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Research Article

Assessment of current water quality status in clam areas in Thai Binh Province and proposal for measures to improve efficiency

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Abstract: This paper presents the results of water quality assessment of clam farming areas for 3 monitoring points in Tien Hai district, Thai Binh province. Using monitoring parameters including: Temperature, pH, Salinity, Alkalinity, N-NO_2-, N-NH_4^+, H_2S, Coliform, Total Vibrio to assess water quality in clam culture area by using methods: The method of calculating the pollutant load due to domestic wastewater, the method of assessing the current state of the water environment based on national standards and the assessment method according to the water quality index (WQI). The results show that the monitoring points in the clam farming area of Thai Binh province: Temperature, pH and H_2S^- in the water are within the limits according to QCVN 10:2023/BTNMT; QCVN 02-19:2014/BNNPTNT and QCVN QCVN 08:2023/BTNMT. Salinity and alkalinity fluctuate greatly, the proportion of samples outside the permissible limits is 54.17% and 12.5%, respectively. N-NH_4^+, N-NO_2^-, have a high percentage of samples with values exceeding the permissible limit, ranging from 41.65 to 62.50% of the monitored samples. Coliform exceeded the limit from 2 to 256 times. The total Vibrio density was 20.83% of samples above the limit. The average water quality indicator on 3 monitoring locations has a percentage rating of Excellent: 20.83%, Good: 12.5%, Medium 12.5%, Bad: 37.5% and very bad: 16.67%. From the results of the assessment, this study suggests management measures, including improving water quality index used to zoning water quality, thus better managing clam areas; and technical measure which improves farming techniques to protect the aquatic environment of farmers.

Keywords: Clam; Thai Binh province; Water quality; WQI; Pollutant load.

1. Introduction

Clam is economic important aquatic species in Asia, especially in Malaysia, China, and Thailand [1]. However, the demand of aquaculture product [2] including of Asian Clam is increase rapidly, meanwhile environmental problems are one of the causes of clam mortality. In addition, the influence of microplastics and heavy metals is also the cause of quality deterioration of cultured clams [3]. Therefore, there have been studies focusing on this field, especially the issues mentioned above, but the monitoring and assessment of the environment is still limited [4].

In recent years, the coastal clam farming in Thai Binh has made strong progress and is always leading the northern provinces of our country in terms of area and annual clam production. Owning a 54-km stretch of coastline with various estuary systems flowing into the ocean, Thai Binh has a tidal flat area containing fertile sources of alluvium, therefore

making it for clam farming [5]. It is estimated by the Sub-Department of Fisheries - Department of Agriculture and Rural Development of Thai Binh that the province has developed 2,500 hectares for commercial clam farming in a total of nearly 3,200 hedectares of intertidal clam farming area so far. Its trading production reached 122,500 tons in 2022, which accounted for 67.36% of the total aquaculture production. The revenue was worth over 2,400 billion VND, an increase of 321.28 billion VND in comparison to 2021, covering a proportion of 58.59% of the aquaculture value [6]. However, besides the achievements in production, there are also many difficulties faced by clam farmers, including problems of disease and environmental control.

The phenomenon of dead clam has often occurred in recent years, mass death on a large scale. Part of the reason is due to techniques and management methods such as raising too much density in some farming households. When clam density is too high, environmental quality deterioration or sudden change may lead to some death of cultured clams and when some of them die decomposing, rotting degrades the environment and kills others. According to a study [7] shows that the mass mortality of clams in the clam farms in Vietnam Tien Hai, Thai Binh usually occurs in most months of the year, however, in February to May every year, the density of dead clams is higher. The long dead time of each batch is about 20-30 days [8]. Therefore, the study objective is to assess the current state of water quality in clam areas in Thai Binh province and prosose measures to improve efficiency.

