PRELIMINARY RESULTS OF WATER QUALITY SURVEY FOR FIVE AQUACULTURAL PONDS IN PHUC THO DISTRICT, HANOI CITY

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Abstract

Aquaculture development in recent years has contributed to enhancing the income and improving the livelihoods of local people, contributing a significant part to the country's economic development. This paper presents the first observation results of aquaculture water quality at five aquaculture ponds in Phuc Tho district, Hanoi city in 2023. The results showed that pH values ranged from 7.01-7.88; total suspended solids (TSS): 15-49.5 mg/L; ammonium: 0.01-3.06 mgN/L; nitrate: 0.14-0.42 mgN/L; nitrate: 0.71-2.16 mgN/L; total nitrogen: 2.95 to 4.75 mgN/L; phosphate: 0.02 - 0.87 mgP/L; total phosphorus: 0.14-1.48 mgP/L; dissolved silica: 0.09-3.03 mgSi/L; total coliforms: 900-13,700 CFU/100 mL; and E. coli: 200-1,800 CFU/100 mL. At most sites, dissolved oxygen, total suspended solids, total nitrogen, total phosphorus, total coliforms and E. coli exceeded the permitted values of the Vietnam Technical Regulation QCVN 08:2023/BTNMT column B which regulates the water quality of aquacultural ponds. Besides, the results of the E.I. calculations (1.87) showed that most of the aquaculture ponds were in Dystrophy states. High eutrophication level together with high microbial contamination may affect the fishery productivity and quality in Phuc Tho district, Hanoi city. As a result, it is needed to propose measures to handle and overcome the current situation and to monitor the water quality regularly to ensure public health.

Keywords: Water quality, aquaculture, fishery pond, Hanoi city, Vietnam.

1. INTRODUCTION

Fisheries and aquaculture play an important role in the global economy and within each country because they provide food, nutrition, income, and livelihoods for hundreds of millions of people around the world. Vietnam has a dense system of rivers and a long coast, which is very convenient for developing fishing and aquaculture activities. The fishery's production was estimated at 9,108 thousand tons whereas the aquaculture production was of 5,233.8 thousand tons, of which farmed fish production was of 3,503.4 thousand tons in 2022 (GSO, 2022). Aquaculture production has contributed to reducing pressure on exploiting natural aquatic resources and increasing income for local people. However, along with finding ways to improve the productivity and quality of aquaculture, the water quality and the factors affecting aquaculture production are getting more attention. Therefore, the survey and assessment of water quality in aquaculture areas is an urgent issue to solve the balance between economic benefits and environmental protection, between the benefits of aquaculture and other industries, and between the households participating in aquaculture activities and community benefits.

This paper presents the survey results of aquaculture water quality at five aquaculture ponds in Phuc Tho district, Hanoi city in the year 2023. The obtained results can contribute to building a dataset and assessing water quality in aquaculture areas. The results provide scientific basis for the sustainable development of aquaculture in Hanoi in particular and in Vietnam in general.

2. MATERIALS AND METHODS

2.1. Study site

Hanoï's capital is in the direction of the northwest of the Red River Delta center, with an area of 335,984 ha in 2021. The aquaculture area was estimated at 23.2 thousand ha, with the fish (carp, tilapia, grass carp, etc.) farming area accounting for 99.95% of the total aquaculture area of Hanoi city. The fishery production reached 120 thousand tons, of which fish reached 119.2 thousand tons in 2021. Phuc Tho district is situated 35 km to the west from the center of Hanoi city, where agricultural land area was of 6,911.4 ha, accounting for 58.3% of the district's total natural area, of which the aquaculture area is 594 ha (Phuc Tho district, 2023; Hanoi statistics office, 2021). The system of ponds, lakes, and wetlands in Phuc Tho district plays an important role in the hydrological system, storing a large volume of water to meet the needs of the district's life and production. In this paper, the water quality of aquacultural farm ponds in Phuc Tho district, Hanoi city was assessed in 2023.

