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Generation and Discharge of Pollutants in Closed Aquaculture

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Abstract [**Objectives**] To gain an in-depth understanding of pollutant generation and discharge from closed aquaculture. [**Methods**] In 2018, the pollutant generation and discharge coefficients of 7 farming modes in 16 farming bases were calculated and analyzed. [**Results**] A total of 28 pollutant generation coefficients and 28 pollutant discharge coefficients were obtained, and the generation and discharge of pollutants in closed aquaculture were grasped preliminarily. Compared with the data of the first census of pollutions sources published by the state in 2008, 7 kinds of pollution generation coefficients increased, while 14 kinds decreased; and 4 kinds of pollutant discharge coefficients increased, while 17 kinds decreased. [**Conclusions**] In recent years, the pollutant generation and discharge coefficients of aquaculture show a decreasing trend.

Key words Aquaculture, Self-pollution, Pollutant generation coefficient, Pollutant discharge coefficient

1 Introduction

Aquaculture is an industry that depends on the water environment. In addition to exogenous pollution, the pollution of aquaculture itself will also cause damage to the local water environment. The main sources of impact on the water environment are feed, fertilizer, fish medicine and other inputs and biological waste, *etc.* With the continuous expansion of the scale of aquaculture in China, the issue of environmental pollution is getting more and more attention. Combining with the aquatic pollution source census project of Tianjin, the generation and discharge coefficients of seven closed aquaculture modes were calculated and analyzed to further explore the pollution generation and discharge status of aquaculture, thereby providing technical reference for quantitative evaluation and calculation of pollution intensity of aquaculture.

2 Materials and methods

2.1 Materials In 2018, 16 farming bases were selected, involving seven farming modes: farming *Cyprinus carpio*, *Carassius auratus*, *Penaeus vannamei* and *Carassius auratus* Linnaeus in freshwater ponds, farming *Trionyx sinensis* in freshwater industrially, farming *P. vannamei* in seawater pond, and farming *Takifugu rubripes* in seawater industrially. In the same production cycle, the water inlets, ponds and outfalls at the 16 monitoring sites were sampled four times, and total 195 samples and 768 monitoring data were obtained. The monitored indicators were total phosphorus, total nitrogen, ammonia nitrogen and chemical oxygen demand (permanganate index).

2.2 Sampling and monitoring methods Sampling and sample fixation were carried out in accordance with the *Monitoring Protocols of Freshwater Fishery Ecological Environment*[1]. The monitoring and analysis methods of freshwater and seawater quality are shown in Table 1.

Table 1 Monitoring and analysis methods of freshwater and seawater

Indicator	Freshwater		Seawater	
	Method	Standard	Method	Standard
Sewage flow	①	HJ/T 91-2002[2]	①	HJ/T91-2002[3]
COD_{Mn}	②	GB/T 11892-1989[3]	⑥	GB 17378.4-2007[7]
Ammonia nitrogen	③	HJ 535-2009[4]	⑦	GB 17378.4-2007[7]
Total phosphorus	④	GB 11893-89[5]	⑧	GB 17378.4-2007[7]
Total nitrogen	⑤	HJ 636-2012[6]	⑧	GB 17378.4-2007[7]

Note: ① Sewage flow meter method, current meter method, volume method; ② Potassium permanganate method; ③ Nessler's reagent spectrophotometry; ④ Ammonium molybdate spectrophotometric method; ⑤ Alkaline potassium persulfate digestion-UV spectrophotometric method; ⑥ Alkaline potassium permanganate method; ⑦ Hypobromite oxidation method; ⑧ Potassium persulfate oxidation method.

2.3 Calculation of pollutant generation and discharge coefficients The pollutant generation coefficient refers to the amount of pollutants produced in the water body by producing 1 kg of aquatic products under normal conditions, expressed as g/kg. The sediments are not included. There are great differences in the pollutant generation coefficients of different farming modes. In this study, a total of 7 farming modes were monitored.

The pollutant discharge coefficient refers to the amount of pollutants that are directly discharged into the external water environment such as lake, river and ocean through different channels among the pollutants generated by producing 1 kg of aquatic products under normal conditions, expressed as g/kg. There are great differences in the pollutant discharge coefficients of different farming modes. A total of 7 farming modes were monitored in this study.

