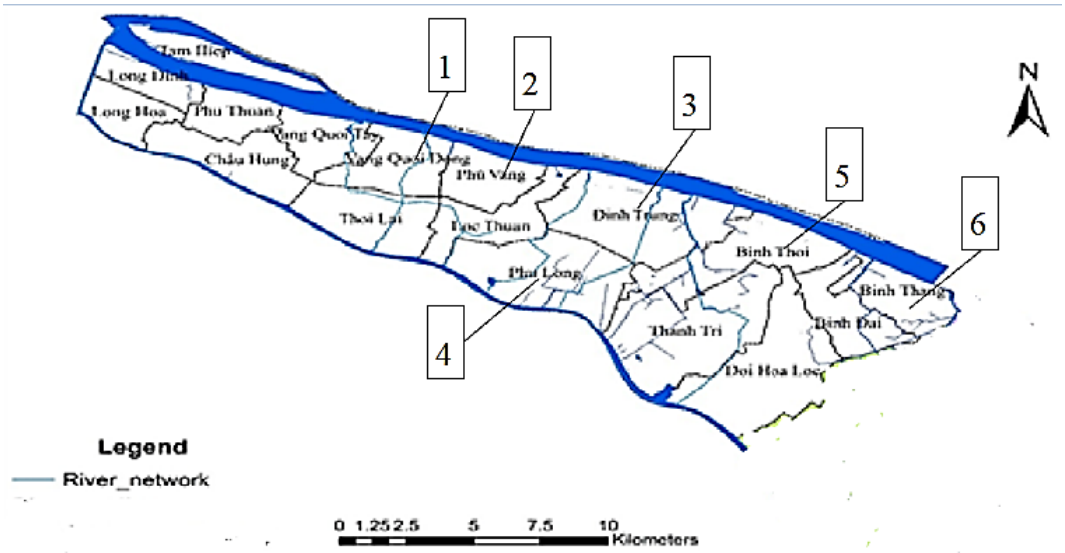

Fig. 1: The sampling sites in Binh Dai District, Ben Tre Province map

1-Vang Quoi Dong; 2-Phu Vang; 3-Dinh Trung; 4-Phu Long; 5-Binh Thoi; 6-Binh Thang

Table 1: The table of describing about water quality in Binh Dai

Parameters	Mean±S.D.
pH	8.1±0.23
Alkalinity(mg/L)	127±46.5
Iron (mg/L)	0.2±0.01
NH_4 (mg/L)	0.4±0.03
NH_3 (mg/L)	0.03±0.004
NO_2 (mg/L)	3.33±0.658
Ca (mg/L)	260±7.1
Mg (mg/L)	305±7.8

growth, and even cause swimming to the surface and death. Table 1 shows that the parameters of pH; Fe; NH_4+ and NH_3 concentration of Binh Dai District are 8.1, 0.2 mg/L, 0.4 mg/L, and 0.03 mg/L respectively. According to Boyd and Tucker [11], these parameter values are suitable for Vannamei development, because Vannamei grows well at pH from 7.5–8.5, Iron from 0.05–0.5 mg/L, NH_4+ from 0.2–2 mg/L, and $NH_3 \leq$ 0.1 mg/L. The finding shows that the care and management of the pond environment were always closely monitored and managed by farmers. However, farmers need to pay attention to and manage the water environment more closely to maintain the stability of alkalinity, pH, Fe, NH_4+, and NH_3 concentration.

The study also evaluates concentration of NO_2-. The average concentration of NO_2- in Binh Dai District is 3.33 mg/L. According to Nguyen Dinh Trung [10], this concentration of NO_2- has exceeded the allowed limit because Vannamei develops at N-$NO_2 \leq$ 0.3 mg/L. The high concentration of NO_2- reduces the function of the shrimp immune system which makes shrimps susceptible to diseases. Moreover, nitrite is toxic to shrimp, and exposure to high concentrations may cause retarded growth and mortalities [12]. The simultaneous presence of NH_3 and NO_2- also causes algae growth in the pond and the harmful algae that can lead to severe hypoxia at night. Besides, these algae also cause serious effects on shrimp health. Therefore, farmers need to have proper solutions to reduce and stabilize N-NO_2 concentration in the remaining months.