2.2. Methodology

Water sampling and analysis

Surface water samples of 5 aquaculture ponds in Phuc Tho district, Hanoi city, were collected in February and March 2023. The details of five aquaculture ponds are presented in the Table 1 and Figure 1.
Table 1. Description of the sampling sites (Phuc Tho district, 2023)

<table>
<thead>
<tr>
<th>Sample name</th>
<th>Location</th>
<th>Aquaculture pond characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Latitude</td>
<td>Longitude</td>
</tr>
<tr>
<td>AP1</td>
<td>21°4'5&quot;</td>
<td>105°37'7&quot;</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>AP2</td>
<td>21°4'12&quot;</td>
<td>105°37'3&quot;</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>AP3</td>
<td>21°4'20&quot;</td>
<td>105°37'48&quot;</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>AP4</td>
<td>21°4'24&quot;</td>
<td>105°37'44&quot;</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>AP5</td>
<td>21°5'35&quot;</td>
<td>105°37'9&quot;</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

At each pond, surface water samples (0-30 cm) were collected at three different points following the Vietnamese standard TCVN 5996-1995, and these three sub-samples were well mixed together to give one sample that represents each site for laboratory analysis. Some physico-chemical variables were in situ measured by WQC-22A (TOA, Japan), including water temperature, pH, conductivity, and dissolved oxygen (DO). Water samples were filtered immediately by vacuum filtration through a precombusted glass fiber filter paper (Whatman GF/F, Ø47 mm) and kept in a freezer (< -20 °C) after filtration until laboratory analysis. Total suspended solids (TSS), total nitrogen (TN), total phosphorus (TP), total coliforms (TC), and E. coli (EC) were determined on water samples without filtration.

In the laboratory, TSS was quantitatively determined on pre-weighed filterpaper. Nutrients (N, P, and Si) were spectrophotometrically analyzed on a UV-VIS V-630 (HACH, USA). TC and EC densities were counted by a direct count method using 3M Petrifilm™. All laboratory analysis were followed the APHA (2017) methods.

Figure 1. Location of five aquaculture ponds studied
To determine nutrient levels and trophic status for these five ponds, the method of Primpas et al. (2010) was applied. The Eutrophication Index (E.I.) values calculated from the measured concentrations of phosphate, ammonia, nitrite, nitrate, and Chl a are as follows:

$$E.I. = 0.279 \times C_{PO4} + 0.261 \times C_{NO3} + 0.296 \times C_{NO2} + 0.275 \times C_{NH3} + 0.214 \times C_{Chl.a}$$

Where: C is the measured concentrations of the variables (nitrite, nitrate, ammonia, phosphate in μM and Chl a, in μg/L).

The E.I. value is then used to classify nutrient levels as ultra-oligotrophy with E.I. < 0.04; oligotrophy with 0.04 < E.I. < 0.38; mesotrophy with 0.38 < E.I. < 0.85; eutrophy with 0.85 < E.I. < 1.51; and dystrophy with E.I. > 1.51 (Primpas et al., 2010).

### 3. RESULTS AND DISCUSSION

#### 3.1. Physical and chemical variables

<table>
<thead>
<tr>
<th>No</th>
<th>Site</th>
<th>DO (mg/L)</th>
<th>pH (-)</th>
<th>Temperature (°C)</th>
<th>Conductivity (S/m)</th>
<th>TSS (mg/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>AP1</td>
<td>3.2</td>
<td>7.3</td>
<td>22.4</td>
<td>0.45</td>
<td>23.0</td>
</tr>
<tr>
<td>2</td>
<td>AP2</td>
<td>4.5</td>
<td>7.9</td>
<td>22.1</td>
<td>0.98</td>
<td>16.3</td>
</tr>
<tr>
<td>3</td>
<td>AP3</td>
<td>3.9</td>
<td>7.6</td>
<td>22.4</td>
<td>0.86</td>
<td>30.5</td>
</tr>
<tr>
<td>4</td>
<td>AP4</td>
<td>2.8</td>
<td>7.0</td>
<td>22.6</td>
<td>0.31</td>
<td>49.5</td>
</tr>
<tr>
<td>5</td>
<td>AP5</td>
<td>4.2</td>
<td>7.8</td>
<td>22.5</td>
<td>0.60</td>
<td>15.0</td>
</tr>
</tbody>
</table>

