Water quality assessment for aquacultivation in Quang Ngai city, Quang Ngai province

Nguyen Van Lam[1], Van Nu Thai Thien[1], Luong Van Viet[2*], Nguyen Thi Ha[1], Vu Thi Thu Hoa[1], Vo Le Huy Dao[3]

[1]Vietnam National University of Forestry - Dong Nai Campus
[2]Industrial University of Ho Chi Minh City
[3]Department of Fisheries of Quang Ngai province

Đánh giá chất lượng nguồn nước nuôi trồng thủy sản ở khu vực thành phố Quảng Ngãi, tỉnh Quảng Ngãi

Nguyễn Văn Lâm[1], Văn Nữ Thái Thiên[1], Lương Văn Việt[2*], Nguyễn Thị Hà[1], Vũ Thị Thu Hòa[1], Võ Lê Huy Đạo[3]

[1]Trường Đại học Lâm nghiệp - Phân hiệu Đồng Nai
[2]Trường Đại học Công nghiệp thành phố Hồ Chí Minh
[3]Chi cục Thủy sản tỉnh Quảng Ngãi
**Corresponding author: vietvanluong@gmail.com*

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ABSTRACT

Aquatic product development and growth are significantly influenced by the water supply used for aquaculture. Evaluating the water quality available for this activity is vital since Quang Ngai city has been a major hub for the growth of aquaculture in Quang Ngai province. Twelve surface water quality parameters were monitored and analyzed at eight sampling points in the river basins of An Nghia and Tinh Khe communes from May to September 2023. The Water Quality Index (WQI) was calculated, and methods including Principal Component Analysis (PCA), calculation of environmental variable weights based on principal components (PC), and Pearson correlation were used to assess the correlation of the investigated factors. In the river basin of An Nghia and Tinh Khe communes, 12 criteria for the assessment of surface water quality were tracked and examined using 8 sampling locations between May and September in 2023. The degree of linkage was assessed using principal component analysis (PCA), weighting environmental factors based on principal components (PC), and Pearson correlation. The water quality index (WQI) was calculated between the factors of the research. The findings show that: (1) The parameters exceeded the permitted limit: DO, Alkalinity, NH_4^+, TP, Vibrio SPP, Coliform, TOC, and TN. The two metrics with the greatest levels of pollution among them are Vibrio SPP and NH_4^+. The WQI index ranges from 52-74 and is within the average water quality range (51-75); (2) PCA analysis reveals that only the first two principal components, PC1 and PC2 can account for 74.39% of the variance, with NH_4^+ (0.089) having the highest weight; (3) NH_4^+ and Vibrio SPP content have a strong correlation (r = 0.95), indicating that both of these parameters can be used to evaluate water quality in the study area in general.

Từ khóa:
Tương quan, nước thải sinh hoạt, chỉ số chất lượng nước, phân tích thành phần chính, ôxy hòa tan.

TÓM TẮT

Nguồn nước được cung cấp cho nuôi trồng thủy sản đóng vai trò quan trọng, quyết định sự sinh trưởng và phát triển của thủy sản. Thành phố Quảng Ngãi là khu vực trọng điểm phát triển nuôi trồng thủy sản trên địa bàn tỉnh Quảng Ngãi. Vì vậy, việc đánh giá chất lượng nước cung cấp cho hoạt động này là vấn đề cần thiết. Mười hai thông số đánh giá chất lượng nước mặt được quan trắc và phân tích với tám điểm lấy mẫu tại lưu vực sông thuộc xã An Nghĩa và Tịnh Khê từ tháng 5 - 9 năm 2023. Chỉ số chất lượng nước (WQI) đã được tính *toán, đồng thời các phương pháp bao gồm phân tích thành phần chính (PCA), tính trọng số của các biến môi trường dựa trên các thành phần chính (PC) và tương quan Pearson được sử dụng nhằm đánh giá mức độ tương quan giữa các nhân tố điều tra. Kết quả cho thấy: (1) Các thông số DO, Độ kiềm, NH_4^+, Tổng Phosphor, Vibrio SPP, Coliform, TOC và Tổng N vượt giới hạn cho phép. Trong đó, NH_4^+ và Vibrio SPP là 2 thông số có mức độ ô nhiễm cao nhất. Chỉ số WQI dao động 52-74 và nằm trong ngưỡng chất lượng nước ở loại trung bình (51-75); (2) Phân tích PCA cho thấy chỉ có 2 thành phần chính đầu tiên PCl và PC2 có thể giải thích được 74,39% biến động của phương sai với biến có trọng số cao nhất là NH_4^+ (0,089); (3) NH_4^+ có mức độ tương quan chặt với hàm lượng Vibrio SPP (r = 0,95) chứng tỏ có thể sử dụng một trong hai thông số này để đánh giá chung cho chất lượng nguồn nước ở khu vực nghiên cứu.*

