Combined process of biofilm+roots for aquaculture wastewater remediation

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Abstract. The mechanism of aquaculture wastewater remediation by combined process of biofilm+roots was studied based on the aquaculture circulatory system. Results showed that under the remediation system, the removal of COD, TP, NH₄-N, TN were 84.59%, 57.81%, 82.43% and 70.96%, respectively. The controllable wastewater treatment which is the coupling of biofilm and roots, was effective and could provide basis and technical support for the implementation of aquaculture wastewater treatment.

1. Introduction

China is a big country of fishery and aquaculture, but aquaculture mostly belongs to the extensive and semi intensive aquaculture mode. A large number of animal excrement, dead animal and plant bodies, bait residue, fishery fertilizer, disinfectant, bactericide, parasiticide and other drugs enter into the water body. The accumulation of organic matter, phosphorus, ammonia, nitrogen and other substances in the aquaculture water body aggravates the eutrophication degree of the water body. Pollution in turn restricts the development of aquaculture [1-2]. Therefore, it is particularly important to recycle aquaculture wastewater and seek a sustainable "green" aquaculture model [3-4].

At present, the main remediation technologies of aquaculture wastewater at home and abroad are physical remediation, chemical remediation and biological remediation. The application of physical and chemical methods is fast, but the cost is high, energy consumption is large, and the possibility of secondary pollution is large, so the application is limited. Bioremediation has been widely used and studied because of its low cost, wide adaptability and ecological effect. Bioremediation can be divided into three categories: plant remediation, microbial remediation and animal remediation.

Phytoremediation of wastewater is to use aquatic plant roots or stems and leaves to absorb, enrich, degrade or fix pollutants in polluted water, so as to eliminate or reduce the pollution intensity and repair the environment [5]. Microorganism is the main promoter of material circulation and energy conversion in ecosystem, which can absorb, metabolize and degrade pollutants in water. In addition, the metabolites and cell components of many microorganisms can promote the growth and development of fish, shrimp, algae and aquatic plants. Many beneficial microorganisms can also inhibit the propagation of pathogenic bacteria and reduce the occurrence of fish and shrimp diseases. At present, the Pearl River Delta area is rich in water systems, developed aquaculture industry, and many sensitive areas of water pollution. In view of the water pollution caused by aquaculture in the Pearl River Delta area, this paper, starting from the basic research, uses the method of plant and biofilm joint repair to preliminarily explore the mechanism of biofilm plant root system joint purification, in order to control the pollution of aquaculture wastewater in the Pearl River Delta area.
2. Materials and methods

2.1. Establishment of aquaculture recycling treatment system
According to the principle, a device for purifying and reusing aquaculture wastewater was made in this experiment. The device is a closed circulation system composed of a treatment tank, a fish tank and a waste water tank. As shown in Figure 1.

![Fig. 1  Schematic diagram of aquaculture wastewater purification system](image)

2.2. Selection of biofilm carrier
Hemp cloth, cotton cloth and silk screen nylon cloth (160 mesh) were selected as membrane carriers respectively, and placed in the aquaculture wastewater. A proper amount of photosynthetic bacteria and Bacillus (provided by South China Sea Fisheries Research Institute, CAFS) were added and aerated for 8 hours every day. One week later, observe the film condition of carriers with different materials. The results showed that the effect of silk screening nylon cloth was the best, the biofilm was clear, but linen and cotton cloth were poor. Linen and cotton cloth are rough and hydrophilic. The nutrients in the waste water are easy to attach to this kind of cloth, but this kind of cloth is easy to rot in the water. The mesh nylon cloth is hydrophobic and relatively difficult to hang film, but it is not easy to rot in the water, and the mesh diameter of mesh nylon cloth is relatively small, which is easy to intercept the nutrients in the wastewater, which is conducive to microbial propagation and hanging film, with the best effect. Therefore, this test uses the screen silk nylon cloth as the membrane carrier.

2.3. Selection of plant root system
Common watercress is used as experimental plants, mainly due to its developed root system, strong pollution resistance and decontamination ability, high economic value, low requirements for environmental conditions and strong adaptability. They can grow well in southern China and Jiangsu, Zhejiang, Anhui and Shanghai regions, with the outstanding advantage that they still grow well in winter in southern China [6-7]. At present, there have been some research reports on the purification of wastewater by hydroponics economic plants [8], but few studies on the purification of wastewater by using the root system of Western cabbage. Therefore, this experiment uses both edible and medicinal value of watercress to purify aquaculture wastewater [9], in order to provide a reference for solving the problem of aquaculture wastewater pollution.

2.4. Construction of simulated culture system
Randomly select 50 common fish species with normal life characteristics, simplify the simulation of the actual aquaculture density, water flow, feed delivery and other aspects, and release the fish species in the fish pond of the treatment system for aquaculture, aerobic domestication for one week, simulation of the aquaculture system. After the system is stable, the simulated aquaculture wastewater will be connected to the combined treatment system of biofilm and root system. See Table 1 for the concentration of main factors of simulated water quality.

| Water quality factor | COD  | TP   | NH₃-N | TN   |
|----------------------|------|------|-------|------|
| Concentration (mg/L) | 125.60 | 6.09 | 9.57  | 18.56 |
2.5. Water sampling
In order to study the treatment effect of different retention time and combined treatment system of biofilm and root system on aquaculture wastewater, samples were taken at two hours intervals, and there were five groups of samples, each group of which analyzed the data of COD, TP, NH4-N and TN respectively.