**Average**
- DO: 3.7 mg/L
- pH: 7.5
- Temperature: 22.4 °C
- Conductivity: 0.64 S/m
- TSS: 26.9 mg/L

**Max**
- DO: 4.5 mg/L
- pH: 7.9
- Temperature: 22.6 °C
- Conductivity: 0.98 S/m
- TSS: 49.5 mg/L

**Min**
- DO: 2.8 mg/L
- pH: 7.0
- Temperature: 22.1 °C
- Conductivity: 0.31 S/m
- TSS: 15.0 mg/L

**MONRE, 2023. QCVN 08:2023/BTNMT (Col. B)**
- DO: ≥ 5 mg/L
- pH: 6.0 - 8.5
- Temperature: -
- Conductivity: -
- TSS: ≤ 15 mg/L

*Note: : No value presents in the QCVN 08:2023/BTNMT (Column B)*

**pH value**

In aquaculture, pH is one of the environmental factors that have a great direct and indirect influence on freshwater fish life, such as growth, survival rate, reproduction, and nutrition. When the environmental pH is too high or too low, it is not favorable for the development of fish culture. The pH of most productive natural waters that are unaffected by pollution is normally in the range of 6.5 to 8.5 (Clements et al., 2021). The average pH values in the water samples ranging from 7.0 to 7.9, was in agreement with other reports in similar water bodies (Mutea et al., 2021; Leonard and Mahenge, 2022) and was within the allowable range of QCVN 08: 2023/BTNMT (column B). These values were suitable as water use for aquaculture.

**Water temperature**

The temperature can influence the activities of aquatic creatures directly or indirectly through the physical and chemical processes of the waterbody. The high temperature or large fluctuations cause shock, reduce the resistance of aquatic animals, increase susceptibility to pathogens, and affect survival rates (Bhateria et al., 2015). On the other hand, colder water temperatures may reduce nutrient digestibility by reducing digestion rates, increasing gut transit time, and lowering gastrointestinal evacuation rates (Miegel et al., 2010). Each species has a preferred or optimum temperature range where it grows best, and the desirable range for aquaculture is between 20 and 32 °C (Kasmir et al., 2014). In this study, the water temperature averaged from 22.1 to 22.6 °C at all observation sites, which was within the optimum temperature range and suitable for fish farming in this area.

**Dissolved Oxygen (DO)**

The behavior of DO in most aquaculture ponds is especially complicated because of the intense biological activity receiving high feed inputs (Boyd et al., 2018). The DO concentration in water samples was low, ranging from 2.8 (AP4 site) to 4.5 mg/L (at AP5 site) and averaging 3.7 mg/L. Thus, all sampled sites had values below the desired range for aquaculture (5-15 mg/L) (Boyd et al., 2014) and therefore had the possibility of causing high levels of hypoxia. Also, at most monitoring sites, DO concentrations were lower than the allowed one of the QCVN 08: 2023/BTNMT column B (≥ 5.0 mg/L) and only reached the permissible threshold of the column D (≥ 2.0 mg/L). The low values of dissolved oxygen can be attributed to fertilizer run-off from the rice fields and organic waste in the water. This has also been observed in some aquaculture ponds along the Hau River, indicating that the deoxygenation rate was caused by the high biological decomposition of organic matter in ponds (Mutea et al., 2021).

