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BIOFOR Biological Aerated Filter in Environmental Biology

Naser Jabeer*

University of Anbar, Iraq

**corresponding author*

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Abstract: There is a strong contrast between urban river pollution and the need to improve the quality of residents' living environment. Comprehensively eliminating urban black and odorous water bodies has become one of the important tasks of urban water management. In this paper, through the application of biological aerated filter in environmental biology, the filter technology will be applied to the purification of urban domestic sewage. Taking River B in city a in the South as the research object, the effects of different filling filter materials, biofilm hanging time of biological aerated filter and other factors on the treatment effect will be studied through a small-scale test system, The actual operation effect of the combined process of multi-stage filtration and biological aerated filter for the treatment of urban black and odorous water is verified by field tests.

1. Introduction

As the water source of the city, urban rivers provide guarantee for urban life and production activities; Secondly, it also has the function of regulating urban floods and alleviating urban heat island [1]. In addition, the construction of urban river bank landscape is also the main work of urban ecological civilization construction. Due to the influence of domestic sewage, rainwater and industrial wastewater in the city, urban rivers have become the main pollution objects [2]. A large number of exogenous pollutants enter urban rivers, exceeding the self purification capacity of urban water bodies, and the dissolved oxygen in the water remains at a low level for a long time [3]. Anaerobic microorganisms decompose the polluted organic matter in the river, causing the water body to turn black, emit odor and damage the water ecosystem [4].

In recent years, biological aerated filter has become a research hotspot of experts and scholars at home and abroad because of its advantages of high efficiency, energy saving and convenient management. The research progress mainly focuses on the optimization of process parameters and efficiency, nitrogen and phosphorus removal, development of filter materials and combined process of biological aerated filter [5]. In the process parameters and efficiency optimization research. Foreign scholars have studied the treatment efficiency of biological aerated filter for oilfield wastewater, and its removal rates of COD, BOD and SS can reach 57.9%, 96.3% and 82.7%. In terms of filter material development, it is found that the average removal rate of nh4+-n by SFM is 90.51%, while the average removal rate of ceramsite is only 82.01%. With the increase of iron content, mbaf has higher hydraulic load, organic load and nitrogen and phosphorus removal effect, and after 120 days of operation, the filler surface has formed a relatively stable flora dominated by eubacteria [6].

Biological aerated filter (BAF) combines biological contact oxidation with rapid filter, so that the same bioreactor has the functions of biodegradation and adsorption filtration at the same time. At present, biological aerated filter is not only widely used in the treatment of urban sewage, but also widely used in the wastewater treatment of food processing, brewing and papermaking industries.

2. Overview of Relevant Concepts

Biological aerated filter (BAF) is a sewage treatment process that combines traditional filtration with biological contact oxidation process. The biological aerated filter realizes efficient and stable operation through regular backwashing without setting a secondary sedimentation tank, which is a typical representative of the development of sewage treatment process in the direction of compounding and integration [7].

2.1. Advantages and Problems

Compared with other traditional biological treatment processes, biological aerated filter has the following advantages [8-9]:

(1) The process is simple. The biological aerated filter integrates the functions of solid-liquid separation and biodegradation. It can adsorb and intercept suspended solids and aging and falling off biofilm and remove them by backwashing. There is no need to set up a separate secondary sedimentation tank and sludge return pump room, which is convenient for operation and management.

(2) The infrastructure investment and operation cost are low. Due to the simple process of biological aerated filter, its capital investment cost is lower than that of the conventional secondary biochemical treatment process, and the granular filler in the filter effectively improves the oxygen transfer efficiency and saves the energy consumption of aeration operation.

(3) Strong impact resistance and good treatment effect. The filler used in biological aerated filter has small particle size, large surface attached biomass and high activity.

The characteristics of biological aerated filter process make it have the following shortcomings in operation [10-11]:

(1) The effect of nitrogen and phosphorus removal is poor. Compared with other biochemical treatment processes, the effect of simultaneous nitrogen and phosphorus removal of biological aerated filter is deficient, especially the effect of simultaneous biological phosphorus removal is poor, which needs to be combined with high-cost chemical phosphorus removal agents, thus affecting its popularization and application.

(2) The filler needs further development. There are many kinds of fillers commonly used in biological aerated filter, but there are still some problems, such as insufficient biomass, and the

phenomenon of filter blockage caused by hardening during operation. The research and development of fillers that can ensure the long-term stable operation of the filter is the direction of further development and optimization of biological aerated filter.