The pollutant generation and discharge coefficients were calculated according to the following formulas:

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$$K_j = \frac{V_{total} \cdot (\overline{P}_{outfall} - \overline{P}_{inlet}) + S_{last} \cdot h_{last} \cdot (P_{pond\ last} - P_{inlet\ last})}{W_{output} - W_{input}}$$

$$Z_j = \frac{V_{total} \cdot (\overline{P}_{outfall} - \overline{P}_{inlet})}{W_{output} - W_{input}}$$

where K_j and Z_j are the pollutant generation and discharge coefficients of the j^{th} aquatic product, respectively, g/kg; V_{total} represents the sum of the drainage in the farming cycle, m^3; $\overline{P}_{outfall}$ and $\overline{P}_{inlet}$ are the average concentrations of certain pollutant in the outfall and water inlet, respectively, mg/L; S_{last}, h_{last}, $P_{pond\ last}$ and $P_{inlet\ last}$ are pond area, water depth, pond pollutant concentration and inlet pollutant concentration, respectively at the last monitoring, m^3, m, mg/L, mg/L; and W_{output} and W_{input} represent the quality of the output and input, respectively, kg.

3 Results and analysis

3.1 Calculation results of pollutant generation and discharge coefficients

The calculation results of the pollutant generation and discharge coefficients are shown in Table 2.

Table 2 Pollutant generation and discharge coefficients g/kg

Farming mode	Species	Pollutant generation coefficient					Pollutant discharge coefficient				
		Type of K value	Total nitrogen	Total phosphorus	Ammonia nitrogen	COD_{Mn}	Type of Z value	Total nitrogen	Total phosphorus	Ammonia nitrogen	COD_{Mn}
Industrial farming in seawater	*Takifugu rubripes*	①	1.985	0.857	0.472	50.380	②	1.979	0.853	0.471	50.018
Farming in seawater pond	*Penaeus vannamei*	①	2.521	0.834	0.151	35.501	②	1.059	0.303	0.057	10.559
Farming in freshwater pond	*Carassius auratus*	①	6.134	0.581	0.403	18.453	②	2.280	0.169	0.158	8.643
Farming in freshwater pond	*Penaeus vannamei*	①	4.114	0.686	0.793	21.130	②	0.628	0.100	0.477	10.079
Farming in freshwater pond	*Cyprinus carpio*	①	5.179	0.557	0.241	12.370	②	2.301	0.243	0.173	5.033
Farming in freshwater pond	*Carassius auratus* Linnaeus	①	6.886	0.851	1.672	36.210	②	3.524	0.229	0.502	21.192
Industrial farming in freshwater	*Trionyx sinensis*	①	13.280	1.932	2.710	81.210	②	2.992	0.498	0.251	16.690

Note: ① Pollutant generation in closed aquaculture; ② Pollutant discharge from closed aquaculture.

3.2 Analysis of pollutant generation coefficient (K value)

Among different farming modes, the pollutant generation coefficient of total nitrogen ranked as farming *T. sinensis* in freshwater industrially > farming *C. auratus* Linnaeus in freshwater pond > farming *C. auratus* in freshwater pond > farming *C. carpio* in freshwater pond > farming *P. vannamei* in freshwater pond > farming *P. vannamei* in seawater pond > farming *T. rubripes* in seawater industrially. Compared with the data of the first census of pollution sources in 2008 published by the state[8], the total nitrogen generation coefficients increased in four farming modes, farming *P. vannamei* in seawater pond, farming *C. auratus* in freshwater pond, farming *P. vannamei* in freshwater pond and farming *C. auratus* Linnaeus in freshwater pond, and decreased in the other three farming modes, farming *T. rubripes* in seawater industrially, farming *C. carpio* in freshwater pond and farming *T. sinensis* in freshwater industrially (Fig. 1A).

The total phosphorus generation coefficients of different farming modes were in the following order: farming *T. sinensis* in freshwater industrially > farming *T. rubripes* in seawater industrially > farming *C. auratus* Linnaeus in freshwater pond > farming *P. vannamei* in seawater pond > farming *P. vannamei* in freshwater pond > farming *C. auratus* in freshwater pond > farming *C. carpio* in freshwater pond. Compared with the data of the first census of pollution sources in 2008 published by the state, the total phosphorus generation coefficients of farming *P. vannamei* in freshwater pond and farming *P. vannamei* in seawater pond increased, and those of farming *T. rubripes* in seawater industrially, farming *C. auratus* in freshwater pond, farming *C. carpio* in freshwater pond, farming *C. auratus* Linnaeus in freshwater pond and farming *T. sinensis* in freshwater industrially decreased (Fig. 1B).

The chemical oxygen demand (COD_{Mn}) generation coefficients of different farming modes ranked as farming *T. sinensis* in freshwater industrially > farming *T. rubripes* in seawater industrially > farming *C. auratus* Linnaeus in freshwater pond > farming *P. vannamei* in seawater pond > farming *P. vannamei* in freshwater pond > farming *C. auratus* in freshwater pond > farming *C. carpio* in freshwater pond. Compared with the data of the first census of pollution sources in 2008 published by the state, the COD_{Mn} generation coefficients of all the farming modes decreased, except that of farming *T. sinensis* in freshwater industrially (Fig. 1C).