**Conductivity and total suspended solids (TSS)**

Conductivity of the water samples varied from 0.04 mS/m (at AP4) to 0.98 mS/m (at AP2). TSS concentrations ranged from 15.0 mg/L (at AP5) to 49.5 mg/L (at AP4). At all monitored water sites (except for AP5), TSS concentrations exceeded the limit of QCVN 08: 2023/BTNMT (≤ 15 mg/L, column B).
3.2. Nutrient concentrations and Chl a

The nutrient concentrations have a great impact on aquacultural productivity and water quality environment. However, these variables always fluctuate temporally and spatially. Figure 2 shows the average results of nutrient concentrations of the aquacultural water samples at five survey sites.

Nitrogen concentrations

The main role of nitrogen (N) in freshwater ecosystems is as one of the key nutrients required for the primary production of higher plants and algae. In this study, the major nitrogen forms such as inorganic nitrogen (nitrate, nitrite, and ammonium), and total nitrogen (TN) were investigated.

Nitrate concentration at 5 monitoring sites in Phuc Tho district ranged from 0.141 (AP1) to 0.421 mgN/L (AP2), with an average value of 0.276 mgN/L. The average value in this study was far higher than the ones obtained in aquaculture water monitoring of intensively catfish ponds in O Mon, Thot Not, and Vinh Thanh areas of Can Tho province in the period 2016-2020 (Can Tho DARD, 2020). Nitrate is a very critical nitrogenous nutrient in fish culture (Abedin et al., 2017). The increase in nitrate concentrations in the survey samples was related to a variety of factors, which may include livestock excreta, uneaten feed (leftovers), or dead floating organisms. Durand et al. (2011) suggested that nitrate levels in water often varied over a wide range, from very small values (< 0.002 mgN/L) in basins that were less susceptible to human impacts to very high values (>14 mgN/L) in agricultural regions in Europe. In this study, nitrate concentrations ranged from 0.710 (at AP1) to 2.163 (at AP4) mgN/L, with an average of 1.645 mgN/L, which was within the desirable ranges of aquaculture (0.1 to 4.5 mgN/L) (Bhatnagar et al., 2013). The mean nitrate value in this study was lower than the one (4.4 mgN/L) obtained in an aquacultural area of Pangasianodon hypophthalmus in An Giang province (Huynh TG et al., 2008) but four times higher than the value observed in the tributary (0.31±0.12 mgN/L) and the estuary (0.39±0.11 mgN/L) of the My Thanh river, Soc Trang province (Tran TG 2020), and 8.9 times higher than the one in the Hau River (range 0.08 - 0.33 mgN/L, Giao et al., 2020).

![Figure 2. Average concentrations of nutrients and Chl a of the five surveyed ponds](image)

Ammonium in water is supplied from the normal breakdown of carcass proteins, phytoplankton, animal excreta, inorganic and organic fertilizers, or supplementary food sources. The ammonium concentration in water samples at the survey sites ranged from 0.008 (at AP4) to 3.064 mgN/L (at AP1), with an average of 1.381 mgN/L. The ammonium concentration observed in this study was nearly 7 times higher than the observed one in aquaculture water in Can Tho city in the period 2016-2020 (0.004-0.799 mgN/L, average 0.198 mgN/L) (Can Tho DARD, 2021) and from 8 to 10 times higher than the observed value in freshwater fish ponds in Cam Thuy district (0.13 mgN/L) and Ba Thuoc district (0.17 mgN/L), Thanh Hoa province (Thanh Hoa DARD, 2022). This result showed that there was an increase in ammonium concentrations in aquaculture water in Phuc Tho district, Hanoi city.