1. INTRODUCTION

Water is a limited resource that is essential to both human life and Earthly life. Water resources are crucial for human health, but they also have an impact on day-to-day living and economic activity [1]. According to Boyd, one of the key elements influencing the effectiveness of industrial endeavors like aquaculture is water quality [2]. Alabaster, who held a similar opinion, added that the physical, chemical, and biological qualities of water quality provide an essential habitat for fish and other aquatic life. According to this source, when there are even little variations in factors like pH, temperature, and DO will impact on organism's development [3]. Joseph stressed that fish mortality is connected to certain aspects of water quality, such as temperature, ammonia, and dissolved oxygen concentration, but not to other aspects, such as pH, alkalinity, hardness, and clarity. Despite having an impact on fish growth, it does not directly poison fish [4]. Numerous techniques for assessing water quality often consider the topic of the complexity of water quality. Moreover, output in ponds and lakes is impacted by water quality, which has an impact on both human health and production efficiency [5]. According to Arain et al. (2015), the physical, biological, and chemical principles that underpin all aquaculture intensification methods are similar, making them internationally comparable [6]. Expert fish farmers assert that "water quality determines the success or failure of aquaculture activities, "which is not surprising given the previously mentioned reasons [7]. For many years, water contamination has been a global concern for ecosystems and human health [8]. Numerous writers have studied how both organic and inorganic contaminants can seriously harm fish and other aquatic life by contaminating water [9]. Hickley, for instance, researched the huge fish kill phenomena in Lake Naivasha, Kenya, in February 2010 [10]. Insufficient dissolved oxygen is the cause of fish death, according to the authors' findings [10]. Periodic water quality monitoring is considered necessary by experts to assess the quality of water used for aquaculture on rivers. Horton [11] was the first to create the Water Quality Index (WQI), which Deininger and Brown enhanced and expanded further [12]. One of the most useful instruments for evaluating the overall quality of water is this index, which produces accurate results [13]. In addition, a number of other studies have evaluated water quality using multivariate statistical analysis. To assess the water quality in their research area, for instance, Shrestha and Kazama selected principal component analysis (PCA) [14]. Quang Ngai, the coastal province, is in the northern part of our nation's South-Central Coast. Aquaculture is seen as a strength for economic development in this province. There are 4,675 hectares of potential aquaculture throughout the province, of which 3,540 hectares are for freshwater aquaculture and 1,135 hectares are for farming on saline and brackish water. The province's water environment is currently being impacted, much like many other regions in the nation, by garbage discharge sources such as household waste from residential areas, industrial clusters, craft villages, and metropolitan districts. Fish deaths have resulted from these activities' substantial effects on the province's surface water supplies in the rivers, particularly in Quang Ngai City's coastline area [15]. For example, the cage aquaculture zones around Quang Ngai City's and Tinh Son district's coastline saw huge fish deaths in 2020 [16]. According to a study from the Quang Ngai province's Department of Fisheries, water quality in the Quang Ngai city region has been regularly examined, although it only goes as far as to evaluate fundamental standards without making any distinctions. comprehensive analysis, including correlation analysis between study parameters and statistical analysis. This study was conducted to assess the quality of water sources for aquaculture in Quang Ngai city, Quang Ngai province, based on the practice. There will be answers to three research questions: (i) Where in Quang Ngai province does Quang Ngai city's surface water quality fall on the standard evaluation scale at the time of the research? (ii) What are the outcomes of the water quality parameter weight calculations based on the primary components? (iii) Of the parameters that are employed, which are highly connected with each other: temperature, salinity, DO, pH, alkalinity, NH_4^+-N, TSS, PO_4^{3-}-P, Vibrio SPP, Coliform, TOC, TN?

2. RESEARCH METHODS

2.1. Research objectives and areas

This study collected surface water samples in Nghia An and Tinh Khe commune, with eight collection points around areas supplied with water for aquaculture activities in Quang Ngai city. Of these, four sampling points are located around the Phu Tho river watershed in Nghia An commune and four collection points are in the Kinh Giang river basin in Tinh Khe commune. Sample collection points show specific locations and coordinates in Table 1. Sampling time is conducted once a month and lasts from May to September 2023.

Table 1. Location of sample collection points in Quang Ngai city, Quang Ngai province

No	Description of sampling location	Sample symbols	Sampling coordinates	
			North latitude (N)	East longitude (E)
1	Nghia An, Quang Ngai City	Location 1 (L1)	15°06'59.9"N	108°53'43.5"E
2		Location 2 (L2)	15°07'04.9"N	108°53'18.2"E
3		Location 3 (L3)	15°07'25.1"N	108°53'30.4"E
4		Location 4 (L4)	5°08'15.8"N	108°53'43.2"E
5	Tinh Khe, Quang Ngai City	Location 5 (L5)	15°09'07.5"N	108°53'38.6"E
6		Location 6 (L6)	15°09'45.7"N	108°53'17.8"E
7		Position 7 (L7)	15°10'40.8"N	108°53'29.1"E
8		Location 8 (L8)	15°12'18.5"N	108°53'33.7"E

2.2. Data collection methods

At several locations in Nghia An and Tinh Khe commune, water sample representatives of the above areas were gathered for this study. The samples were then taken to the Institute of Aquaculture Research and Development III laboratory for analysis.

Fourteen water quality parameters were calculated and analyzed including: temperature, salinity, Dissolved Oxygen (DO), pH, alkalinity, NH_4^+-N, TSS, PO_4^{3-}P, Vibrio SPP, Coliform, Total organic carbon (TOC), total N (TN).