Mineral elements play a crucial role for aquatic animals because they are directly involved in the biosynthesis processes that happen inside the animal body. The demand for minerals in Vannamei farming is extremely high. Vannamei has a fast growth rate, and the molting process of

shrimp takes place continuously [13]. In addition, high stocking density also makes mineral needs in shrimp ponds high. Minerals have many physiological functions to maintain acid-base balance and osmotic pressure regulation. Among the main minerals such as Fe, Cu, Zn, Ca, Mg and P, calcium (Ca) and magnesium (Mg) are integral for peeling and forming new shells. If there is a lack of such minerals, shrimp are easy to bend and have soft shells. When the breeding density of Vannamei is high, ponds require timely and intense mineral supplementation. In general, the mineral content in ponds must be equivalent to the salinity of diluted seawater. The study found that calcium and magnesium content was 305 mg/L and 260 mg/L respectively. According to Boyd [14], this content of calcium and magnesium is suitable for Vannamei growth, because Vannamei develops with Calcium $\leq$ 500 mg/L and Magnesium $\leq$ 1.500 mg/L when alkalinity is stable. Because hardness (calcium and magnesium) is derived from the dissolution of limestone [11], farmers need to regularly control and maintain the calcium and magnesium content in their ponds to create suitable habitat for Vannamei shrimp.

B. Comparison of water quality between regions of Binh Dai District

After evaluating the overall status of the water quality of the whole Binh Dai District, the study conducted a specific assessment of water quality criteria of six regions of Binh Dai District. Zone 1 and Zone 2 (Vang Quoi Dong, Phu Vang) are adjacent to the freshwater environment, but they have been affected by salinity in recent years. Zone 5 and Zone 6 (Binh Thang, Binh Thoi) are the areas adjacent to the sea that have high salinity. Zone 3 and Zone 4 (Dinh Trung, Phu Long) are brackish water zones. The evaluation of water quality factors aimed to differentiate the six regions and to find the area where people manage water quality suitable for the development of Vannamei shrimp. At the same time, the analysis aimed to identify adverse parameters within the farming environment to support timely management. Results of water quality parameters of the six farming areas in Binh Dai District are shown in Table 2.

Firstly, Table 2 shows that the pH value of the six areas in Binh Dai District is 8.1, but the difference is not statistically significant ($p > 0.05$). According to Boyd and Tucker [11], this pH is within the suitable range for white leg shrimp growth (pH 7.5–8.5). Secondly, the alkalinity of the six regions of Binh Dai District is from 114 to 147 mg/L. Meanwhile, Binh Thoi has the highest alkalinity (147 mg/L), which is statistically significant ($p < 0.05$) compared to the other regions. Thirdly, the alkalinity of the remaining regions is not different ($p > 0.05$). According to Tran Viet My [9], the alkalinity in these six regions is suitable for white leg shrimp growth, which require alkalinity from 70 to 180 mg/L.

The iron content of the six areas in Binh Dai District ranged from 0.15–0.23 mg/L ($p > 0.05$). According to Boyd and Tucker [11], the iron content of all six regions were within the allowed limit for the growth of white leg shrimp (0.05–0.5 mg/L). The NH_4+ content of six areas in Binh Dai District ranged from 0.30–0.35 mg/L ($p > 0.05$). NH_4+ concentrations in all six regions were within the tolerance range of cultured shrimp and suitable for the growth of Vannamei shrimp (0.2–2 mg/L) [11]. This shows that farmers strictly managed their ponds, using the correct processes and applications of pond management techniques.

