Assessment of Current Situation of Aquaculture Pollution in Tianjin and Its Prevention and Control Measures

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Abstract. In order to grasp the current situation of aquaculture pollution in Tianjin, the situation of Tianjin aquaculture and the characteristics of tail water discharge were studied. The results showed that Tianjin’s aquaculture area in 2019 was 398,000 mu, of which 384,000 mu was freshwater aquaculture; the tail water discharge was 448 million cubic meters, of which freshwater aquaculture emissions were 384 million cubic meters; the main pollution factor for freshwater aquaculture was chemical oxygen demand (CODCr) and total phosphorus, chemical oxygen demand (CODCr) all exceed the standard, the total phosphorus compliance rate is 18.8%, ammonia nitrogen and total nitrogen are both up to the standard; the main pollution factors of pond aquaculture in marine aquaculture are chemical oxygen demand (CODCr) and reactive phosphate and total phosphorus. The main pollution factors of factory-aquaculture are inorganic nitrogen, reactive phosphate and total nitrogen. The concentration of inorganic nitrogen, reactive phosphate, total nitrogen and total phosphorus in factory-aquaculture using circulating water is higher than that using non-circulating water; Tianjin’s annual aquaculture chemical oxygen demand discharges 32,700 t, ammonia nitrogen 348.0 t, total phosphorus 367.3 t, and total nitrogen 2025.6 t; countermeasures and suggestions are put forward for the pollution of aquaculture.

1. Introduction

The water environment pollution caused by the rapid development of Tianjin aquaculture industry in the past two decades has become increasingly prominent, and it has also affected the sustainable development of the aquaculture industry [1]. During the 13th Five-Year Plan period, the state and Tianjin City have successively launched pollution prevention and control battles. Among them, the ‘Action Plan for Agricultural and Rural Pollution Control’ and ‘Several Opinions on Accelerating the Promotion of Green Development of Aquaculture Industry’ require strengthening the prevention and control of aquaculture pollution and the protection of water ecology, promote healthy aquaculture breeding, and accelerate the promotion of water conservation and emission reduction in breeding. Currently there are reports on the pollution of aquaculture [2], the current status of mariculture in Tianjin [3-5] and the calculation of pollution load of aquaculture in Tianjin [6], but the data is relatively backward and incomplete. There are very few comprehensive studies on the pollution emissions characteristics and pollution status evaluations of different aquaculture methods. Based on this, investigations and monitoring were carried out on the current status of Tianjin’s aquaculture and the pollution emission characteristics of different aquaculture methods, and the major water pollutant
emissions of aquaculture in Tianjin were also evaluated and analyzed. It puts forward corresponding strategies and suggestions for the prevention and control of aquaculture pollution, which are of great significance for precise pollution control, scientific pollution control, and support for the fight against pollution.

2. Research method

2.1 Data source

The data of this research comes from various statistical yearbooks, annual reports, surveys and field surveys and monitoring. The status of the marine aquaculture industry in Tianjin has been investigated, the characteristics of pollution emissions have been studied, and 16 typical pond freshwater aquaculture, 26 typical pond mariculture, and 13 factory-mariculture (7 in circulating water breeding, 6 in non-circulating water breeding), the monitoring time is from August to October 2020.

2.2. Monitoring indicators and analysis methods

Freshwater aquaculture monitoring indicators include chemical oxygen demand (\( \text{COD}_{\text{Cr}} \)), ammonia nitrogen, total nitrogen, and total phosphorus. Marine aquaculture monitoring indicators include chemical oxygen demand (\( \text{COD}_{\text{Mn}} \)), ammonia nitrogen, inorganic nitrogen, reactive phosphate, total nitrogen, and total phosphorus. The analysis method of freshwater aquaculture implements the ‘Integrated Wastewater Discharge Standard’ (DB12/356-2018) [7]; the analysis method of \( \text{COD}_{\text{Mn}} \), ammonia nitrogen, inorganic nitrogen, and reactive phosphate in marine aquaculture implements the ‘Marine Monitoring Specification Part 4: Seawater Analysis’ (GB 17378.4-2007) [8], the total nitrogen analysis method implements the ‘Marine Monitoring Technical Regulations Part 1: Seawater’ (HY/T 147.1-2013) [9], the total phosphorus analysis method implements the ‘Marine Survey Specification Part 4: Investigation of Seawater Chemical Elements’ (GB/T 12763.4-2007) [10].