Reference sampling containers were in accordance with ISO 5667-1 (TCVN 6663-14) standards. TCVN 6663-14 (ISO 5667-14) contains instructions on the QA quality procedure assurance of environmental water sampling.

Table 2. Parameter analysis method

No	Parameters	Analytical methods in the laboratory	TCVN
1	Temperature	Multi-parameter measuring machine HANNA(HI9828)	
2	Salinity	Multi-parameter measuring machine HANNA(HI9828)	
3	DO	Winkler method	TCVN 6491: 1999
4	pH	Multi-parameter measuring machine HANNA(HI9828)	TCVN 6492:2011
5	Alkalinity	Determination of total alkalinity and composite alkalinity	TCVN 6636-2:2000
6	NH_4^+-N	Spectrometer operated by hand	TCVN 6179-1: 1996
7	TSS	Determination of TSS using glass fiber filter	TCVN 6625: 2000
8	PO_4^{3-}-P	Spectrometry using ammonium molybdate	TCVN 6202:2008
9	Vibrio SPP	Oxidase reaction test	TCVN 7905-2:2008
10	Coliforms	Critical dilution (MPN)	TCVN 6187-1: 1996
11	TOC	Determine (TOC) and (DOC)	TCVN 6634:2000
12	TN	Ample decomposition method using persulfate	TCVN 6624:1-2000

For all laboratory tests, the study employs quality assurance and quality control (QA/QC) processes based on analytical methods. Five percent of the data was used in duplicates, five percent was used for extra testing, and quality control reference standards were employed. For every new session, a standard calibration curve is created to guarantee that the background signal variance is constant and less than 1% throughout all data. The results of additional testing were within the 90 - 100% acceptable range. To accurately reflect the pollutant characteristics of the study area, a number of variables were pre-selected at important points in the network of sample stations. From May to September of 2023, water samples were gathered. Using a plastic bottle that had been acid-washed, each sample was collected from 10 to 15 cm below the water's surface. During each sampling trip in each period, water samples were collected three times between 6:00 am and 10:00 am from 08 data collection locations. The samples were delivered to the environmental laboratory for analysis after being kept in a vacuum liquid nitrogen freezer.

2.3. Data analysis

The study uses multivariate statistical approaches, such as Principal Components Analysis (PCA), for some of the factors under investigation to better understand water quality by interpreting complicated data matrices and the study system's ecological state [17].

These instruments aid in the identification of variables that may impact water quality and can promote trusted water resource management and response pollution issue [18].

A principal component (PC), which is a linear combination of the original variables, is a dimension of a k-dimensional space (k<m). Each dimension is called a PC which means a linear combination of original variables.

This study uses R software, version 4.0.3, with the "Factoextra" package to perform PCA technique computations. (Look up and compute parameters, sometimes called cos^2 or R^2 - coefficient of determination that indicates the load or contribution of each variable in the PC. When it comes to reflecting quality Survey River, the variable with the largest contribution will be the most significant. The weight (Wi) of variable i when calculating WQI will be displayed according to each variable's involvement in the PC.

The WQI index was determined by a study based on the values of water quality assessment factors. The weights and scores assigned to each survey parameter are added up to create this index [19]. In multivariate analysis, the gathered data were first transformed using a standard scale to remove the impact of varying measurement ranges and variances of variables before delving into the WQI index analysis [19].

In this study, sampling location was used as the predictor and water quality parameters represent the response variable. The ANOVA statistical method was applied to test whether the mean values of water quality parameters varied among the eight sampling locations. All statistical analyzes were performed on the Microsoft Excel 2016 application.

A criterion for statistical significance was selected, with alpha (α) ≤ 0.05 being the chosen threshold. Furthermore, the study used National Standard (QCVN 08: 2023/BTNMT) on surface water quality to compare with surface water quality at data collection locations [20].

Water quality is also assessed concurrently with the issuance of technical guidelines for the computation and publication of the Vietnam Water Quality Index (VN_WQI 1460/QD-TCMT) [21].

Calculation of WQI value is applied according to the following formula.

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

In there,

WQI: Calculated results for group I parameters;

WQII: Calculation results for parameters group II;

WQIII: Calculation results for parameters group III;

WQIV: Calculation results for parameters. group IV;

WQV: Calculation results for group V parameters.

Finally, the study uses the correlation analysis method to find the relationship between the water quality metrics across time.

3. RESULTS

3.1 Surface water quality assessment

Monitoring and analyzing 40 surface water samples, including 12 parameters: temperature, salinity, DO, pH, alkalinity, NH_4^+-N, TSS, PO_4^{3-}-P, Vibrio SPP, coliform, and TOC and the TN at eight locations (L) in Quang Ngai city to serve aquaculture activities gives the following results: Temperature, pH, alkalinity and salinity parameters are within the allowable limits according to standards, 8 the remaining parameters are presented in Figures 1 - 8.