TN concentrations at 5 monitoring sites ranged from 2.945 to 4.747 mgN/L (at AP5), with an average of 3.736 mgN/L. Compared with the QCVN 08:2023/BTNMT, TN concentrations in this study was higher than the allowable limit of the column B (Figure 2). Previous studies have shown that, for systems with poor nutrients (TN concentration < 1 mgN/L), N is considered a limiting factor and inorganic nitrogen is quickly absorbed by the organism to maintain growth and development. When the TN concentration is greater than 1 mgN/L, it proves that the hydrological system is affected by human activities that increase the supply of nitrogen to the water bodies (agricultural cultivation, concentrated livestock, and wastewater in urban areas, etc.) (Durand et al., 2011).
Phosphorus concentration

Phosphate concentrations in the water samples at 5 survey sites ranged from 0.017 (AP4) to 0.869 mgP/L (at AP1). The average value of phosphate concentration at 5 survey sites in Phuc Tho (0.355 mgP/L) was closed to the previously announced value in the shrimp farming tributary area in Soc Trang province (0.36±0.16 mgP/L) (Tran TG et al., 2020); and lower than the aquaculture water in Binh Chanh commune, Binh Son district. Quang Ngai province (1.85 mgP/L) (Quang Ngai DARD, 2022). Our value was 2.6 times higher than the average value of the aquaculture water in Hau River, Mekong Delta (in the range of 0.1-0.3 mgP/L, Mutea et al., 2021); 2 times higher than the aquaculture water in Can Tho city in the period 2016-2020 (in the range of Not detected - 1.184, average of 0.173 mgP/L) (Can Tho DARD, 2021) and 11.8 times higher than the water in fish pond in Thanh Hoa province in August, 2022 (Thanh Hoa DARD, 2022). According to Fadiran et al. (2008) eutrophication can occur when the phosphate concentration in surface water is from 0.03 to 0.1 mgP/L. Therefore, the high values observed in the surface waters of Phuc Tho district may be indicative of the risk of eutrophication.

The mean TP values ranged from 0.137 (at AP4) to 1.476 mgP/L (at AP1), averaging 0.715 mgP/L which was lower than the one (2.11 to 4.78 mgP/L) in striped catfish (Pangasianodon hypophthalmus) water in the Mekong Delta (samples were taken in An Giang, Can Tho, and Hau Giang provinces) (Vu NU, 2018). However, compared with the allowed value of the QCVN 08:2023/BTNMT (column B), TP concentrations at three sites (AP1, AP2 and AP5) were higher by from 2.6 to 4.9 times, indicating the risk of eutrophication in the study area.

High levels of phosphate and TP in aquaculture ponds in Phuc Tho district, Hanoi, may be related to the amount of feed used, and this can also affect surface water quality when the amount of phosphate discharged into the environment is high (Iscen et al., 2007).

Dissolved silica

In addition to N and P, silica is also an essential element for the development of phytoplankton. The average value of silica concentration in water samples at different sites ranged from 0.091 to 3.033 mgSi/L higher (Iscen et al., 2007). The feed used, and this can also affect surface water quality when the amount of phosphate discharged into the environment is high.

Chlorophyll a

Chl a concentrations varied from 0.28 (at AP4) to 4.91 μg/L (at AP5) with an average of 3.83 μg/L for all sites. The Chl a levels in this study were lower than those (> 10 μg/L) reported for some aquaculture ponds in Ho Chi Minh City by Duong et al. (2018) but closed with the one (0.2-4.6 μg/L) observed in the East River, New York City, USA (Li et al., 2018). Normally, the Chl a is around a few hundred μg/L, but in the dry season, its concentration can be as low as 0.02 μg/L (Nguyen VC, 2002). Compared with the QCVN 08:2023/BTNMT column B (≤ 35 μg/L), Chl a concentration at all sampling sites was within the allowable limit (Fig. 2).

Eutrophication Index

The E.I. value for each site varied from 0.72 (Mesotrophy) to 2.33 (Dystrophy) (Table 3). Except for the AP4 site which was at the Mesotrophy level, the remaining sites were at the eutrophication level. Overall, E.I value averaged 1.81, classified as Dystrophy level for the five studied ponds.