3. Results and discussion

3.1. Removal effect of COD by wastewater circulation system
As shown in Figure 2, with the operation of the wastewater aquaculture cycle system, the COD removal rate increases gradually, and the maximum removal rate can reach 84.59%. It is speculated that the soluble organic matter in the wastewater is absorbed by the bacteria through the cell wall and plasma membrane of the microorganism. The insoluble organic matter first adheres to the bacteria, and then decomposes into soluble substances by extracellular enzymes secreted by the cells and infiltrates into the cells. Through the biochemical functions of oxidation, reduction, decomposition and synthesis in the body of microorganisms, some organics are transformed into nutrients needed by microorganisms, and the other organics are oxidized and decomposed into simple inorganic substances such as CO2 and H2O, which release energy at the same time. And plants strengthen the decomposition and utilization of organic matter in wastewater, plant root area directly absorbs and utilizes available nutrients in wastewater, transports oxygen for self nourishing microorganisms and enhances and maintains the hydraulic transmission of medium.

There have been many research results on the microbial and Phytoremediation of aquaculture wastewater, but the research on the microbial phytoremediation is less. In this system, there are a large number of composite fungicides cultured by biofilm, which greatly strengthen the removal of organic matters in water with the function of plant root zone. In the practical engineering, we should select the bacteria according to the nutrient characteristics of the aquaculture wastewater, and cultivate the most suitable bacteria by adjusting the pH value, aeration state, aeration time and other environmental conditions.

3.2. Removal effect of TP by wastewater circulation system
As shown in Figure 3, with the operation of the wastewater aquaculture cycle system, the TP removal rate gradually increases, with the maximum removal rate of 57.81%. Analysis of the results of this part of the experiment preliminarily concluded that the small part of phosphorus in the wastewater was absorbed by microorganisms to synthesize cell substances while removing carbon, and most of the phosphorus was removed by polyphosphate bacteria, which mainly depended on the absorption and utilization of plant roots, which was also consistent with the conclusion that the absorption / sorption of plants was the main way of total phosphorus removal. Rhizosphere is the main part of plant decontamination and phosphorus removal, which provides aerobic, anoxic and anaerobic conditions for the survival of microorganisms and the degradation of nutrients. It is equivalent to many A/ A / O treatment units in series or parallel, which can remove phosphorus from wastewater through nitrification, denitrification and excessive accumulation of phosphorus by microorganisms. Therefore, it is particularly important to use the aquatic plant system in the actual project, select and plant aquatic plants with strong pollution resistance, good decontamination effect, suitable for the local environment, developed root system and certain economic value.
3.3. Removal effect of nitrogen by wastewater circulation system

As shown in Fig. 4 and Fig. 5, the highest removal rates of ammonia nitrogen and total nitrogen in the wastewater circulating system are 82.43% and 70.96% respectively, with good removal effect. Biofilm is widely used to remove NH3-N from aquaculture wastewater. There are two stages in the oxidation of ammonia to NO3-N: one is that ammonia oxidizing bacteria (AOB) oxidizes ammonia to NO2-, the other is that nitrite nitrifying bacteria (NOB) oxidizes NO2- to NO3-. The biofilm filled with fillers usually provides solid substrate and suitable growth environment for the growth of AOB and NOB. On the other hand, ammonium nitrogen, nitrate nitrogen and nitrite nitrogen are the first to be used by plant roots. TN first decomposes into ammonia under the action of denitrifying microorganism in the membrane, and part of ammonia dissociates into ionic ammonium (NH4+ -N) in the water. In the water body rich in dissolved oxygen, nitrobacteria and nitrifying bacteria multiply in large numbers, while ammonium nitrogen is oxidized into nitrous nitrogen (NO2- -N) by nitrobacteria. Nitrous nitrogen is a very unstable intermediate product, which is quickly oxidized to nitrate under the action of nitrifying bacteria Nitrogen (NO3- -N). If there is anoxia in the water, the aerobic microorganism will be restrained, and the anaerobic microorganism will multiply in large quantities. The ammonia formed by the decomposition of organic matter in the water will not be further oxidized to nitrite and nitrate nitrogen, and the original nitrite and nitrate nitrogen will also be reduced to ammonia by denitrifying bacteria, and ammonia will be reduced to nitrogen by denitrifying bacteria, and will escape from the water surface to achieve the purpose of nitrogen removal. Therefore, it can be inferred that the removal of ammonia mainly depends on the microorganism in the membrane [10].

4. Conclusion

In this experiment, the aquaculture wastewater rich in COD, TP, NH4-N and TN in the Pearl River Delta region was taken as the research object. A wastewater aquaculture recycling system was established to study the mechanism of joint remediation of biofilm + plant root system when purifying this kind of water rich in organic matters, so as to reduce the pollution of aquaculture on the water environment. The following conclusions were drawn.

(1) The microorganism in the membrane is fully coupled with the plant culture to build a highly efficient wastewater treatment system with strong controllability, which does not consume energy,
low cost and good effect. Combined with green environmental protection feed, microbial preparation and other means, it can more effectively solve the water pollution and environmental pollution caused by aquaculture.

(2) There are various biofilm treatment devices for aquaculture wastewater, with different structures and technological processes. Therefore, it is necessary to establish reasonable supporting technologies for breeding, ingredients, water quality purification and other supporting technologies under ecological aquaculture according to the actual situation of the region, and implement the sustainable development strategy.

(3) It is very important to use the aquatic plant system in the actual project to select and plant the aquatic plants with strong pollution resistance, good decontamination effect, suitable for the local environment, developed root system and certain economic value.

(4) In the ecological remediation technology, it is a beneficial attempt to use effective microbial agents and a variety of plants to purify wastewater. The specific remediation mechanisms of membrane plant symbiosis, plant enzymology, physiological and biochemical pathways, membrane microbial composition, and antagonistic environmental impact factors need to be further study.

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