(3) The requirements for system automation are high. During the operation of biological aerated filter, the filler is easy to harden, resulting in increased head loss, filter plugging and other problems.

2.2. Formation Mechanism of Black and Odorous Water

Sulfur mainly enters the water body in the form of organic sulfur and sulfate. Due to severe hypoxia in the water body, organic sulfur decomposes to form hydrogen sulfide, and sulfate radical forms s2-[12] under the reduction of sulfate reducing bacteria. A large number of accumulated ferrous ions combine with s2- to form FES, which enters the water body under the influence of hydraulic scouring and other factors, making the water body black [13]. With the participation of different anaerobic microorganisms, the following biochemical reactions will occur in the above process:

$$\text{Sulfur containing protein} \rightarrow \text{Cysteaminecystis} + H_2 \rightarrow H_2S + NH_3 + CH_3CH_2COOH \quad (1)$$

$$SO_4^{\ 2-} + \text{organic compound} \rightarrow H_2S + H_2O + CO_2 \quad (2)$$

$$Fe^{3+} \rightarrow Fe^{\ 2+} \quad (3)$$

$$Fe^{\ 2+} + H_2S \rightarrow FeS \quad (4)$$

In anoxic water, organic pollutants will produce a large number of odorous substances such as hydrogen sulfide, ammonia, amine, mercaptan under the anaerobic degradation of anaerobic microorganisms [14-15]. After a series of biochemical reactions, the acid hydrolysates of humic acid and fulvic acid form a large number of smelly ammonia and extremely smelly thioether compounds [16]. When there are a large number of actinomycetes in the water, they can use the mercaptans and thioethers generated by the anaerobic decomposition of sulfur-containing proteins for biological metabolism to produce stinky 2-methyl isozyl alcohol and kaempferol. In addition, algae will also form after death and cracking β- Odor substances such as ionone (aldehyde) [16-17]. Among them, the biochemical reactions of NH3, H2 S, etc. in water are as follows [18]:

$$HCOOC(NH_2)HCH_2SH + 2H_2O \rightarrow CH_3COOH + HCOOH + H_2S + NH_3 \quad (5)$$

3. Pilot Test of Combined Process of Biological Aerated Filter

3.1. Overview of Test River

The test site selected for the pilot test is located in city A. City a is located in the east of China and the middle of the lower reaches of the Yangtze River, with a total area of 6587 square kilometers. The terrain is dominated by low mountains and gentle hills. City a has a humid climate in the north subtropical zone. The plum rain period lasts from June to July every year. The annual average precipitation is 1106mm and the annual average temperature is 15.4 °C. The water area of city a accounts for more than 11% of the total regional area of the city, and there are 120 large and small rivers in the city. B River starts from the north of Y village on the south side of the river and ends at B bridge pump station. The river is basically in a closed state, with a total length of about

270m, a river width of 7~13m, a water depth of about 1.0~1.5m, a water area of 4016m2, and an estimated total water volume of 5000m3. It is a soft bottom riverbed.

3.2. Current Situation of River Pollution

The river network of city a is crisscross and dense, belonging to an area with a wide water area. The rivers in the city are mainly narrow channels with slow flow speed, and most of them belong to closed, semi closed and slow-moving rivers. With the massive hardening of the bank, the ecological degradation of the bank is serious, and there are few aquatic plants in the river, so the overall ecology of the river is poor. The river B selected this time is in the old urban area of the city. Although the old drainage pipe network has been reconstructed, there is still a problem of mixed flow of rain and sewage. Some pollutants still enter the river with the rainwater overflow well, and there are many commercial houses on both sides of the river. During the rainfall process, a large number of surface runoff pollutants also enter the river. Because the environmental capacity of the river itself is small, and the self-regulation ability is almost nonexistent, it is easy to produce black odor.

Through the investigation of river water quality, the main environmental problems of the water body are sorted out as follows:

(1) Great impact of external pollution

Although the dry flow sewage and initial rain have been intercepted at the front of the river, the sewage and rain in the well and the sludge deposited in the pipeline have been intercepted into the river in the face of heavy rainfall or pump station maintenance, causing pollution to the water body.

(2) The water body basically loses its self purification function

The revetment of the whole section of the river is in the form of masonry sloping, with low biodiversity, degraded water ecosystem and poor self purification capacity.

(3) The water body is relatively closed

The north of village y is located at the end of the water body, with only one small flow tap water replenishment point, and the water flow is basically illiquid. Even when the water is diverted and drained, because the replenishment only relies on the gravity flow of dn400 pipeline, the hydraulic exchange is relatively slow, the pollutants are difficult to dilute and diffuse, and the pollutants are unevenly distributed, becoming a dead corner of the river.