NH_3 content in the six regions of Binh Dai District ranged from 0.02–0.05 mg/L ($p > 0.05$). According to Le Van Cat et al. [15], NH_3 in equilibrium in water always exists in two forms NH_3 and NH_4+ depending on pH and temperature. As pH increases, free NH_3 increases relative to NH_4+. Increasing water temperature also increases the NH_3 ratio, but the effect of temperature is smaller than the effect of pH. Assessing the toxicity of NH_3 is always directly related to the pH of the water. According to Boyd and Tucker [11], NH_3 concentrations in the six Districts of Binh Dai District were suitable for the development of white leg shrimp ($NH_3 \leq 0.1$ mg/L).

The concentration of NO_2- in the six regions of Binh Dai District ranges from 1.54–9.58 mg/L. Dinh Trung commune (9.58 mg/L) has the high-

Table 2: The results of ANOVA about water quality of 6 areas in Binh Dai

Parameters	Vang Quoi Dong	Phu Vang	Dinh Trung	Phu Long	Binh Thoi	Binh Thang
pH	8.1 ± 0.03^{a}	8.1 ± 0.04^{a}	8.1 ± 0.03^{a}	8.0 ± 0.03^{a}	8.1 ± 0.02^{a}	8.1 ± 0.02^{a}
Alkalinity (mg/L)	114 ± 5.3^{a}	129 ± 9.1^{a}	127 ± 7.5^{a}	115 ± 3.8^{a}	147 ± 3.1^{b}	130 ± 3.8^{a}
Iron (mg/L)	0.18 ± 0.028^{a}	0.15 ± 0.023^{a}	0.21 ± 0.023^{a}	0.23 ± 0.037^{a}	0.22 ± 0.033^{a}	0.22 ± 0.025^{a}
NH_4^+ (mg/L)	0.3 ± 0.05^{a}	0.5 ± 0.07^{a}	0.4 ± 0.10^{a}	0.4 ± 0.06^{a}	0.4 ± 0.05^{a}	0.3 ± 0.06^{a}
NH_3 (mg/L)	0.02 ± 0.004^{a}	0.05 ± 0.018^{a}	0.02 ± 0.005^{a}	0.02 ± 0.004^{a}	0.02 ± 0.003^{a}	0.03 ± 0.011^{a}
NO_2^- (mg/L)	1.54 ± 0.248^{a}	2.62 ± 0.835^{a}	9.58 ± 3.743^{b}	1.98 ± 0.349^{a}	2.38 ± 0.239^{a}	1.90 ± 0.278^{a}
Ca (mg/L)	371 ± 21.5^{e}	320 ± 21.1^{d}	207 ± 8.7^{b}	237 ± 12.6^{bc}	266 ± 12.7^{c}	157 ± 6.9^{a}
Mg (mg/L)	371 ± 20.8^{b}	375 ± 27.1^{b}	288 ± 16.5^{a}	263 ± 14.6^{a}	271 ± 12.9^{a}	262 ± 13.6^{a}

Note: The value in the table is the mean $\pm$ S.D. In each row, different superscript letters indicate a significant difference (ANOVA, $p < 0.05$)

est value and is different from other regions ($p < 0.05$). According to Nguyen Dinh Trung [10], the concentration of NO_2- in the six regions exceeded the allowable limit and can cause poisoning for shrimp. Shrimp only grow and develop when the NO_2- concentration is less than 0.3 mg/L. The conclusion shows that when waste in the shrimp farming process is excessive and not being removed, the water generates toxic gas. The bigger the shrimps are, the more they eat, and the more they emit, the higher the amount of NO_2-. If the farmers do not handle increases in gas accumulation, the shrimp will be easily infected and die [13]. Therefore, shrimp farmers need to focus on reducing the amount of toxic gas in the pond to stabilize the pond water environment in the remaining months of the year.