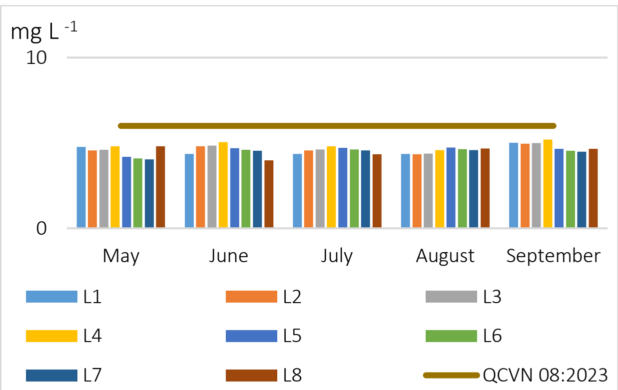

Figure 1. DO

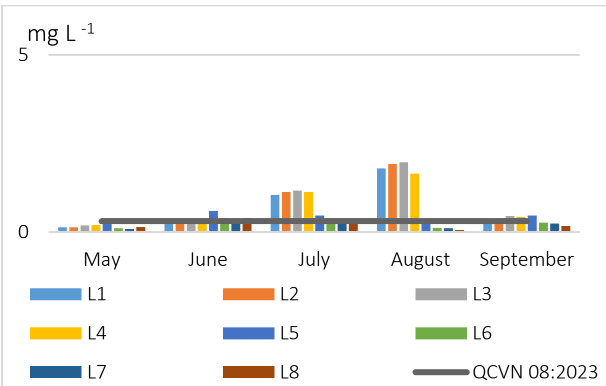

Figure 2. NH_4^+

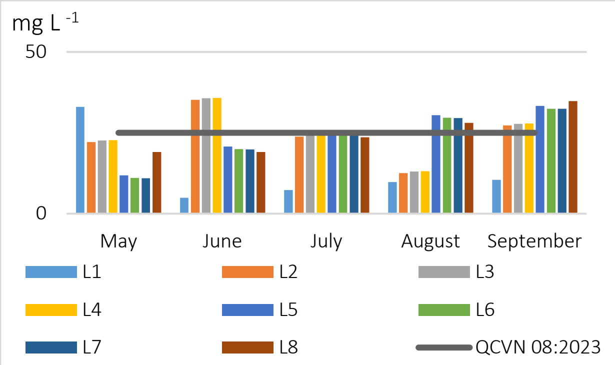

Figure 3. TSS

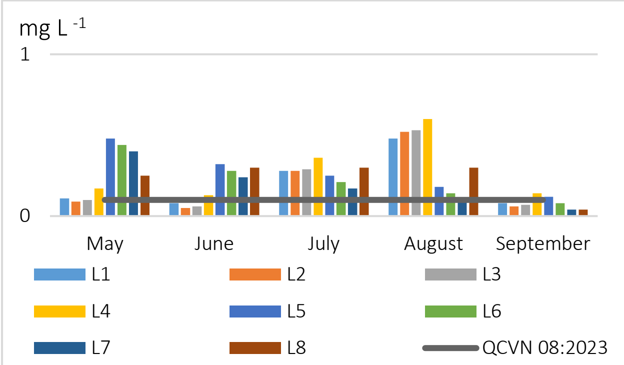

Figure 4. City

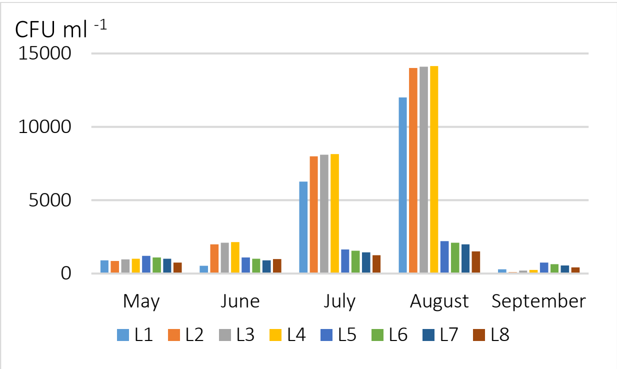

Figure 5. Vibrio SPP

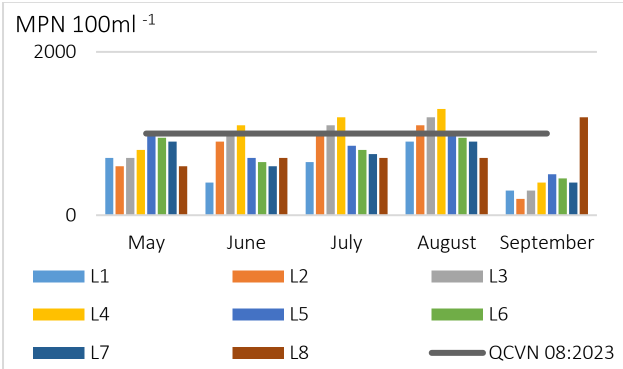

Figure 6. Coliform

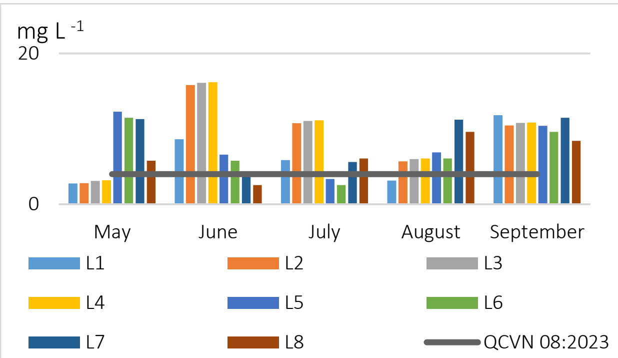

Figure 7.TOC

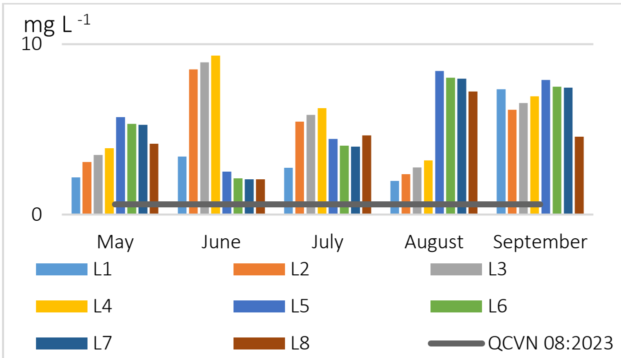

Figure 8. TN

When comparing DO to the surface water quality criteria specified in QCVN 08:2023, all monitoring data are found to be over the permissible range (DO > 6 mg L^{-1}) (Figure 1). QCVN 08:2023 indicates that the NH_4^+ indicator is below the threshold only in May and September. All NH_4^+ indicators in the remaining months range from 0.32 to 1.97 mg L^{-1} above the permissible limit for surface water quality (Figure 2).

In several areas, the suspended solids (TSS) level in the following months was higher than permitted: May (L1), June (L2, L3), August (L5, L6, L7, L8). Only one area (L1) fell below the permitted level in September alone, all other locations were above the limits. The range of values that are above the limit is 25.47-35.79 mg L^{-1} (Figure 3). The findings of TP demonstrate that numerous parameters, concentrated between May and August, exceed the QCVN 08:2023 limit. In July and August, all positions were above the limit, with position 4 (L4) having the highest value (0.6 mg $L^{-1)}$, which is six times higher than the limit (0.1 mg L^{-1}) (Figure 4). Vibrio SPP is an indicator that is not limited to QCVN 08:2023, but this is an important indicator in aquaculture activities. This indicator often causes diseases in aquatic salt water and freshwater animals: fish, crustaceans, mollusks. Through analyzed data, the results show a large fluctuation from 100 (CFU ml^{-1}) up to 1410 (CFU ml^{-1}), focusing on the months July and August with positions giving high values such as L1, L2, and L3 (Figure 5). Compared to the Coliform