4. Analysis of River Water Quality Treatment Test

4.1. Water Quality Investigation

Table 1. River water quality monitoring data

Water quality index	Company	Range
Ammonia nitrogen	mg/L	1.1-1.7
DO	mg/L	1.5-2.6
Transparency	cm	25-67
ORP	mv	83.3-123.5
CODcr	mg/L	9-74
TN	mg/L	1.2-23
TP	mg/L	1.5-3.1
Turbidity	NTU	21-58

The specific water quality is shown in Table 1. During the test, the temperature of the river water body was in the range of 19~30 ℃, and the pH value was in the range of 7~8. Under normal conditions, river B was a slightly black and odorous water body.

4.2. Analysis of Ammonia Nitrogen Removal Effect in the Test

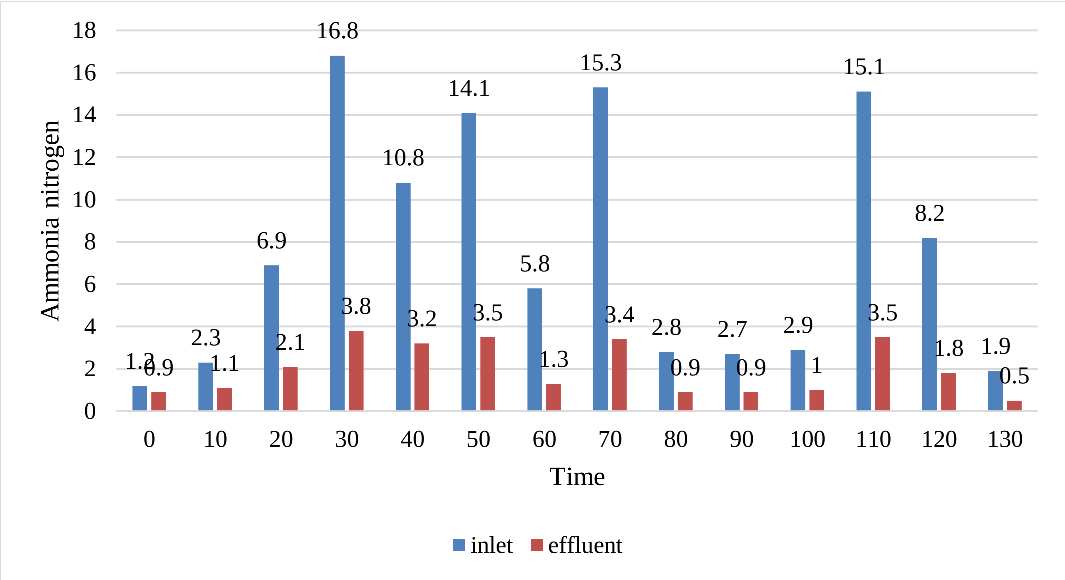

Figure 1. Removal effect of ammonia nitrogen

As shown in Figure 1, the integrated equipment began to operate in the middle and early ten days of May. From June to July, the city ushered in the plum rain season. The rainfall was relatively frequent, the river was relatively polluted by runoff, and the ammonia nitrogen influent concentration of the integrated equipment fluctuated greatly, with the maximum influent concentration reaching 16.8mg/l. However, under the condition of high ammonia nitrogen influent, the average removal rate of ammonia nitrogen by the integrated equipment was also higher than 70%. It can be seen that the equipment can maintain a good effect on the removal of ammonia nitrogen when the ammonia nitrogen in the influent fluctuates. As the pilot test continued, the ammonia nitrogen removal capacity of the equipment increased steadily from August to September, and the ammonia nitrogen removal rate remained above 80%, which was better than the previous treatment effect. The reason was that the biological activity of nitrifying bacteria gradually increased with the increase of water temperature. Studies have found that the growth of nitrifying bacteria will increase by 10% when the water temperature rises by one degree. Judging from the concentration value of ammonia nitrogen in the inlet and outlet water, the range of ammonia nitrogen in the inlet water of the integrated equipment is 1.2~16.8 mg/l, and the range of ammonia nitrogen concentration in the outlet water is 0.5~2.1 mg / L. although the fluctuation of ammonia nitrogen concentration in the inlet water is relatively large, the ammonia nitrogen concentration in the outlet water is far lower than that in the inlet water, which shows that the equipment has a strong ability to resist impact load, and the effluent concentration of the equipment is basically maintained below 1 mg / L in normal weather, It can fully meet the ammonia nitrogen standard of class IV surface water. Based on the above analysis, it can be shown that the integrated equipment has a good ammonia nitrogen removal effect, and has a certain role in promoting the river water quality standard to reach the surface class IV water.