2. Materials and Methods

2.1. Study area

Thai Binh is a coastal delta province, with 5 large estuaries flowing into the sea creating a large tidal area of about 25,000 ha, in which the highland and mid-tide areas are 7,000 ha, and the low-tidal areas 18,000 ha are very favorable for the development of saline and brackish aquaculture including clam farming [9]. For many years, farmers in Tien Hai district have invested in clam farming with an economic value of hundreds of billions of VND, contributing to improving the lives of fishermen. Tien Hai is a coastal district, located in the southeast of Thai Binh province, with a natural area of over 226 km^2, a population of over 23,000 people. With 23 km of coastline, Tien Hai has many advantages to develop a comprehensive marine economy in terms of exploitation, aquaculture, seafood processing and eco-tourism. In recent years, clam farming is Tien Hai's strength, in 2014, the total area

Figure 1. Location of the study area.

of clam farming in the whole district is about 2,370 ha, of which, nearly 2,000 ha of commercial clam culture and 374 ha of clam seed rearing. Clam farming in Tien Hai district has continuously developed in terms of area, productivity, output, economic efficiency and has become a profession that brings high income and great export value. Every year, the clam brings to Tien Hai hundreds of billions VND and creates more jobs for rural workers here. The warning time has a high risk of affecting the cultured clams such as heat wave, rain, and flood when factors such as salinity change greatly. The study area in Thai Binh was selected in Tien Hai district located in the sea gate (Figure 1).

2.1.2. Sampling

Three coastal sampling locations in Thai Binh province: Con Thu, Khu 3, Cong 8 with a frequency of 1 time/month. Water samples were collected into plastic bottles and kept cold and transferred to the laboratory for analysis of these parameters: Temperature, pH, Salinity, Alkalinity, $N\text{-}NO_2^-$, $N\text{-}NH_4^+$, H_2S, Coliform, total Vibrio. The monitoring period is from April to November 2022.

Sampling method according to (TCVN 5994:1995) “Water quality - Sampling - Guidance on sampling from natural lakes and man- made lakes” [10]. Preservation water samples according to (TCVN 6663-3:2016) “Water quality - Sampling - Part 3: Preservation and handling of water samples” [11]. Sampling time is at low tide in the month when the water is lowest in the day. This is the time when the water quality is at its worst.

2.2. Methods

2.2.1. Calculation of pollutant load due to domestic wastewater

In the study areas, clam culture wastewater is discharged directly into rivers, lakes and the sea, therefore, the potential load of pollutants due to domestic wastewater will in fact be calculated as the load of untreated wastewater.

To calculate the load of pollutants due to domestic wastewater of the area, based on the waste generation coefficient according to the following formula:

$$T = M \times H \quad (1)$$

where T is the contaminant load (kg/day); M is the number of people (people); H is the waste generation coefficient (g/person/day). H is taken based on calculations by the World Health Organization (WHO) calculated for many developing countries, the amount of pollutant released by each person daily into the environment for the case of primary treatment.

2.2.2. Monitoring method

The process of monitoring and data collection is shown in Figure 2.

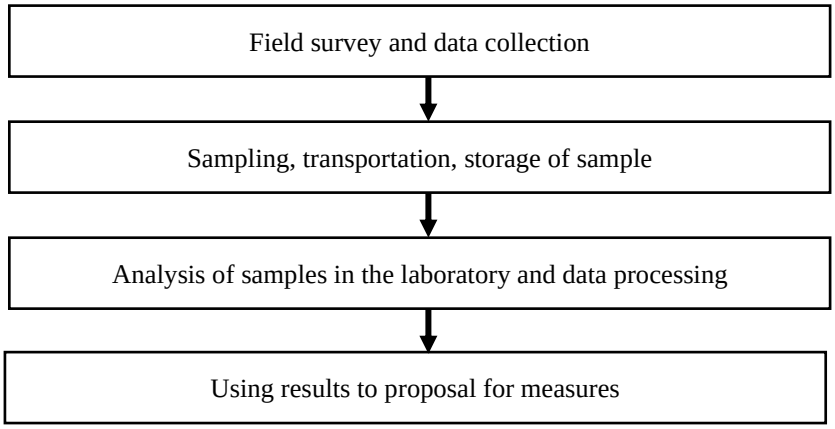

Figure 2. Flowchart of study structure.

