Effect of plastic carbon fiber-biofilm technology on landscape water purification

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Abstract. In this study, a new type of plastic carbon fiber filler was applied to biofilm technology. The optimum purification conditions for eutrophic landscape water were discussed by controlling the filling amount, aeration volume and pollutant concentration. The activated sludge from the sewage treatment plant is used for aeration and filming to explore the effect of the filler on the purification effect of the landscape water body. Studies have shown that the composite filler has a good removal effect on COD$_{cr}$, TN and TP in eutrophic water, and is a highly efficient new water treatment material.

1. Preface
With the development of urbanization process, the eutrophication of landscape waters has intensified, and the excess of nitrogen and phosphorus is the root cause. As an effective sewage treatment technology, biofilm technology has gradually begun to be used in the treatment of eutrophic landscape water with the development of carrier materials. This project uses a new type of plastic carbon fiber material independently researched and developed as a water treatment material. In this study, the composite material was used to explore the effects of different fiber content, aeration volume and pollutant concentration on the purification effect of landscape water.

2. Materials and Methods

2.1 Experimental materials

2.1.1 Experimental water body
In this experiment, manual water distribution was used, and the lightly polluted water bodies above the V class standard were prepared according to the water quality standard of surface water environment quality standard GB3838-2002. The specific water quality indicators are shown in Table 1.

| index | Concentration (mg·L$^{-1}$) | Type IV water ($\geq$) | Type V water ($\geq$) |
|-------|----------------------------|-----------------|-----------------|
| COD$_{cr}$ | 78.90 | 30 | 40 |
| TN | 3.47 | 1.5 | 2 |
| TP | 0.59 | 0.1 | 0.2 |
| pH | 6.58~7.23 | -- | -- |
| DO | 7.25 | -- | -- |

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2.1.2 Experimental sediment
The experimental bottom mud was taken from the second settling tank of Xintang Wastewater Treatment Plant in Guangdong Province. It is grayish brown, flocculent, and has good sedimentation performance. Microorganisms are observed under the microscope, and the sludge activity is high.

2.1.3 New plastic carbon fiber
The new plastic carbon fiber is a new type of composite filler independently developed by the project (Figure 1) A composite fiber bundle formed of a plastic ring piece, a center rope, a carbon fiber, and a support sleeve in series. Through the unique perforation fixing method, the tow is evenly distributed around the plastic ring piece, which is not easy to fall off, avoiding the centering of the filler, improving the center oxygen supply, and the snowflake needle-like structure in the middle of the plastic ring piece has good water distribution and cloth. The gas effect makes the filler have the advantages of good mass transfer effect, high oxygen utilization rate, no blockage, impact resistance and stable treatment.

2.2 Experimental apparatus and method
The experimental device is shown in Figure 2. It consists of a 1200L plastic box, an aeration pump (hailea-aco-308), a gas pipe, an aeration strip, and a new plastic fiber. The experiment is divided into 2 phases:

Stage 1: The fiber bundle is hung into the device of Figure 2 to which activated sludge has been added. Quantitative nutrients such as glucose, ammonium chloride, potassium dihydrogen phosphate, magnesium sulfate and ferrie sulfate are added every day, under aeration. Static film-hanging treatment, during the 5 d period, take 4 pieces of fiber, and dry it in an oven at 105 °C for 24 h, then weigh the average value, and the difference between the average value of the four pieces of fiber before the film is taken as Biofilm increments. The membrane is mature and stable for the next stage of experiment.

Phase 2:
(1) Membrane filling experiment: 80 L experimental water distribution was added to 5 experimental devices of the same specification (Figure 2), and bundles of successful fiber bundles 1, 3, 6, 9 and 12 were respectively added, 15 pieces per bundle. The fiber sheet has a net weight of ±0.8 g on each combined packing, so the film filling density is 0.1, 0.3, 0.6, 0.9, and 1.2 g·L⁻¹, and samples are taken every 1 d to determine the COD in the water sample, TN, TP concentration, the removal rate of each index was calculated, and the removal rules of each index under different membrane filling amounts were analyzed.

(2) Add experimental water to each of the four identical devices, and hang into 6 bundles of successful fiber bundles. The controlled aeration amounts are 0.00 min·L⁻¹, 0.50 min·L⁻¹, and 1.25 min·L⁻¹, 2.50 min·L⁻¹, samples were taken every 3 h, and the concentrations of COD, TN, and TP in the water samples were measured.
3. Results and discussion

3.1 Changes in biofilm volume during membrane loading
As shown in Figure 3 (left), after 5 days of hanging film, white viscous material adhered to the fiber sheet, and the sticky material became yellowish brown in the middle and late stages (Figure 3, right). It can be seen from Figure 4 that the amount of biofilm during the filming period increases from 0 to 20 day with increasing time, and gradually stabilizes at 20 to 30 days. It indicates that the fiber has been successfully filmed at 20-25 d when the nutrition is sufficient, and the biofilm on the fiber is also basically stable.

Figure 3 Surface changes of fiber sheet during the biofilm formation.