4.3. Analysis of Total Nitrogen Removal Effect

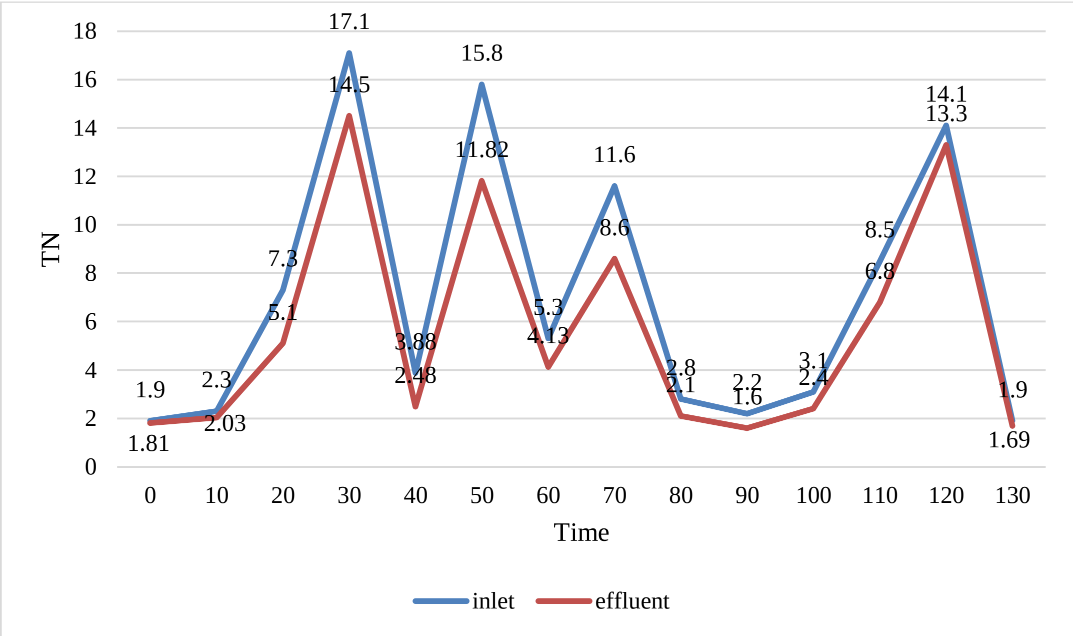

Figure 2. Removal effect of total nitrogen

As shown in Figure 2, a large number of nitrogen elements will lead to eutrophication of the water body after entering the water body, which is manifested as water bloom in fresh water. After the water body is further deteriorated, it will form a black and odorous water body. Monitoring the change of total nitrogen is also of positive significance to analyze the treatment effect of black and odorous water body. The total nitrogen removal effect of the combined process on urban black and odorous water is shown in Figure 5-6. During the pilot test, the removal effect of total nitrogen was relatively poor. The influent concentration of total nitrogen ranged from 1.7 to 16.9 mg/l, and the effluent concentration was 1.3 to 14.5 mg / L. there was little difference between the influent value and the effluent value. During the test, due to the influence of rainwater and other aspects, the total nitrogen inflow value of the equipment fluctuated greatly, and the total nitrogen removal function was not significant. This is mainly due to the short hydraulic retention time of the equipment and the high content of dissolved oxygen, which inhibits the denitrification reaction. The main reason for the low removal rate of total nitrogen is that the hydraulic retention time of the equipment is short, and the denitrification requires a long reaction process, so the obvious removal effect of total nitrogen cannot be achieved; At the same time, there is a high dissolved oxygen content environment inside the equipment, and there is a competitive electron between oxygen and nitrate. Generally, when the dissolved oxygen content is less than 0.5 mg/l, a better denitrification effect will be achieved.

Although the integrated equipment has a weak ability to remove total nitrogen, the nitrogen in the water body after treatment by the equipment is mainly in the form of nitrate, which will not deteriorate the water quality. At the same time, a large amount of nitrate in the water body is absorbed by aquatic plants, which can improve the ecological environment of the water body and reduce the black and smelly degree of the river.