limit of 1000 (MPN 100 ml^{-1}), this indicator is mostly within the allowable limit of QCVN 08:2023, with some locations exceeding it such as L2, L3 in June to August (Figure 6). Total organic carbon (TOC) ranges from 2.77 mg L^{-1} to 16.17 mg l^{-1}, the allowable limit for this indicator according to QCVN 08:2023 is 4 mg L^{-1}. Figure 7 shows that all parameters exceeded the limit, in which all locations exceeded the limit in September, ranging from 8.41 mg L^{-1} to 11.43 mg $L^{-1.}$ In contrast to all the above indicators, the TN indicator results exceed QCVN 08:2023 with a limit of 0.6 mg $L^{-1.}$ In this study, TN ranges from 1.98 mg L^{-1}. l to 9.33 mg L^{-1}, many times higher than the standard, specifically from 3.3 to 15.6 times, with the pollution level of Total N (Figure 8). Data from field monitoring and laboratory sample analysis were used to analyze the water quality index (WQI) in accordance with Decision No. 1406/QD-TCMT [21]. Table 3 below displays the results of WQI.

Table 3. WQI calculation results

	L1	L2	L3	L4	L5	L6	L7	L8
May	84	84	84	84	59	64	65	73
June	64	54	53	54	63	68	78	78
July	59	52	52	52	77	84	74	72
August	69	60	58	58	66	72	65	67
September	59	60	59	59	59	67	64	69

According to Figure 9, the water quality index (WQI) is used to quantitatively describe the water quality at 8 specific locations from position 1 (L1) to position 8 (L8) between May and September. The WQI is calculated on a scale (the range of values according to Decision 1460/QD-TCMT) that corresponds to symbols and distinct colors to assess the water quality to meet the requirements for use in aquaculture. L1, L2, L3 and L4 had results in the May monitoring period of 84; L8, L9 (78) in the June monitoring period; and L5 (77) in the July monitoring period had results in the good grade (76-90) of green on the water quality assessment scale. Throughout monitoring periods, the remaining locations have WQI values between 52 and 74, which falls within the medium water quality assessment range (51-75).