Each monitoring parameter will use different analytical methods shown in Table 1.

Table 1. Parameter and analytical methods.

No	Parameter	Method	Location
1	Temperature,	Machine YSI Pro 1020	On-site
2	pH	Machine YSI Pro 1020	On-site
3	Salinity	Refractometer	On-site
4	Alkalinity	SMEWW 2320 B: 2011	Laboratory
5	$N\text{-}NO_2^-$	SMEWW 4500-NO2 B: 2017	Laboratory
6	$N\text{-}NH_4^+$	SMEWW 4500-NH3 F: 2017	Laboratory
7	H_2S^-	SMEWW 4500-S2- D:2017	Laboratory
8	Coliform	TCVN 6187-2:1996	Laboratory
9	Total Vibrio	Buller (2004)	Laboratory

2.2.2. The method of assessing the current state of the water environment is based on national standards

To assess the current state of water quality in the clam farming area for warning purposes, this study will rely on the issued national standards to evaluate each monitoring parameter. National standards applied for assessment include:

- National technical regulation on sea water quality (QCVN 10:2023/BTNMT) [12].
- National technical regulation on brackish water shrimp farming establishments - conditions to ensure veterinary hygiene, environmental protection, and food safety (QCVN 02-19:2014/BNNPTNT) [13].
- National technical regulation on surface water quality (QCVN 08:2023/BTNMT) [14].
- Procedures for quarantine of aquatic animals and aquatic animal products (TCN 101:1997) [15].

2.2.3. Index method WQI

Water Quality Index WQI is an index calculated from surface water quality monitoring parameters in Vietnam, used to provide a quantitative description of water quality and its use, expressed on a scale (Table 2). The study used the calculation of water quality index according to No. 1460/QD-TCMT dated November 12, 2019 [16].

Table 2. Levels of water quality assessment according to the WQI index.

WQI	Water quality	Color
91 - 100	Excellent: Good for domestic water supply	Blue
76 - 90	Good: Used for domestic water supply purposes but need to be treated appropriately	Green
51 - 75	Medium: Use for irrigation and other equivalent purposes	yellow
26 - 50	Bad: Used for navigation and other equivalent purposes	Orange
10 - 25	Very bad: Water is heavily polluted, need to be treated in the future	Red
< 10	Extremely: Water sources are polluted; water sources need to be remedied and treated	Brown

3. Results and discussion

3.1. Assessment of water quality in clam areas based on pollutant load

From formula (1), we have a table to calculate pollutant load of domestic wastewater in the clam farming area of Tien Hai district, Thai Binh province according to Table 3.

Table 3. Pollutant load due to domestic wastewater in the study area.

No.	Commune	Pollutant load (kg/day)					
		TSS	COD	Nitrogen Total	Phosphorus Total	BOD_5	Grease
1	Nam Thinh	589.638	19.746	49.365	13.164	271.508	109.700
2	Dong Minh	905.365	30.319,2	75.798	20.213	416.889	168.440
	C_{max}	100		50	10	50	

Currently, domestic wastewater is not treated and discharged directly into rivers and sea, so the potential load of pollutants due to domestic wastewater will be calculated by: Amount of untreated wastewater. In Table 3, the pollutant load in all parameters because the wastewater of the 2 communes is very high, exceeding QCVN 40: 2021/BTNMT National Technical Regulation on industrial wastewater [17]. In which, Dong Minh commune has a higher coefficient than Nam Thinh commune because it has a larger population with TSS = 905,365 kg/day; COD = 30.319,2 kg/day; Nitrogen Total = 75,798 kg/day; Phosphorus Total = 20,213 kg/day; BOD_5 = 416,889 kg/day and grease = 168,440 kg/day.