2.3. Evaluation method

The chemical analysis method is a simplification of the field measurement method, which mainly uses the difference in the concentration of pollutants in and out of the aquaculture system, combined with the drainage volume to estimate the discharge of pollutants in aquaculture itself [11]. This assessment only considers the quality of aquaculture tail water discharge, so the following formula is used:

\[
P = Q \times C_{\text{out}} \times 10^{-6}
\]

In the formula, \( P \) is the pollutant discharge load (t); \( Q \) is the discharge (m\(^3\)); \( C_{\text{out}} \) is the pollutant concentration in the discharged water (mg/L).

The correlation between the concentration levels of \( \text{COD}_{\text{Mn}} \) and \( \text{COD}_{\text{Cr}} \) uses the following formula [12]:

\[
\text{COD}_{\text{Cr}} = 1.55 \times \text{COD}_{\text{Mn}} + 10.2
\]

The evaluation of the pollution factors of \( \text{COD}_{\text{Cr}} \), ammonia nitrogen, total nitrogen and total phosphorus of freshwater aquaculture implements the secondary standards in the ‘Integrated Wastewater Discharge Standard’ (DB12/356-2018); the evaluation of pollution factors of \( \text{COD}_{\text{Mn}} \), inorganic nitrogen and reactive phosphate in marine aquaculture implements the ‘Marine Aquaculture Water Discharge Requirements’ (SC/T 9103-007) [13] in the first level standard, the evaluation of ammonia nitrogen, total nitrogen, total phosphorus pollution factors is implemented in ‘Surface Water Environmental Quality Standard’(GB 3838-2002) [14] in the category V water environmental quality standards.
3. Results and discussion

3.1. The area and distribution of aquaculture in Tianjin

Tianjin aquaculture includes freshwater aquaculture and mariculture. Freshwater aquaculture is mainly pond aquaculture. Mariculture includes pond aquaculture and factory-mariculture. Factory-mariculture is divided into circulating water aquaculture and non-circulating water aquaculture. As of March 2020, Tianjin’s aquaculture area is 398,000 mu, of which 384,000 mu is freshwater aquaculture, mainly distributed in Baodi District, Binhai new developed area and Jinghai District, and 14,000 mu of marine aquaculture is mainly distributed in Hangu Yangjiabo Town, Binhai new developed area and Zhaishang Street, followed by Tanggu and Dagang (Table 1, Table 2). There are 13,000 mu of seawater aquaculture in ponds, 1135.5 mu of factoryized seawater aquaculture, of which 846.0 mu using circulating water, 289.5 mu using non-circulating water, and 169.5 mu of factory-mariculture using circulating water have zero discharge of tail water.

Table 1. Area of aquaculture in Tianjin.

| Aquaculture methods         | Production form         | Area (mu) |
|----------------------------|-------------------------|-----------|
| Mariculture                 |                         |           |
| Pond aquaculture            | Individual contracting  | 13 006.5  |
| Non-circulating water       | Corporate               | 289.5     |
| Circulating water factory-mariculture | Corporate        | 846.0     |
| Freshwater aquaculture      | Cooperatives / Individual contracting | 383 808.4 |
| Total                       | /                       | 397 950.4 |

Table 2. Area and distribution of aquaculture in Tianjin.

| Administrative District     | Area (mu) |
|-----------------------------|-----------|
| Baodi District              | 76 521.4  |
| Binhai new developed area   | 62 902.4  |
| Jinghai District            | 54 466.6  |
| Wuqing District             | 48 122.4  |
| Ninghe District             | 47 151.8  |
| Xiqing District             | 38 059.3  |
| Jinnan District             | 28 486.4  |
| Dongli District             | 22 327.8  |
| Beichen District            | 10 546.5  |
| Jizhou District             | 9 365.9   |
| Total                       | 397 950.4 |

3.2. The pollution of aquaculture tail water in Tianjin

In pond aquaculture, mariculture basically has no fixed discharge outlets, which are discharged through pumps and water pipes, and the freshwater aquaculture has fixed discharge outlets.