Table 3. The Eutrophication Index value in the aquaculture areas in Phuc Tho district

<table>
<thead>
<tr>
<th>Sites</th>
<th>E.I. value</th>
<th>Classify nutrient level</th>
</tr>
</thead>
<tbody>
<tr>
<td>AP1</td>
<td>2.33</td>
<td>Dystrophy</td>
</tr>
<tr>
<td>AP2</td>
<td>1.96</td>
<td>Dystrophy</td>
</tr>
<tr>
<td>AP3</td>
<td>1.70</td>
<td>Dystrophy</td>
</tr>
<tr>
<td>AP4</td>
<td>0.72</td>
<td>Mesotrophy</td>
</tr>
<tr>
<td>AP5</td>
<td>2.33</td>
<td>Dystrophy</td>
</tr>
<tr>
<td>All area</td>
<td>1.81</td>
<td>Dystrophy</td>
</tr>
</tbody>
</table>

Figure 3. E.I values in the studied ponds

Note: The green, orange and red lines indicate the upper limit for mesotrophy eutrophy and Dystrophy respectively.
Microbiological indicators (total coliforms and E. coli)

TC densities of the survey sites ranged widely from 900-13,700 CFU/100 mL, with the lowest value at AP2 and the highest value at AP5. The average value of the whole survey area reached 5,200 CFU/100 mL (Fig. 4). These values were higher than those obtained in 5 surface water samples in Kien Giang province (from 1,520 CFU/100 mL to 4,057 CFU/100 mL) (Tran TD, 2018) and higher than those obtained in aquaculture water in Thanh Thuy, Nga Son, Hau Loc, Ba Thuoc and Cam Thuy districts, Thanh Hoa province (from 1,800 CFU/100 mL to 3,300 CFU/100 mL) (Thanh Hoa DARD, 2022). Comparing to the QCVN 08:2023/BTNMT (column B), TC densities at AP4 (5,600 CFU/100 mL) and AP5 (13,700 CFU/100 mL) were 1.1 and 2.7 times respectively higher than the limit value. This pose a risk for food safety in these aquaculture ponds.

EC densities at five ponds ranged from 200 (AP2) to 1,800 CFU/100 mL (AP5), averaging 940 CFU/100 mL (Table 4). Compared with the Vietnam Regulation (column B), the values at AP1 and AP5 sites exceeded the limit one by 1.1 and 1.8 times, respectively. This may be due to the influence of domestic wastewater or livestock farming from different communes near the zone studied. Therefore, it is necessary to pay attention to the density of microorganisms in the water in these aquaculture ponds to ensure the safety of food quality and human health in this area.

![Figure 4. TC and EC densities in water of five studied ponds](image)

3. CONCLUSIONS

The observation results of aquaculture water quality at five aquaculture ponds in Phuc Tho district, Hanoi city in 2023 were presented in this study. The results showed within different observed variables of water quality including DO, TSS, TN, TP, TC and EC at most sites exceeded the permitted values of the Vietnam Technical Regulation QCVN 08:2023/BTNMT which regulates the water quality of aquacultural ponds. Besides, E.I. calculations (averaged 1.87) showed that most of the aquaculture ponds were in Dystrophy states. Very high eutrophication level (Dystrophy) together with high microbial contamination may affect the fishery productivity and quality in Phuc Tho district, Hanoi city. As known, this has occurred in areas surrounded by aquaculture farms and agricultural runoff, thus wastewater treatment application is required to avoid deterioration of water quality in order to provide sustainable water use for aquaculture production. As a result, our study revealed the need for measure application to handle and overcome the current situation and to monitor the water quality regularly to ensure public health.

However, our study was performed with limited sampling frequency and monitoring variables. Thus it is necessary to expand the sampling frequency and monitoring variables in many localities in order to better assess the aquaculture water quality in Vietnam.

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