From the calculation table of pollutant load due to domestic wastewater in the study area, we have the following chart:

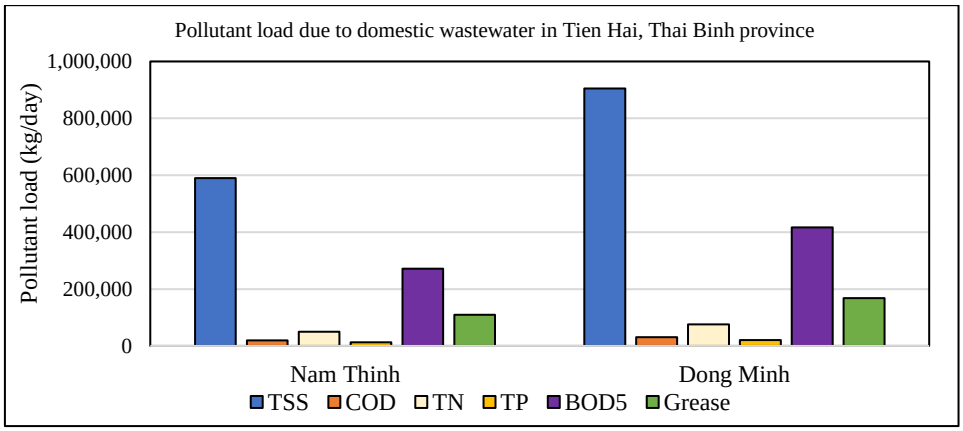

Figure 3. Pollutant load due to domestic wastewater in the study area.

Pollutant load varies due to different ranges of domestic wastewater in the study area. Particularly, Nam Thinh commune which has a smaller population, therefore, has a lower pollutant load (TSS = 589,638 kg/day; BOD_5 = 271,508 kg/day) in comparison to Dong Minh commune (TSS = 905,365 kg/day; BOD_5 = 416,889 kg/day).

3.2. Assessment of water quality in clam areas based on national standards

3.2.1. Group of basic water environment parameters

- The temperature: The water at the monitoring points in the clam culture area has an average temperature of 27.7^{o}C. In November, the water has the lowest temperature at all monitoring points and the water in August has the highest temperature in the year (Figure 4). The water temperature at the monitoring points in general has a suitable value and has not affected the cultured clams. However, it is necessary to implement saving measures in the summer from July to September when the temperature reaches the highest and in the winter when the temperature drops. These extreme fluctuations will weaken the clams, causing mass mortality [18].

- The pH at the monitoring points has an average value of 7.82 (Figure 4). At the time of heavy rain [19], in June and October, the water has the lowest pH of the year (Con Thu = 6.99) and in August, the highest pH of the year (Khu 3 = 8.3) is approximately within the allowable limits (6.5-8.5), according to QCVN 10:2023/BTNMT. In general, the pH in farming areas in Nam Thinh and Dong Minh commune is in the appropriate range and does not change much.

- The average salinity of the water at the monitoring points is 9.1‰. The salinity here is often influenced by freshwater discharges from residential areas and craft villages, so there is a big fluctuation [20]. From May to October, at the time of heavy rain, the river water rises to the sea, so the salinity drops to the lowest (Khu 3 = 1‰), which is lower than the allowable limit, according to QCVN 10-MT:2015/ BTNMT. From November to April, it is the time of

little rain, so the salinity does not change significantly at the monitoring points. Particularly, at the point of Khu 3, the highest salinity of 26‰ is within the allowable limits (5-35) according to QCVN 10:2023/BTNMT (Figure 4).

- Alkalinity at monitoring points has an average value of 87.85 mg/l. In September and October, the value ranges from 44 to 74 mg/l. In particular, Cong 8 (September, October) and Khu 3 (October) record the values which are below the allowable range according to QCVN 02-19:2014/BTNNPTNT. This happens due to the influence of fresh water and espepcially fresh water from the in-field drains. In the period of November - August, the alkalinity is relatively stable, within the allowable range (60-180 mg/l) according to QCVN 02-19:2014/BTNNPTNT.