Regardless of whether mariculture or freshwater aquaculture, the average depth of pond aquaculture is about 1.5 m, and the water is drained once a year, mainly from September to November each year, and all are drained without any treatment before draining.

Factory-mariculture is drained intermittently every day. Only about half of the existing 34 factory farms have constructed and used tail water treatment facilities, and there are abnormal operating conditions, the tail water treatment rate is low; in addition, the area coverage rate of the circulating
The water aquaculture model is only 70%; Some of them have fixed discharge ports, but none of them have been standardized. The average water depth of the breeding pond in the factory workshop is about 0.5 m. Among them, the daily water exchange volume for circulating water aquaculture accounts for about 20% of the total aquaculture water volume, and the daily water exchange volume for non-circulating water aquaculture is approximately 100% of the total aquaculture water volume.

According to the current aquaculture situation, the annual discharge volume of aquaculture in Tianjin is about 450 million m$^3$, of which 380 million m$^3$ is freshwater aquaculture and about 70 million m$^3$ is mariculture. Among them, the annual annual discharge volume of seawater pond aquaculture is 13.013 million m$^3$, and the annual discharge volume of factory aquaculture is 51.510 million m$^3$ (Table 3). The aquaculture tail water is directly discharged into the surface water body, and partly into the sea through rivers.

**Table 3. Discharge of aquaculture tail water in Tianjin.**

| Aquaculture methods | Type of breeding | Breeding area (mu) | Annual discharge (10000 m$^3$) | Percentage (%) |
|---------------------|------------------|------------------|---------------------------------|----------------|
| Mariculture         | Pond aquaculture | 13 006.5         | 1 301.3                         | 2.90           |
|                     | Non-circulating water factory-mariculture | 289.5         | 3 524.0                         | 7.85           |
|                     | Circulating water factory-mariculture   | 676.5         | 1 647.0                         | 3.67           |
| Freshwater aquaculture | Pond aquaculture | 38 3808.4       | 38400.0                        | 85.58          |
| Total               |                  | 397780.9         | 44 872.3                       | 100            |

The monitoring results of aquaculture tail water are shown in Table 4. The COD$\text{Cr}$ of freshwater pond aquaculture exceeded the standard, and the total phosphorus compliance rate was only 18.8% (Table 5). The multiples of COD$\text{Cr}$ and total phosphorus exceeded the standard were 0.10~1.90 and 0.01~3.88 respectively (Table 5), ammonia nitrogen and total nitrogen are up to standard. It can be seen that the pollution factors of freshwater aquaculture in ponds are mainly COD$\text{Cr}$ and total phosphorus, which respectively represent the degree of pollution of the water body by organic matter and nutrients. The reason for the lower compliance rate is that the phosphorus content in the aquaculture feed is 1.5% ~3%, the feed utilization rate is low, and the organic matter and nutrients in the residual feed and feces increase the concentration of COD$\text{Cr}$ and phosphorus. Second, the aquaculture tail water is directly discharged without treatment.