As for the mineral elements in the pond, the calcium (Ca) content of the six areas in Binh Dai District ranged from 157 to 371 mg/L. Vang Quoi Dong (371 mg/L) had the highest calcium concentration in total. According to Boyd [14], the calcium content of the six regions reached suitable values for the growth of Vannamei shrimp. The magnesium (Mg) content of the six areas in Binh Dai District ranged from 262–375 mg/L. In particular, Mg content in Vang Quoi Dong (371 mg/L) and Phu Vang (375 mg/L) reached the highest value. Dinh Trung, Phu Long, Binh Thoi, Binh Thang had similar Mg content (288 mg/L, 263 mg/L, 271 mg/L, and 262 mg/L, respectively). According to Boyd [14], the total magnesium content of the six regions was all within the allowable levels ([Mg] $\leq$ 1,500 mg/L). However, the magnesium content of six regions is still low, so people need to increase the magnesium mineral to a more stable value. Magnesium deficiency will lead to easily opaque and soft shells and affect growth and shrimp mortality [16]. The total amount of calcium and magnesium, in general, and the magnesium content, in particular, are directly related to the alkalinity in the pond [13]. If the alkalinity in the pond is low, the total amount of calcium and magnesium will not be high. The total amount of alkalinity will increase when using lime. Thus, shrimp farming households need to check the alkalinity in the pond regularly to contribute to the alkalinity and stabilize the total amount of calcium and magnesium in the shrimp ponds.

The bar chart shows more clearly the difference in the content of the parameters of alkalinity (a), NO_2 (b), Ca (c), and Mg (d). It helps to compare the differences in the concentration of the parameters within six regions surveyed in Binh Dai District. When comparing all water quality parameters, including pH, alkalinity, Fe, NH_4+ content, NO_2- concentration, and the total amount of minerals calcium and magnesium in the six regions together, only alkalinity and mineral (e.g. Ca and Mg) have differences in statistical meaning ($p < 0.05$) between the six