Figure 4. Changes in Temperature, pH, Salinity, Alkalinity of water clam areas 4-11/2022 in Tien Hai, Thai Binnh province.

3.2.2. Nutritional parameter group

- The average concentration of N-NH_4^+ at the monitoring points is 0.359 mg/l (Figure 5). In which, from May to August, the concentration increased, exceeding the allowable limit according to QCVN 02-19:2014/BNNPTNT by 2.84 times (the highest in August at Cong 8 = 0.85 mg/l). The reason is that in the summer, the high temperature increases the decomposition of organic matter in the water, thereby increasing N-NH_4^+ and the impact of organic waste from the field. On the contrary, in September - April of the following year, the temperature decreases, leading to a decrease in the concentration of N-NH_4^+ within the allowable limit (< 0.03).

- The average nitrite ($N\text{-}NO_2^-$) content at the monitoring points is 0.053 mg/l (Figure 5). In which, from August to November, the $N\text{-}NO_2^-$ content is 2.3-2.5 times higher than the threshold of 0.05 mg/l according to QCVN 10:2023/BTNMT (the highest is in November at Cong 8 = 0.125 mg/l). In contrast, from April to July, the $N\text{-}NO_2^-$ concentration was low within the allowable range (the lowest was in July at Cong Lan 1 = 0.024 mg/l).

- Total sulfide (H_2S) in clam culture water has low value, average is 0.001 mg/l (Figure 5). There is no case with value higher than 0.05 mg/l according to QCVN 02-19:2014/BNNPTNT.