The ammonia nitrogen of mariculture reached the standard. The compliance rates of COD$_{\text{Mn}}$, total nitrogen, total phosphorus, inorganic nitrogen, and reactive phosphate in pond mariculture were 20%, 57.1%, 47.4%, 52.2%, and 30.8% respectively. The main pollution factors were COD$_{\text{Mn}}$, total phosphorus and reactive phosphate, exceeding the standard 0.04~1.03 times, 0.08~2.05 times, 0.06~13.36 times, respectively. Inorganic nitrogen and reactive phosphate in factory-based mariculture exceeded the standard. Inorganic nitrogen and reactive phosphate in circulating aquaculture were 1.25~9.41 times and 4.24~8.08 times higher, respectively. Inorganic nitrogen and reactive phosphate in non-circulating aquaculture were in excess of 0.55~1.49, and 1.42~3.38, respectively; COD$_{\text{Mn}}$, total nitrogen, and total phosphorus compliance rates for circulating aquaculture were 100%, 14.3%, and 57.1%, respectively, and the multiples of total nitrogen and total phosphorus exceeding standards were 0.09~3.19, 0.03~0.06, respectively; The compliance rates of COD$_{\text{Mn}}$, total nitrogen and total phosphorus for non-circulating aquaculture were 83.3%, 50.0%, and 100%, respectively, and the multiples of COD$_{\text{Mn}}$ and total nitrogen exceeding the standard were 0.06, 0.07~0.67, respectively. It can be seen that the concentration of total nitrogen and total phosphorus in circulating aquaculture is higher than that of non-circulating aquaculture. The reason is probably that although the filtration unit of the circulating water process will reduce some organic pollutants, the concentration of nitrogen and phosphorus increases cumulatively through the extension of cycle time [3].
Table 4. Water quality of aquaculture tailwater in Tianjin.

| Pollutants                      | COD (mg/L) | Ammonia nitrogen (mg/L) | Total nitrogen (mg/L) | Total phosphorus (mg/L) | Inorganic nitrogen (mg/L) | Reactive phosphate (mg/L) |
|--------------------------------|------------|-------------------------|-----------------------|-------------------------|---------------------------|---------------------------|
| Standard                       | 10 (freshwater) | 1.5 (freshwater) | 2.0 (freshwater) | 0.4 | 0.50 | 0.05 |
| Pond aquaculture               | 4.98~20.30 (14.55) | 0.003~1.201 (0.545) | 0.48~4.75 (2.27) | 0.15~1.22 (0.53) | 0.039~1.440 (0.633) | 0.006~0.718 (0.184) |
| Non-circulating water factory- | 3.06~10.60 (6.53) | 0.057~1.205 (0.757) | 1.16~3.33 (2.07) | 0.20~0.35 (0.27) | 0.774~1.243 (1.068) | 0.121~0.219 (0.168) |
| Circulating water factory      | 3.97~8.13 (5.99) | 0.004~1.563 (0.373) | 1.70~8.37 (4.12) | 0.34~0.63 (0.45) | 1.125~5.207 (2.942) | 0.262~0.454 (0.340) |
| Freshwater aquaculture         | 44~116 (84) | 0.29~1.83 (0.74) | 2.96~6.53 (5.06) | 0.19~1.95 (0.85) | / | / |

Note: Values outside the brackets represent the concentration range, values in the brackets represent the average concentration.

Table 5. Situation of aquaculture tail water exceeding/up to standard in Tianjin.

| Aquaculture methods              | COD | Ammonia nitrogen | Total nitrogen | Total phosphorus | Inorganic nitrogen | Reactive phosphate |
|----------------------------------|-----|-----------------|----------------|-----------------|-------------------|--------------------|
| Pond aquaculture                 | 0.04~1.0 / (100) | / | 0.37~1.3 (57.1) | 0.08~2.05 (47.4) | 0.49~1.88 (52.2) | 0.06~13.36 (30.8) |
| Non-circulating water factory-   | 0.06 / (100) | / | 0.07~0.6 (50.0) | / | 0.55~1.49 (0) | 1.42~3.38 (0) |
| Circulating water factory        | / / (100) | / | 0.09~3.1 (14.3) | 0.03~0.06 (57.1) | 1.25~9.41 (0) | 4.24~8.08 (0) |
| Freshwater aquaculture           | 0.10~1.9 / (100) | / | 0.01~3.88 (18.8) | / | / |

Note: Values outside the brackets represent the multiple of exceeding the standard (dimensionless), values in the brackets represent the rate of compliance (%).