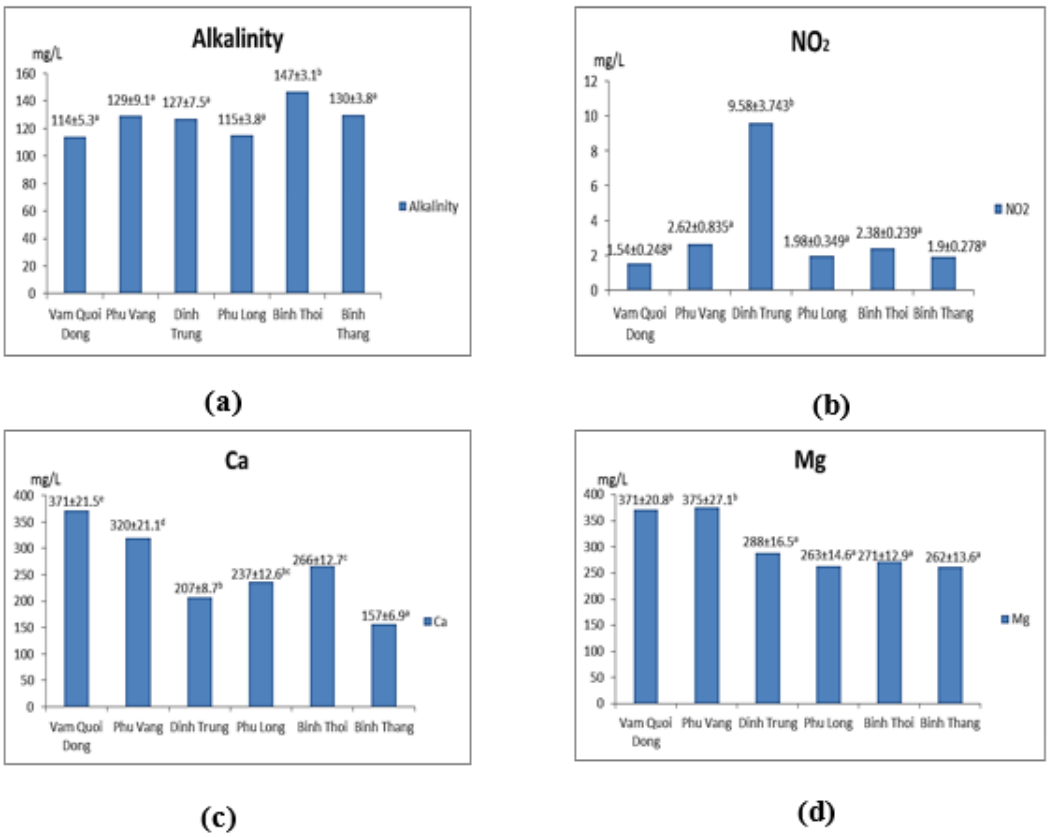

Fig. 2: Differences in alkalinity (a), N-NO_2 (b), Ca (c) and Mg (d) of 6 areas in Binh Dai

regions. The study combined eight water quality parameters of the six shrimp farming areas in Binh Dai and then used MANOVA analysis methods to explore the difference in the overall water quality in the six regions, thereby assessing water quality management measures for shrimp farmers. Results of the MANOVA test on water quality among six surveyed areas are shown in Table 3.

Table 3: The result of four test in MANOVA analysis

Accreditation	Sig. values (*p*)
Pillai's Trance	0.000
Wik's Lambda	0.000
Hotelling's Trace	0.000
Roy's Largest Root	0.000

Table 3 shows that the water quality of the six regions was sharply significant ($p < 0.01$). Also, all water quality parameters including alkalinity, N-NO_2, calcium and magnesium between the six regions were significantly different ($p < 0.01$). Analyzing pH, Fe, NH_4+, and NH_3 concentrations between the six surveyed regions showed no statistically significant difference ($p>0.05$). Table 2 and Table 3 show that the water quality of the six shrimp culture areas in Binh Dai in Ben Tre Province was significantly different. The study compared MANOVA for water quality in pairs between the six regions. The results are reported in Table 4.

Table 4 shows that when comparing each pair, the water quality of the six shrimp culture areas of Binh Dai District was statistically different ($p < 0.01$). Therefore, the study conducted a cluster analysis to evaluate the similarities between regions. The results are shown in Table 5 and Figure 3.

Figure 3 shows that the water quality of Zone 5 (Binh Thoi) is similar from the water quality

Table 4: Results of assessing water quality of each region by MANOVA analysis

Comparing overall water quality between regions	**Sig. value (*p*)**	**Conclusion**
Vang Quoi Dong - Phu Vang	0.000	Water quality between the two regions is statistically significant (p<0.01)
Vang Quoi Dong - Dinh Trung	0.000	Water quality between the two regions is statistically significant (p<0.01)
Vang Quoi Dong - Phu Long	0.000	Water quality between the two regions is statistically significant (p<0.01)
Vang Quoi Dong - Binh Thoi	0.000	Water quality between the two regions is statistically significant (p<0.01)
Vang Quoi Dong - Binh Thang	0.000	Water quality between the two regions is statistically significant (p<0.01)
Phu Vang - Dinh Trung	0.000	Water quality between the two regions is statistically significant (p<0.01)
Phu Vang - Phu Long	0.000	Water quality between the two regions is statistically significant (p<0.01)
Phu Vang - Binh Thoi	0.000	Water quality between the two regions is statistically significant (p<0.01)
Phu Vang - Binh Thang	0.000	Water quality between the two regions is statistically significant (p<0.01)
Dinh Trung - Phu Long	0.000	Water quality between the two regions is statistically significant (p<0.01)
Dinh Trung - Binh Thoi	0.000	Water quality between the two regions is statistically significant (p<0.01)
Dinh Trung - Binh Thang	0.000	Water quality between the two regions is statistically significant (p<0.01)
Phu Long - Binh Thoi	0.000	Water quality between the two regions is statistically significant (p<0.01)
Phu Long - Binh Thang	0.000	Water quality between the two regions is statistically significant (p<0.01)
Binh Thoi - Binh Thang	0.000	Water quality between the two regions is statistically significant (p<0.01)