The ammonia nitrogen generation coefficients of all the farming modes are in the following order: farming *T. sinensis* in freshwater industrially > farming *C. auratus* Linnaeus in freshwater pond > farming *P. vannamei* in freshwater pond > farming *T. rubripes* in seawater industrially > farming *C. auratus* in freshwater pond > farming *C. carpio* in freshwater pond > farming *P. vannamei* in seawater pond. Ammonia nitrogen generation coefficient is not mentioned in the first census of pollution sources in 2008, so no comparison is made.

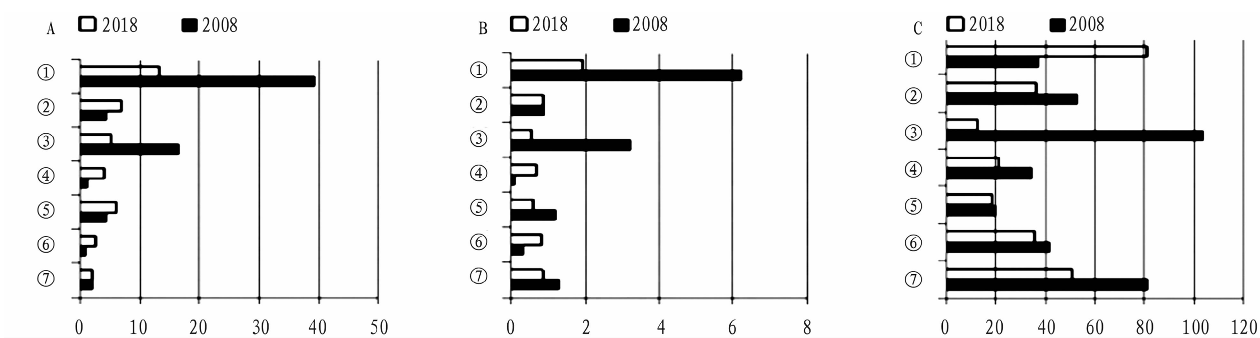
3.3 Analysis of pollutant discharge coefficient (Z value)

The order of the total nitrogen discharge coefficients of different farming modes was farming *C. auratus* Linnaeus in freshwater pond > farming *T. sinensis* in freshwater industrially > farming *C. carpio* in freshwater pond > farming *C. auratus* in freshwater pond > farming *T. rubripes* in seawater industrially > farming *P. vannamei* in seawater pond > farming *P. vannamei* in freshwater pond. Compared with the data of the first census of pollution sources in 2008 published by the state, the total nitrogen discharge coefficients of farming *P. vannamei* in seawater pond and farming *C. auratus* Linnaeus in freshwater pond increased, and those of farming *T. rubripes* in seawater industrially, farming *C. auratus* in freshwater pond, farming *P. vannamei* in freshwater pond, farming *C. carpio* in freshwater pond and farming *T. sinensis* in freshwater industrially decreased (Fig. 2A).

Among different farming modes, the total phosphorus discharge coefficients ranked as farming *T. rubripes* in seawater industrially > farming *T. sinensis* in freshwater industrially > farming *P. vannamei* in seawater pond > farming *C. carpio* in freshwater pond > farming *C. auratus* Linnaeus in freshwater pond > farming *C. auratus* in freshwater pond > farming *P. vannamei* in freshwater pond. Compared with the data of the first census of pollution sources in 2008 published by the state, the total phosphorus discharge coefficient increased in the modes of farming *P. vannamei* in seawater pond and farming *P. vannamei* in freshwater pond, and decreased in the modes of farming *T. rubripes* in seawater industrially, farming *C. auratus* in freshwater pond, farming *C. carpio* in freshwater pond, farming *C. auratus* Linnaeus in freshwater pond and farming *T. sinensis* in freshwater industrially (Fig. 2B).

The COD_{Mn} discharge coefficients of different farming modes were in the following order: farming *T. rubripes* in seawater industrially > farming *C. auratus* Linnaeus in freshwater pond > farming *T. sinensis* in freshwater industrially > farming *P. vannamei* in seawater pond > farming *P. vannamei* in freshwater pond > farming *C. auratus* in freshwater pond > farming *C. carpio* in freshwater pond. Compared with the data of the first census of pollution sources in 2008 published by the state, the COD_{Mn} discharge coefficients of the seven farming modes all decreased (Fig. 2C).

The ammonia nitrogen discharge coefficients of different farming modes were in the order as farming *C. auratus* Linnaeus in freshwater pond > farming *P. vannamei* in freshwater pond > farming *T. rubripes* in seawater industrially > farming *T. sinensis* in freshwater industrially > farming *C. carpio* in freshwater pond > farming *C. auratus* in freshwater pond > farming *P. vannamei* in seawater pond. Ammonia nitrogen discharge coefficient is not mentioned in the first census of pollution sources in 2008, so no comparison is made.