3.3. The pollution load of aquaculture tail water in Tianjin

According to Yuan Xin’s report, the COD\textsubscript{Mn} concentration in marine aquaculture was converted into COD\textsubscript{Cr}, and the pollution load of aquaculture in Tianjin was calculated based on the annual discharge.
and average concentration of tail water (Table 6). The annual emissions of $\text{COD}_{\text{Cr}}$, ammonia nitrogen, total nitrogen and total phosphorus from aquaculture in Tianjin are 33,700 t, 324.07 t, 2,113.38 t and 350.22 t, respectively, of which freshwater aquaculture accounts for 95.66%, 87.66%, 91.94%, and 93.20% respectively. In marine aquaculture, the pollutant emissions of non-recirculating aquaculture are higher than those of pond aquaculture and circulating aquaculture, and the total nitrogen and total phosphorus emissions of circulating aquaculture are higher than that of pond aquaculture.

**Table 6. Pollution load of aquaculture tail water in Tianjin.**

| Aquaculture methods          | $\text{COD}_{\text{Cr}}$ (t) | Ammonia nitrogen (t) | Total nitrogen (t) | Total phosphorus (t) |
|------------------------------|-------------------------------|----------------------|--------------------|----------------------|
| Mariculture                  |                               |                      |                    |                      |
| Pond aquaculture             | 426.18                        | 7.09                 | 29.54              | 6.90                 |
| Non-circulating water        |                               |                      |                    |                      |
| factory-mariculture          | 716.08                        | 26.68                | 72.95              | 9.51                 |
| Circulating water            |                               |                      |                    |                      |
| factory-mariculture          | 320.84                        | 6.14                 | 67.86              | 7.41                 |
| Freshwater aquaculture       |                               |                      |                    |                      |
| Pond aquaculture             | 32256.00                      | 284.16               | 1943.04            | 326.40               |
| Total                        | 33719.09                      | 324.07               | 2113.38            | 350.22               |

If the aquaculture tail water meets the discharge standards, the annual emission reductions of $\text{COD}_{\text{Cr}}$, total nitrogen and total phosphorus can reach 32,800 t, 133.59 t, and 311.96 t, respectively, and the emission reduction ratios will be 97.20%, 6.32% and 89.04% (Table 7).

**Table 7. The compliance and emission reduction of aquaculture in Tianjin.**

| Emission reduction | COD (t) | Total nitrogen (t) | Total phosphorus (t) |
|--------------------|---------|--------------------|----------------------|
| Mariculture        |         |                    |                      |
| Pond aquaculture   | 374.53  | 19.71              | 5.48                 |
| Non-circulating    |         |                    |                      |
| water factory      | 156.72  | 50.22              | 0.00                 |
| Circulating water  |         |                    |                      |
| factory-mariculture| 0.00    | 63.66              | 4.03                 |
| Freshwater         |         |                    |                      |
| aquaculture        |         |                    |                      |
| Pond aquaculture   | 32 256.00| 0.00               | 302.45               |
| Total              | 32 787.25| 133.59             | 311.96               |

**Table 8. Reconstruction of aquaculture model compliance with emission reduction in Tianjin.**

| Pollutants                               | $\text{COD}_{\text{Cr}}$ (t) | Total nitrogen (t) | Total phosphorus (t) |
|------------------------------------------|-------------------------------|--------------------|----------------------|
| Non-circulating aquaculture emissions /t | 716.08                        | 72.95              | 9.51                 |
| Transformed into circulating water /t    | 181.13                        | 14.10              | 2.82                 |
| Annual emission reduction after          |                               |                    |                      |
| transformation /t                        | 534.95                        | 58.85              | 6.69                 |
| Reduction ratio /%                       | 74.70                         | 80.68              | 70.36                |
3.4. Countermeasures and suggestions for aquaculture pollution prevention and control