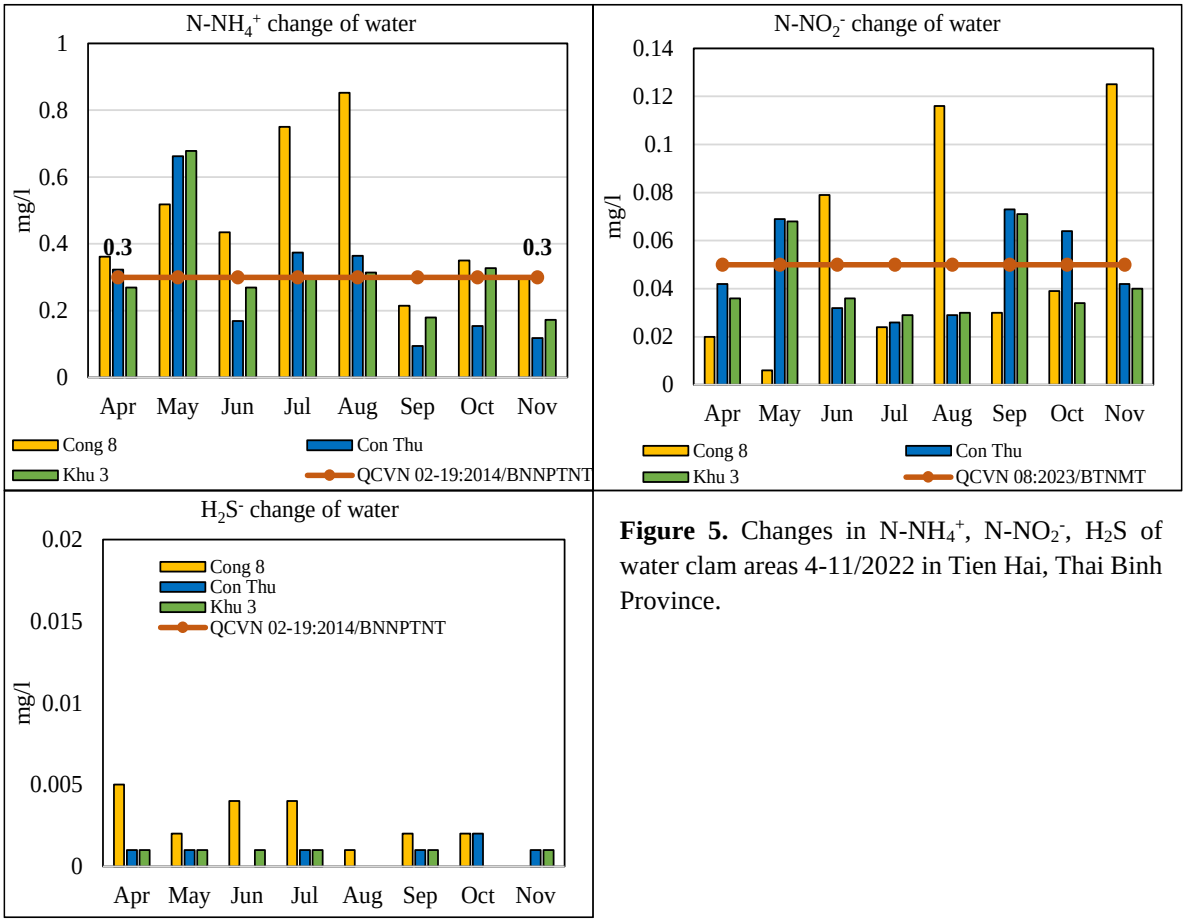

Figure 5. Changes in $N\text{-}NH_4^+$, $N\text{-}NO_2^-$, H_2S of water clam areas 4-11/2022 in Tien Hai, Thai Binh Province.

3.2.3. Density of Coliform, Vibrio total in water

- Total Coliform density in water of clam culture area has high value, average 51,633 (CFU/100 ml), at monitoring points in all months, Coliform density is higher than the allowable limit compared to QCVN 10:2023/BTNMT (the highest in July is 560 times higher) (Figure 6). High total Coliform density indicates that the culture water shows signs of contamination. This is a sign that the environment in the farming area is tending to be polluted, causing food insecurity.

- The total density of Vibrio at the monitoring points has an average concentration of 878 mg/l (Figure 6), the highest was in August at the monitoring point Ne (7,100 CFU/100 ml) exceeding the allowable limit 7.1 times according to TCN 101:1997 Quarantine process of aquatic animals and aquatic animal products. With a high concentration of Vibrio in water, there will be an increased risk of cultured molluscs being infected with bacterial pathogens that cause Vibrio spp.

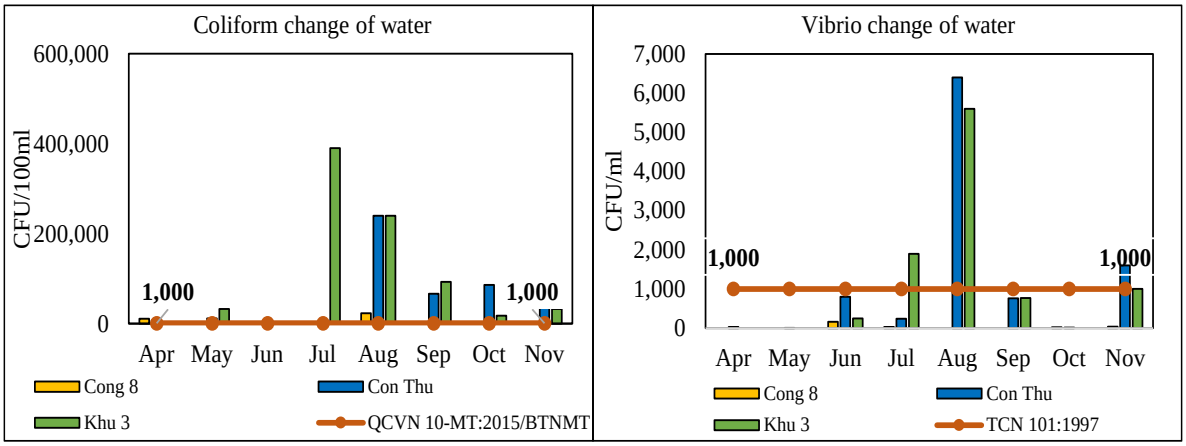

Figure 6. Change in Coliform, Vibrio of clam areas 4-11/2022 in Tien Hai, Thai Binh Province.