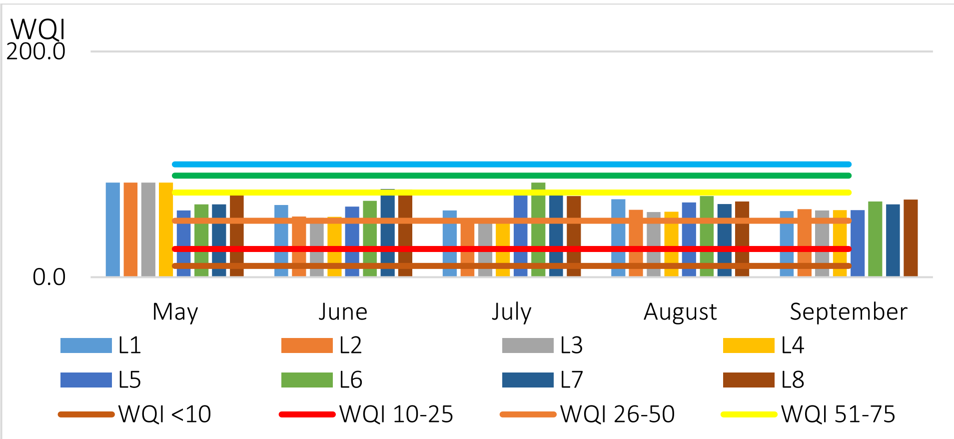

Figure 9. Water quality index (WQI)

3.2. Weights of water quality parameters calculated according to main components.

Principal components (PC): Utilize the principal component analysis method PCA to obtain the Eigenvalue and variance explained ratio (Proportion Explained) of each PC as illustrated in Figure 10. This will reduce the information dimension for the original data set Zij (i = 1 - 8, j = 1-12). The findings indicate that simply the first two principal components (PC1 and PC2), whose explanation rates are 43.19% and 31.20%, respectively, were able to explain up to 74.39% of the variance of the original data set. The weights of the variables will be determined using the first two main components considering this outcome.

The importance (contribution) of variables in PCA analysis.

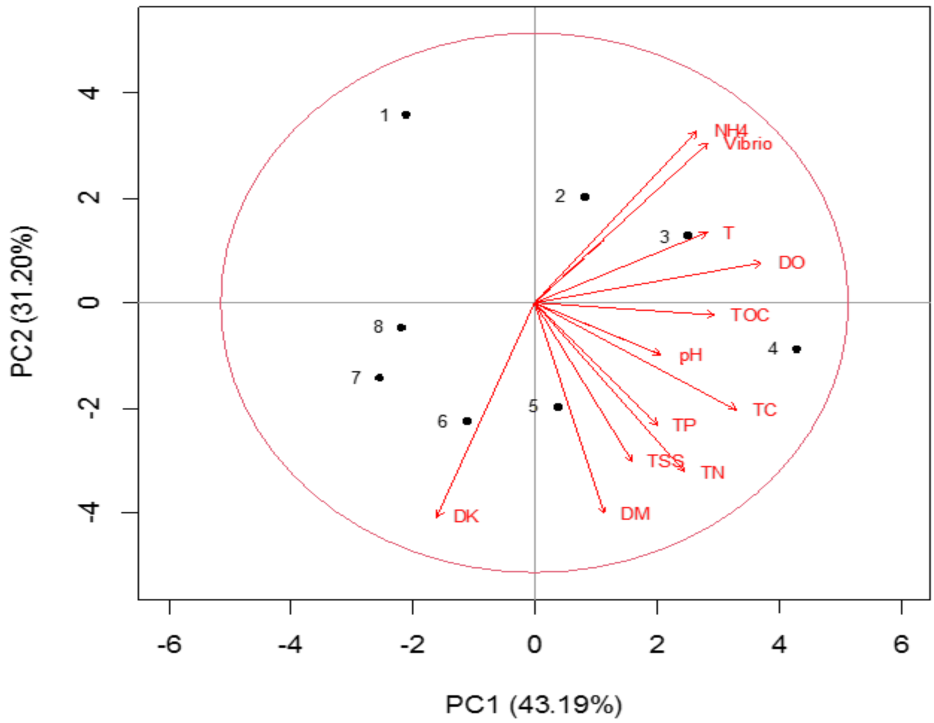

Figure 10. Loadings of variables in principal components space

Results of the principal components analysis for the environmental variables: longer vectors for the variables indicate a bigger contribution in the principal components space; the red circle shows the balanced contribution of the variables. The first principal component has the biggest weights (species scores) for the three variables DO, TC, and TOC, while the second principal component has the largest weights for the three variables DK, DM, and NH_4^+. PC1's three variables, DK, TSS, and DM, are the least weighted, whereas PC2's variables are pH, DO, and TOC. Table 4 presents a summary of the findings from the computation of the variable weights.

Table 4. Weights of variables in principal components

No	Environment variables	PC1	PC2	Total weight	Intermediate weight	Weight
1	NH_4^+	0.27	0.34	0.61	1.9375x	0.103
2	Vibrio	0.29	0.32	0.61	1.9063x	0.103
3	Alkalinity (DK)	0.17	0.42	0.59	1.8438x	0.099
4	TN	0.25	0.33	0.58	1.8438x	0.097
5	Total Coliform (TC)	0.34	0.21	0.55	1.7188x	0.092
6	Salinity (DM)	0.12	0.41	0.53	1.6563x	0.089
7	TSS	0.17	0.31	0.48	1.5000x	0.081
8	DO	0.39	0.08	0.47	1.4688x	0.079
9	City	0.21	0.24	0.45	1.4063x	0.076
10	Temperature (T)	0.29	0.14	0.43	1.3438x	0.072
11	TOC	0.31	0.02	0.33	1.0313x	0.055
12	pH	0.21	0.1	0.32	x	0.054
					Total = 18.66x	***Total = 1.0***