4.4. Analysis of COD Removal Effect

Table 2. COD removal effect

Time	Inlet	Effluent
0	19.8	13.9
10	14.9	9.1
20	23.6	18.6
30	76.6	28.3
40	67.1	24.2
50	54.7	22.3
60	16.9	5.1
70	64.3	23.6
80	11.2	5.8
90	9.8	4.2
100	15.6	8.6
110	19.7	5.6
120	55.1	20.2
130	13.2	4.9

According to table 2, in general, the operation effect of the integrated equipment is good. From August to September, the influent water is relatively stable, the COD removal rate is in the range of 50~60%, and the average removal rate is 54.9%. At the same time, it can be found that when the influent concentration of COD is high, the removal rate will not decline, because the organic concentration in the water body increases, and the microorganisms in the equipment have sufficient nutrient sources and proliferate in large numbers, which can effectively remove the organic matter in the black and smelly water body. Based on the above analysis, the integrated equipment has a stable COD removal capacity. Although the influent concentration fluctuates greatly, the effluent value meets the standard of class IV surface water. In order to further improve the COD removal capacity of the equipment, it is necessary to extend the hydraulic retention time, which can not meet the expectation of quickly alleviating the black odor phenomenon. From the perspective of engineering, the treatment effect of the equipment can meet the requirements.

4.5. Analysis of Turbidity Removal Effect

It is easy to know from the figure that the turbidity value of the water body fluctuates greatly. The incoming water turbidity ranges from 16.0 to 50.2 NTU, and the outgoing water turbidity ranges from 1.32 to 12.4 NTU. The highest removal rate is 94.4%, and the lowest removal rate is 68.3%. In most cases, the removal rate of turbidity remains around 90.0%. The reason for the occasional low removal rate is that the backwashing of the equipment is not carried out in time, so the turbidity value of the effluent will be high. From the operation of the integrated equipment to August 29, add PAC coagulant with a concentration of 5-20 mg/l to the upper part of the biological aerated filter, and the turbidity removal effect is better, but it has no obvious advantage compared with no PAC coagulant. The reason is that most suspended particles are basically filtered out after the influent passes through the multi-stage filtration of mud water separator, sand filter tank, biological aerated filter and three-stage filter, After adding PAC coagulant, the removal effect of turbidity cannot be significantly enhanced, but the coagulant has a strong promoting effect on the removal of phosphorus. Based on the above analysis, the integrated equipment can achieve better turbidity removal effect by relying on physical filtration and biological adsorption.

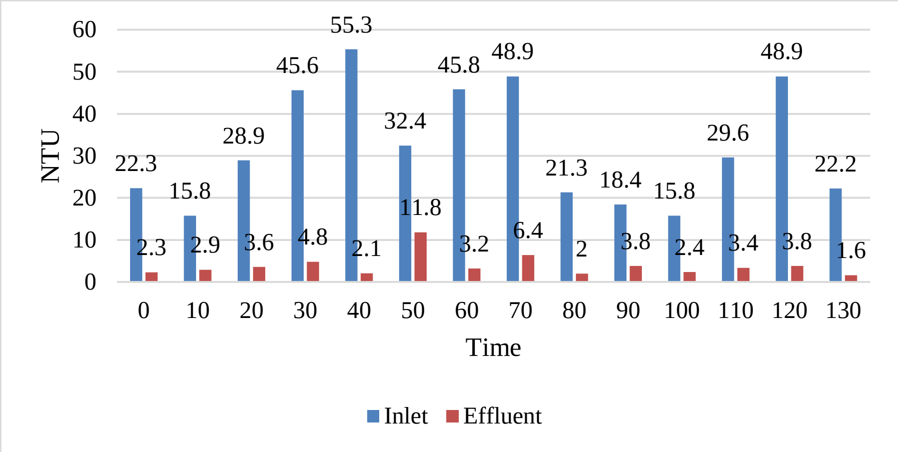

Figure 3. Turbidity removal effect

5. Conclusion

In this paper, the multi-stage filtration biological aerated filter combined process is used to treat urban black and odorous water. Through long-term experimental operation, the feasibility of the promotion of this process is verified. The whole test process is divided into laboratory pilot test and field pilot test. The effects of influent ammonia nitrogen concentration, hydraulic load and filter material filling height on the removal of ammonia nitrogen and COD in water by three groups of biological aerated filters are studied; In the field pilot test part, the multi-stage filtration biological aerated filter combined process designed on the basis of small-scale test theory is mainly studied to remove ammonia nitrogen, total nitrogen, COD, total phosphorus and turbidity in urban black and odorous water, and good results have been achieved.

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Data Availability

Data sharing is not applicable to this article as no new data were created or analysed in this study.

Conflict of Interest

The author states that this article has no conflict of interest.

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