3.2.4. Overall rating according to the WQI index

The WQI index of the clam culture area is shown in Figure 7. At monitoring points with very bad WQI water quality index in May, August, and October. Excellent and good water quality occurs at Cong 8 in May, July, September, and October; at Con Thu in June and July; in Khu 3 in April and June. The rest of the other monitoring points have bad WQI for most of the month. The average water quality indicator on 3 monitoring locations has a percentage rating of excellent: 20.83%, good: 12.5%, medium 12.5%, bad: 37.5% and very bad: 16.67%.

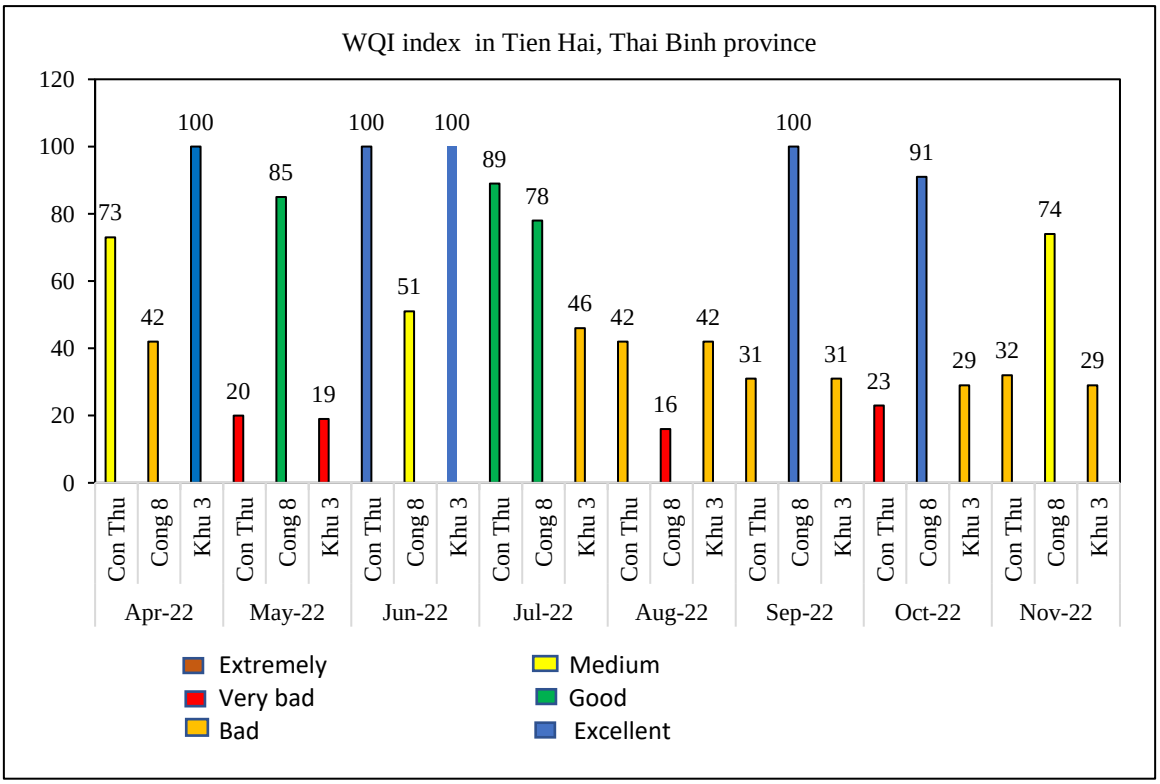

Figure 7. WQI index of water clam areas in Thai Binh province.