According to Table 4, pH has the least impact on the PCs (total contribution = 0.32). The intermediate weight of the pH variable, denoted by the letter x, is the overall weight of pH. Next, confirm each variable's intermediate weight, which is equal to the ratio of each variable's contribution to the pH variable. Because 18.66x = 1 is the total number of intermediates for all variables, the weight of the variable pH(x) = 0.054 and the weight Wi of the other variables (the total of the weights of all the variables) are then inferred from there (all variables = 1). Evaluating and measuring the impact of variables on the environmental quality of surface water requires careful consideration of weight determination. These factors have significant weights and have a significant impact on the quality of surface water. Among them are NH_4^+, vibrio, alkalinity (DK), and total N (TN). NH_4^+ has the largest weight among them all (0.033), with NH_4^+ (weight = 0.103) having the highest weight among the variables.

3.3. Correlations between surface water quality parameters

Examine the association between water quality variables at eight monitoring stations from May to September, based on Pearson correlation analysis, determine the relationship between the water quality components. The findings of the study correlation indicate that, throughout the sample periods from May to September 2023, the concentrations of water quality indices, such as temperature T (°C), pH, NH_4^+, TSS, Vibrio SPP, and TOC, concentrated to decrease over time (negative correlation). Throughout the study period, TP and DO show a tendency to rise over time (positive association). The results of analysis also demonstrate a strong statistical relationship between various water quality indicators, including pH and salinity; Vibrio SPP and temperature; NH_4^+ and TSS, TP, and Vibrio SPP; TSS and DO, NH_4^+, TP, and TN; Vibrio SPP and temperature, NH_4^+, and TP; and total N with DO, TSS, TP, and TOC at significance level $p < 0.01$.

Table 2. Correlation between water quality factors

	Temperature	Salinity	DO	pH	NH_4^+	TSS	City	Vibrio SPP	TOC	TN
Temperature	1.00									
Salinity	-0.12 *	1.00								
DO	0.04 *	-0.22 *	1.00							
pH	-0.10 *	0.56 **	0.08*	1.00						
NH_4^+	0.39 **	-0.13 *	-0.15*	-0.15*	1.00					
TSS	-0.14 *	-0.02 *	0.56**	-0.05*	-0.42*	1.00				
City	0.28 *	0.28 *	-0.55**	0.17*	0.66**	-0.64**	1.00			
Vibrio SPP	0.42 **	0.01*	-0.22*	-0.07*	0.95**	-0.38*	0.71**	1.00		
TOC	-0.20 *	-0.05*	0.27*	-0.19*	-0.12*	0.30*	-0.23*	-0.13*	1.00	
TN	-0.12 *	0	0.45**	-0.09*	-0.35*	0.60**	-0.47**	-0.30*	0.79**	1.00

*Note: *Correlation is significant at p value <0.05, ** Correlation is significant at p value <0.01*

The analysis's findings also demonstrate that: NH_4^+ and Vibrio SPP both rise with temperature, with a correlation level of $p < 0.01$; the correlation with Vibrio SPP reaches its highest value (0.42), while the correlations with the other parameters are negative. Dissolved oxygen (DO) content has a negative correlation with TP (-0.55) and a positive correlation with TSS (0.56) and TN (0.45). Total phosphorus will drop in water as the amount of dissolved oxygen rises.

The ammonium cation (NH_4^+) is assessed to have the greatest association with a wide range of parameters, in which the strongest correlation is with Vibrio SPP (0.95), when NH_4^+ increases, parameters such as TP, Vibrio SPP increase and negatively correlated with TSS. The only other correlated variable that is as strong as total organic carbon (TOC) and TN (0.79) is NH_4^+, the correlation level is second only to NH_4^+. The parameter TN has a similar level of correlation with the other parameters, along with NH_4^+. It is positively correlated with the parameters DO, TSS, and TOC, and has a strong correlation with TP. For the remaining parameters, the correlation is negative.

4. DISCUSSION

Aquaculture activities provide a special emphasis on the assessment of water quality [8]. The study's parameters, including pH, alkalinity, salinity, and temperature, were all within permissible bounds. There were metrics that went over the permitted limits in addition to those that were well examined. Impacts on aquatic product development and growth, as well as surface water quality, including Through metabolism, DO has a direct impact on an organism's growth and development. The range of DO values was from 4.03 to 5.2 mg L^{-1}, which is lower than what is allowed in aquaculture and may lead to severe hypoxia [22]. Organic waste and mostly drained wastewater from homes, businesses, and lodging facilities may be the cause of the low DO value at the test location. Animals and people can contract vibriosis from the gram-negative bacteria Vibrio SPP [23]. Of all the bacteria, Vibrio species develop at the fastest pace and react nearly instantly to conditions that are favorable to their growth, such as high temperatures, salt, and dissolved oxygen [24]. Vibrio concentrations in this investigation were quite high; the highest value, recorded at location 4 in August, was 14,150, which is hazardous to aquatic life. Most places contain TOC content that exceeds permitted limits. Finding the TOC concentration in water is considered as a pollution indicator. Higher microbial growth and, thus, higher oxygen demand are indicators of higher organic content. Water quality index is widely applied in European countries in national monitoring programs [25]. The WQI index is also used by many domestic authors to evaluate surface water quality for water bodies in Vietnam [26]. Lam (2023), evaluating surface water quality on Dong Nai River in Vinh Cuu district, showed WQI index results ranging from 70.2-78.0, determining the cause from industrial, domestic, and agricultural wastewater [27]. WQI in this study falls between 52 and 74, which falls within the medium water quality evaluation threshold (51-75). Aquaculture's impact on water quality will be measured by this index. Shrimp and fish growth and development [22]. Fish cage farming operations and wastewater from homes, businesses, and hotels are the primary sources impacting the quality of the water.