of Zone 6 (Binh Thang) with the closest differed distance. The distance of Zone 3 (Dinh Trung) is close to Zone 5 and Zone 6 (Binh Thoi and Binh Thang), showing that the water quality of these three regions is less different from each other. On the other hand, considering the distance is 10, Figure 3 also shows that the water quality in Zone 1 (Vang Quoi Dong) is close to the Zone 2 (Phu Vang), which proves that the water quality in these two regions is similar. The amount of water in Zone 2 (Phu Vang) is different from the water quality of the other five remaining regions.

C. General discussion

In general, water quality parameters (except for N-NO_2) in the six surveyed areas in Binh Dai District met the targets and are suitable for shrimp culture [11, 12]. The N-NO_2 index in Binh Dai District greatly exceeded the permitted level (3.33 ± 0.658), in which Dinh Trung is the area with the highest N-NO_2 content. The study's results show that pH within the six regions in Binh Dai is more stable due to well-implemented pH management. The increase in pH depends on the buffering of the water from alkalinity. When the water has high alkalinity, the water pH is less changed. The rain reduces pH in water and stirs the mud layer (black soil), which can cause severe, fatal infections in shrimp by creating anaerobic bacteria and generating toxic H_2S gas [16]. For pond alkalinity, the average total alkalinity of Binh Dai Province is 127 mg/L.

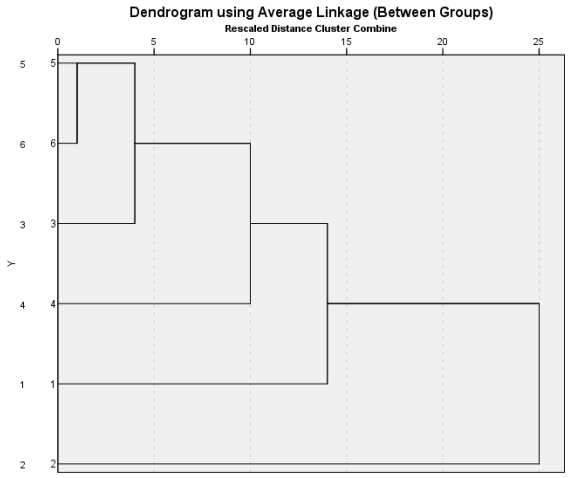

Fig. 3: The dendrogram shows clusters and distances of water quality differences of 6 regions in Binh Dai

Table 5: The results of cluster analysis for water quality of six regions in Binh Dai

Cluster	Euclidian	Euclidian [1-25]	Areas
1	7.414	1.00	1, 2, 3, 4, (5, 6)
2	9.471	4.00	1, 2, 4, (3, 5, 6)
3	13.006	10.00	(1, 2), 4, (3, 5, 6)
4	15.496	14.00	2, (1, 3, 4, 5, 6)
5	22.528	25.00	(1, 2, 3, 4, 5, 6)

1-Vang Quoi Dong; 2-Phu Vang; 3-Dinh Trung; 4-Phu Long; 5-Binh Thoi; 6-Binh Thang

The result is equivalent to the optimum alkalinity for white leg shrimp farming [15].

V. CONCLUSION

The study found that in Binh Dai District from January to May of 2021, the water quality factors in ponds-including alkalinity, NH_4+, Iron, and the total amount of calcium and magnesium-were appropriate for white leg shrimp farming. However, the magnesium content within the six regions is still low for shrimp culture. The presence of NO_2- concentration in the culture ponds ranges from 1.54–9.58 mg/L (highest in Dinh Trung) and is higher than the permitted levels compared to the standards for shrimp farming. Moreover, when comparing each pair, there were statistically significant differences in the water quality of the six shrimp culture areas in Binh Dai District.

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