3.2.5. Proposed solutions

a) Management measures

- Strengthen the management, inspection, and assessment of the observance of the provisions of the law on environmental protection at clam farming establishments and households.

- Strengthen the inspection and technical guidance of farming, prevention of environmental pollution for organizations and individuals engaged in farming activities; strictly manage the supply of chemical materials on the market according to the State's regulations.

- Strengthening programs for monitoring, monitoring, and periodically warning about environmental and disease outbreaks in concentrated farming areas; monitoring water quality to forecast environmental developments as well as possible diseases, thereby taking timely solutions when problems occur.

- Instructing people to collect agricultural by-products, packages and tools containing chemicals used in production, farming, etc., for treatment at appropriate points in accordance with regulations; regularly take water samples periodically to check environmental factors and give advance recommendations to farming areas for farmers to proactively prevent.

- Building a model of community management in farming areas, focusing on discharging waste and infected wastewater in diseased ponds into the natural water environment, causing loss to farming communities in the area.

b) Technical measures

- At the time of high tide, to avoid sudden changes in salinity, the fisheries management agency should notify the irrigation management agency to coordinate the adjustment at the inland sluice point and the time to discharge water into the sea at the same time. high tide point. It is necessary to check the salinity in the water regularly, to handle it promptly.

- It is recommended that farmers notify management agencies promptly when detecting mass dead clams. It is necessary to monitor the progress and reduce the bacterial density such as: collecting garbage, dead clam carcasses, cleaning and disinfecting around the growing area... when the total density of Vibrio is high.

- To limit the influence of temperature on hot days that will make clams weak, farmers need to clean the rearing yard and stagnant water puddles. Clean cages, nets, remove garbage and dead clam carcasses to avoid environmental pollution, create ventilation, reduce coliform, and reduce food sources for clams, limit the influence of pathogenic bacteria at tide up and down.

- In the process of clam culture, people should pay attention to raising clams with low density, to avoid competition for food and increase the health of cultured clams. Inspect and harvest clam yards that have reached commercial size.

- According to the results of monitoring the farming area, from October to February next year, mass mortality of clams often occurs due to the influence of factors such as density of culture and the environment of the farming area with strong fluctuations in salinity, temperature, etc. Therefore, before entering the above time, farmers need to check, raise clams with low density, monitor the weather to take measures to protect cultured clams.

4. Conclusion

From the monitoring results, the water quality for clam culture in Tien Hai district, Thai Binh province is poor. Of which, 3/9 parameters are outside the allowable limits (temperature, pH, H_2S). Salinity and alkalinity have percentage of samples outside the permissible limits is 54.17% and 12.5%, respectively. $N\text{-}NH_4^+$, $N\text{-}NO_2^-$, total Coliform had a high percentage of samples with values exceeding the permissible limit. The total Vibrio density was 20.83% of samples above the limit. The average water quality indicator WQI on 3 monitoring locations has a percentage rating of excellent: 20.83%, good: 12.5%, medium 12.5%, bad: 37.5% and very bad: 16.67%. From there, it is necessary to have management and technical measures to limit the phenomenon of dead clams. From this study, in the future, the author proposes that there should be a common set of parameters to assess the quality of aquaculture environment and apply according to a common standard.

Authors contribution: Constructing research idea: N.T.T.P., M.P.T., A.M.D.; Select research methods: N.T.T.P., A.M.D.; Data collection: N.T.T.P., M.P.T., A.M.D.; Data processing: N.T.T.P., A.M.D.; Writing original draft preparation: N.T.T.P., M.P.T., A.M.D.; Writing review and editing: N.T.T.P., M.P.T., A.M.D.

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Conflicts of interest: The authors declare that this article was the work of the authors, has not been published elsewhere, has not been copied from previous research; there was no conflict of interest within the author group.

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