PCA has been widely used in recent years to address a wide range of environmental issues, such as optimizing the water quality network system, investigating the primary polluters in polluted areas, and conducting comprehensive assessments of the spatial and temporal variations of surface and groundwater quality [28]. Anh and his colleague evaluated the water quality of the Hau River based on the principal component, giving the results: PC1 explains about 30.42% of the total variance, PC2 explains 16.06% of the total variance, accordingly, this principal component comes from originating from agricultural activities and people's daily activities [29].

In this study, the results show that only the first two principal components (PC1 and PC2) explained up to 74.39% of the variation of the original data set. Thus, the weights of the variables will be calculated based on the first two principal components. Luu and colleagues classified the weights into “strong”, “medium” and “weak” levels, corresponding to values > 0.75, 0.75-0.5 and 0.50-0.30, respectively [19]. In this study, for PC1, the variables DO, TC and TOC had weights ranging from 0.31 to 0.39. PC2 has three variables DK, DM, TSS and NH_4^+ with weights ranging from 0.34 to 0.42. Compared to Luu's classification, the weights range from 0.3 - 0.5 at the level "weak" found that coastal areas are exposed to high salinity seawater, in addition NH_4^+ assesses the main source of pollution from domestic wastewater, these variables can be understood as representing direct action and indirectly by humans in the form of domestic wastewater, restaurants, hotels, and agricultural pollution [30]. The discovery of factors that significantly affect water quality is a common theme among these investigations' weights have varying fluctuations at varying speeds. Thus, high-weight factors indicate the primary contaminants affecting the growth and development of aquatic products when assessing water quality for aquaculture purposes [31]. The results of the Anova test indicate that the factors have a moderate correlation (r = 0.56) with the remaining indicators, including salinity and pH, total N and TSS with TP, and DO and TSS.

In this study, the values of temperature, pH, and salinity were not significantly different ($p > 0.05$). Water quality parameters have a strong correlation such as NH_4^+ with Vibrio SPP (r = 0.95); Total N with TOC; Total Phosphor with Vibrio SPP (r = 0.71). The results of analysis between water environmental factors and Vibrio SPP bacteria show a strong correlation (positive correlation) with NH_4^+ and total Phosphor, with Pearson correlations r = 0.95 and r = 0.71 ($p < 0.01$), respectively, and negative correlated with TSS (r = -0.64, $p < 0.01$).

According to these findings, there is a higher chance that seafood will become contaminated with harmful Vibrio genus bacteria when the density of Vibrio SPP bacteria in the water in the agricultural region arises, particularly from May to September each year. To reduce the detrimental effects of human activity on the aquaculture process, wastewater must be cleaned and under control before being released into receiving sources. This will help to minimize the impact of harmful bacteria and other microorganisms during this period.

5. CONCLUSION

The findings of the study on water quality indicate that several metrics, including DO, alkalinity, NH_4^+, TP, Vibrio SPP, Coliform, TOC, and TN, are over permitted levels. While NH_4^+ ranges from 0.32 mg L^{-1} to 1.97 mg L^{-1}, all NH_4^+ indicators surpass the permitted limit for surface water quality. Vibrio SPP and NH_4^+ are two metrics that are thought to have higher pollution levels than the other parameters. Through data analysis, Vibrio SPP revealed significant variations between 100 and 14,150 (CFU ml^{-1}), with an emphasis on the months of July and August and places that gave high values, like (VT1, VT2, VT3). Aquatic product growth and development are impacted by this value.

The results of the water quality index demonstrate that all parameters fall within the standards (76-90) water quality assessment scale threshold, except for positions 1, 2, 3, and 4, where the result was 84 in the May monitoring period; positions 7, 8 (78) in the June monitoring period; and position 5 (77) in the July monitoring period. is equivalent to green. The remaining locations during the monitoring periods are within the medium water quality assessment threshold (51–75) with WQI values ranging from 52 to 74.

The results of principal component analysis for environmental variables show that PC1 and PC2 explained 74.39% of the variation of the original data set. In the first principal component (PC1), DO, TC and TOC are three variables which have the greatest weights, while the second principal component (PC2) is DK, DM, NH_4^+. The variables with the highest weights, including NH_4^+, Vibrio SPP, Alkalinity, and TN, are also displayed in the results. The association between NH_4^+ and Vibrio SPP is the strongest, according to correlation analysis results, with a Pearson correlation coefficient of (r = 0.95 $P < 0.01$).

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