3.4.1. Standardize breeding production. Reasonably select breeding waters according to the plan of the breeding waters and tidal flats, scientifically determine the breeding scale and breeding density according to the environmental carrying capacity of the breeding waters, and carry out the environmental impact assessment of aquaculture projects in accordance with the law to effectively reduce the impact on the water environment. Reasonably determine aquaculture methods, strengthen the integration of green and environmental friendly modern fishery technology and model applications, encourage the implementation of healthy aquaculture models such as circulating water factory aquaculture and pond engineering circulating aquaculture, and develop ecological aquaculture without or low feeding. Scientifically determine the species to be cultured, and properly raise a certain number of filter-feeding fish or shellfish in pond culture. Increase the conversion rate of bait. The bait contains a lot of nutrients. The remaining bait will not only settle to the bottom of the pond and cause nutrient enrichment in the bottom sludge, but also some nutrients will dissolve in the water, seriously polluting the water environment. Use high-quality and efficient artificial full-price compound feed and immune preparations, strictly limit the direct feeding of chilled animal-derived bait, establish and improve records of bait and additive use, and precise control of the amount of bait according to the breeding species, breeding stage, and water environment characteristics. Standardize the use and management of fishery drugs, and the principles of aquaculture drugs are that do not harm human health and do not damage the ecological environment of the water area. Develop green ecological prevention and control technologies, strengthen disease prevention and control, develop and promote the application of green and safe ecological fishery drugs, establish and improve records of the use of fishery drugs, use fishery drugs reasonably and precisely according to the breeding objects, drug characteristics, and water environment characteristics, reduce the use of fishery drugs.

3.4.2. Strengthen tail water discharge management. The tail water from pond culture in Tianjin is directly discharged without treatment. The treatment rate of tail water from factory-mariculture is low, the non-circulating aquaculture method is backward, the water consumption is large, the amount of pollutant discharge is large, the coverage rate of tail water treatment facilities is low, and the operation status is not perfect, some pollutants discharged from the tail water seriously exceed the standard, which has a great impact on the water environment. It is necessary to select appropriate aquaculture wastewater treatment technology to strengthen the management of aquaculture tail water according to local conditions; accelerate the transformation of circulating aquaculture mode, and vigorously develop ecological aquaculture without or less bait in ponds; in addition, speed up equipment construction and tail water treatment facilities for water pollution and strengthen maintenance to ensure its normal operation.

3.4.3. Strengthen the supervision of management departments. At present, neither the state nor Tianjin has issued a discharge standard specifically for aquaculture. The comprehensive sewage discharge standard is applicable to freshwater aquaculture, but for mariculture, some control items and analysis methods are not applicable to a certain extent. The management department shall strengthen the supervision and management of aquaculture tail water discharge, and improve the basis for supervision and management.

4. Conclusion
(1) The area of aquaculture in Tianjin is 398,000 mu, of which 384,000 mu is freshwater aquaculture, mainly distributed in Baodi District, Binhai new developed area and Jinghai District, and 14,000 mu of marine aquaculture is mainly distributed in Binhai new developed area.

(2) The annual drainage volume of aquaculture in Tianjin is about 450 million m³, of which 380 million m³ is freshwater aquaculture. The aquaculture tail water is directly discharged into the surface water body, and partly into the sea through rivers.
(3) Pollution factors for freshwater aquaculture in ponds are mainly \( \text{COD} \), and total phosphorus. Pollution factors for marine aquaculture in ponds are mainly \( \text{COD}_{\text{Cr}} \), total phosphorus, and reactive phosphate. Pollution factors for industrial marine aquaculture are mainly inorganic nitrogen and reactive phosphorus. The concentration of total nitrogen and total phosphorus in circulating aquaculture is higher than that in non-circulating aquaculture.

(4) The annual emissions of \( \text{COD}_{\text{Cr}} \), ammonia nitrogen, total nitrogen, and total phosphorus from aquaculture in Tianjin are 33,700 t, 324.07 t, 2,113.38 t, and 350.22 t respectively, of which freshwater aquaculture accounts for more than 90%. In marine aquaculture, the pollutant emissions of non-recirculating aquaculture are higher than that of pond aquaculture and circulating aquaculture, and the total nitrogen and total phosphorus emissions of circulating aquaculture are higher than that of pond aquaculture. To achieve discharge standards, marine aquaculture needs to drastically reduce pollutant emissions, and it is necessary to vigorously develop circulating aquaculture models.

(5) The prevention and control of aquaculture tail water pollution requires concerted efforts in the production process, discharge management, and supervision.

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