![Figure 3](image)

Figure 4 Changes in the number of biofilms on the surface of the fiber during membrane formation.

![Figure 4](image)

3.2 Effect of different time and membrane filling amount on purification effect
As shown in Figure 5, Figure 6, Figure 7, during the experiment, the removal rates of COD<sub>cr</sub>, TN, and TP increased first and then decreased with the increase of fiber membrane filling amount, which was due to the filling amount of fiber membrane in a certain range. Increased, the habitat of water microbes increased, promoting the growth and reproduction of microorganisms, thus promoting the purification of COD<sub>cr</sub>, TN, TP. When the fiber content is 0.9 g·L<sup>-1</sup>, the removal rate of COD<sub>cr</sub> and TN is 98.33% and 60.01%, and the removal rate of TP is slightly lower than that of 0.6 g·L<sup>-1</sup> is 80.12%. When the amount is 0.6 g·L<sup>-1</sup>, the removal rate of TP is 83.6%, and the removal rate of COD<sub>cr</sub> and TN is slightly lower than 0.9 g·L<sup>-1</sup>, which is 91.67% and 53.13%, respectively. From the perspective of cost-effectiveness, the optimum membrane filling amount should be 0.6 g·L<sup>-1</sup>. As shown in Figure 8, Figure
9. Figure 10, the COD_{cr} and TN concentrations in water decreased to the lowest on the 4th day, and the COD_{cr} and TN removal rates did not change significantly on the 5th day. It is the lowest, but the change is not obvious on the 4th day compared with the 5th day. It is because of the lack of carbon sources in the water after the 4th day. When the membrane loading was 1.2 g·L\(^{-1}\), the removal rate of COD_{cr}, TN and TP was significantly lower than 0.9 g·L\(^{-1}\), but the removal efficiency was better than 0.1 g·L\(^{-1}\). The reason is that the microbe lacks sufficient carrier under the filling amount of 0.1 g·L\(^{-1}\), and it is not easy to form enough biofilm to absorb nitrogen and phosphorus\(^3\). The rich pore-structure inside the fiber is suitable for the proliferation of nitrifying bacteria, stimulate microbeal activity and generate sufficient foot. The nitrification and denitrification of biofilms and the dephosphorization of polyphosphates reduced the total nitrogen concentration of total nitrogen. Organic matter, nitrogen and other substances. In the final five membrane loadings, the COD_{cr} concentration decreased below 10mg·L\(^{-1}\), the TN concentration decreased below 1.5 mg·L\(^{-1}\), Meet the Class IV water quality standards. It shows that the combination of plastic carbon fiber has a good purification effect on landscape sewage, and it is an efficient new water treatment material.

![Figure 5](image5.png)  
Figure 5 Removal rate of COD_{cr} under different membrane filling.

![Figure 6](image6.png)  
Figure 6 Removal rate of TN under different membrane filling.

![Figure 7](image7.png)  
Figure 7 Removal rate of TP under different membrane filling.

![Figure 8](image8.png)  
Figure 8 Change of COD_{cr} concentration with different time.
3.3 Influence of different aeration rates on purification effect
It can be seen from Figure11, Figure12, Figure13, Figure14, that under the same conditions, increasing the amount of aeration in the water can significantly promote the removal of COD$_{cr}$, TN and TP, and the removal rate increases with the increase of aeration. When the aeration amount reaches a certain amount, the removal rate is no longer increased greatly. For example, the aeration rate of 2.5min·L$^{-1}$ is not significantly improved compared with the removal rate of 1.25 min·L$^{-1}$, indicating the amount of aeration. Exceeding a certain amount does not significantly improve the purification effect. The reason is that when the amount of dissolved oxygen is low, the activity of microorganisms in the water body is inhibited, and the removal effect is poor. When the amount of aeration increases, the amount of dissolved oxygen in the water increases, which promotes nitrogen oxidizing bacteria, polyphosphate bacteria and membranes. The activity of the microorganisms leads to an increase in the removal effect. However, when the dissolved oxygen content in the water body is saturated, the aeration amount continues to increase and cannot effectively promote the purification effect.
Figure 13 Removal efficiency of TP under different aeration rates.

Figure 14 Removal rates of COD, TN, TP under different aeration rates.

4. Conclusion
(1) The removal rate of COD, TN and TP in micro-polluted landscape water by new combination carbon fiber increases with the increase of membrane filling amount in a certain range. When it exceeds a certain amount, it does not increase with the increase of membrane filling amount. And from the viewpoint of cost efficiency, the optimum film filling amount is 0.6 g·L⁻¹.

(2) Within a certain range, the removal rate of COD, TN and TP increases with the increase of aeration, but when the aeration exceeds 1.25 min·L⁻¹, the removal rate is no longer effective. Obviously, it indicates that when the aeration amount is too large, the fiber filler does not significantly promote the purification effect of the water body.

(3) Combined plastic carbon fiber is a cost-effective water purification material for the high removal rate of COD, TN and TP in micro-polluted water, respectively, which are 98.33%, 60.01%, 83.76%, and low cost.

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