Note: ① Farming *Trionyx sinensis* in freshwater industrially; ② Farming *Carassius auratus* Linnaeus in freshwater pond; ③ Farming *Cyprinus carpio* in freshwater pond; ④ Farming *Penaeus vannamei* in freshwater pond; ⑤ Farming *Carassius auratus* in freshwater pond; ⑥ Farming *Penaeus vannamei* in seawater pond; ⑦ Farming *Takifugu rubripes* in seawater industrially. The same as below.

Fig. 1 Comparison of total nitrogen, total phosphorus, COD_{Mn} generation coefficients (g/kg)

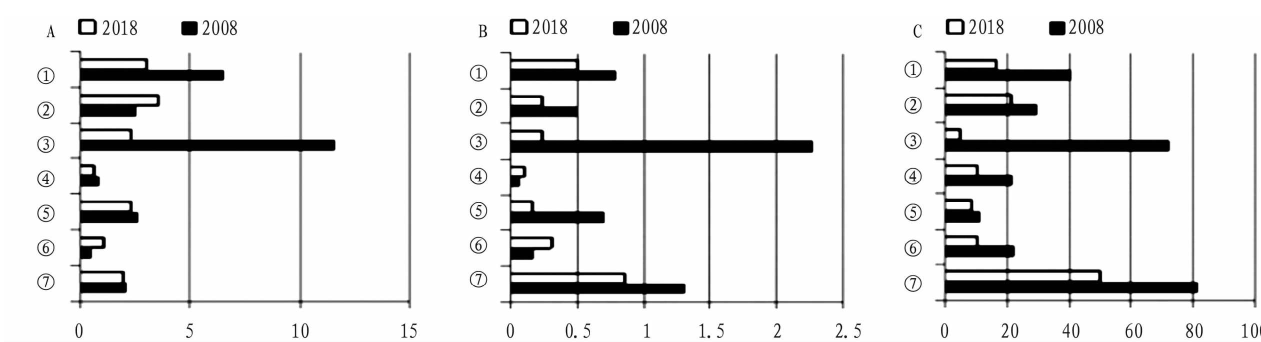


Fig. 2 Comparison of total nitrogen, total phosphorus, COD_{Mn} discharge coefficients (g/kg)

4 Conclusions and recommendations

4.1 Conclusions In this study, combined with the actual situation of aquaculture in Tianjin, seven water bodies of closed aquaculture type were selected, and their generation and discharge coefficients of four pollutants, total nitrogen, total phosphorus, ammonia nitrogen and COD_{Mn} were measured and studied. A total of 28 pollutant generation coefficients and 28 pollutant discharge coefficients were obtained. The pollution intensity of the main types of aquaculture in Tianjin has been preliminarily found out, providing technical support for further accounting of pollutant generation and discharge of aquaculture. Compared with the data of the first census of pollution sources in 2008 published by the state, 7 kinds of pollutant generation coefficients increased, while 14 kinds decreased; and 4 kinds of pollutant discharge coefficients increased, while 17 kinds decreased. Overall, the pollutant generation and discharge coefficients showed a decreasing trend.

4.2 Recommendations The impact of aquaculture on water bodies depends on the farming mode, species, production and management, and level of wastewater treatment. In order to reduce water pollution and reduce pollutant discharge, attention must be paid to the following issues. First, a reasonable farming capacity should be determined, instead of pursuing high yield blindly. Second, feed should be input reasonably, and the efficiency of feed utilization should be improved. Excessive input of feed is an important factor causing pollution. Third, the treatment of aquaculture waste water should be strengthened. Fourth, new green farming methods should be promoted vigorously to optimize the farming structure, and three-dimensional, ecological and healthy farming modes should be developed to take the road of sustainable development.

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party resources such as schools, associations and enterprises should be integrated through school-enterprise cooperation, to strengthen the cooperation of "government, school, association and enterprises". E-commerce classes are added to the existing local school system, which can absorb local teenagers to participate in the systematic learning and training of e-commerce. Students who participate in e-commerce can be given appropriate subsidies for admission and completion to guide students to choose e-commerce. Meantime, the government should hold targeted e-commerce special training and e-commerce vocational skills competition activities to stimulate the enthusiasm for e-commerce learning and to improve the vitality of e-commerce entrepreneurship and innovation, thus providing a steady stream of fresh blood for local e-commerce enterprises.

4.3 Increasing rural e-commerce brand support The author found that the agricultural products sold by e-commerce in Datong County are still dominated by original agricultural products, lacking of deep processing of products. Although the products are relatively cheap, it is not competitive in the market considering transportation costs, freshness and other factors. After the implementation of e-commerce sales model, enterprises will face a more diversified number of consumers, and a relatively larger competition as well. Therefore, a group of agricultural products processing enterprises should be developed to make the products sold into characteristic agricultural products with high added value.

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