Experiment on Surface Water Pretreatment by Biological Contact Oxidation Process Filled with Modified Suspending Biochemical Packing

Wen-Feng TANG¹, ² Feng-Ying Sun¹

¹College of Earth and Environment, Anhui University of Science & Technology, huainan 232001, China
²College of Civil Engineering, Huainan Union University, huainan 232038, China
E-mail: fengtang0@163.com

Abstract. In this paper, surface water of mining cities is pretreated by biological contact oxidation process filled with modified suspending biochemical packing, the characteristics of natural biofilm and the removal of organic pollutants, ammonia nitrogen, total nitrogen and turbidity in surface water were studied. The results show that the structure of mature biofilm is stable and the microbial population appears diversity, and the system has good removal effect on ammonia nitrogen and total nitrogen during the stabilization period, while the removal of organic pollutants and turbidity is slightly worse, the removal effect of the system on organic pollutants, ammonia nitrogen and total nitrogen is better at higher temperatures; on the contrary, the system has a good removal effect on turbidity at lower temperatures.

1. Introduction

The rapid development of China’s economy in the last 40 years has significantly improved the living standards of the people, but at the same time it also brings about great pollution to the water ecological environment. The quality of most surface water in China is deteriorating and its quality is characterized by high ammonia nitrogen, high turbidity and high organic pollutants, which poses a great threat to the safety of drinking because water surface water is the main source of drinking water. Faced the deterioration of surface water quality, traditional water treatment technology has become inadequate and the water supply has been unable to meet the requirements for drinking water, so the search for alternative or improved processes is an inevitable trend. Pretreatment means some proper physical, chemical and biological processes are used before the conventional process to realize primary removal of pollutants in water to reduce the burden of routine and deep processing and improve the removal efficiency of pollutants and drinking water quality¹. The biological contact oxidation method is a high efficient water treatment process for purifying wastewater by the biofilm attached to the packing, which is the biofilm method with the characteristics of activated sludge method and has the characteristics of high efficiency and energy saving, small footprint and no need of spoil disposal². The selection of packing is the core of biological contact oxidation and directly affects the water quality and operation management of biological contact oxidation³. Through simulating the experiment, in which the biological contact oxidation process was added before the conventional water treatment process and the modified suspending biochemical packing was used for
biological pretreatment surface water, the effects of biological contact oxidation on organic pollutants, turbidity, ammonia nitrogen and total nitrogen in biological pretreatment stage were studied to provide theoretical reference for further research and even engineering practice.

2. Materials and methods

2.1. Experimental equipment and process

The experimental equipment is shown in Fig.1. The raw water enters at the bottom and flows out from the top. The biological contact oxidation reactor of experimental equipment is made of organic glass column, whose diameter and total height are 350mm, 3.0m respectively, and the modified suspending biochemical packing is installed in the reactor, the filling rate is 50%; the packing specification is D25×9mm; the specific surface area is greater than 500m²/m³; the proportion is 0.95g/cm³; the void ratio is 95%, and the accumulative number is 130,000/m³. The modified suspending biochemical packing has a larger specific surface area and impact resistant ability; the porous structure of the fillers and the addition of nanomaterials which can promote bioenzyme catalysis, are more conducive to the growth and reproduction of various microorganisms and the adhesion of biofilm. A perforated tube aeration system is set at the bottom of the reactor for aeration.

![Fig.1 Process of biological contact oxidation for pretreatment of surface water](image)

2.2. Experimental water and conditions

The experimental water was taken from a reservoir. The water intake point is 5~8m from the shore, and the water quality indicators are shown in table 1.

| Items                  | Value            | unit   |
|------------------------|------------------|--------|
| Chemical oxygen demand | 8.54~12.68       | mg/L   |
| Ammonia nitrogen       | 6.45~8.75        | mg/L   |
| Turbidity              | 12.5~31.8        | NTU    |
| Water temperature      | 5.0~24.0         | °C     |
| Total nitrogen         | 8.67~10.72       | mg/L   |
| pH value               | 6.6~8.5          |        |

Water inflow, gas-water ratio and hydraulic retention time of this experiment are 1.0~1.5m³/h, 1:1 and 35min~40min respectively. This experiment lasted for 10 months, that is, from the beginning of March to the end of December. Water samples are sampled every Monday and Thursday during the trial period to measure pollutant concentration indexes such as organic pollutant, ammonia nitrogen, turbidity and total nitrogen. In order to eliminate the accidental error, the average monthly data is taken as the final test value of this month.
2.3. Experimental items and methods
Organic pollutant: Acid potassium permanganate method; Ammonia nitrogen: Sodium reagent spectrophotometry; Total nitrogen: Potassium persulphate uv spectrophotometric method; Turbidity: Turbidimeter method.

3. Results and analysis

3.1. Biofilm culturing

3.1.1. Method of biofilm culturing.
The cultivation and formation of biofilm in suspending packing bioreactor is the key to the normal operation of the process\textsuperscript{4}. the method of natural biofilm culturing was used in order to ensure the quality of biofilm culturing, and during the biofilm culturing, the water inflow was controlled between 0.9\textsuperscript{3}h and 1.0\textsuperscript{3}h, and the gas-water ratio was 0.75:1. The pollutants such as organic pollutant, ammonia nitrogen and turbidity were measured daily from the 8th day after the beginning of biofilm culture and the removal rate of ammonia nitrogen is used as the basis for determining whether the biofilm is successful or not.

In the initial stage of biofilm culturing(On 7th day), a light yellow translucent film is found on the packing surface, but it is loose. Two weeks later, the filler is observed with a large number of zoogloeas and a small number of protozoa and the distribution of microorganisms is uniform, and some of the floating fillers appear to have obvious yellow-brown patches.

3.1.2. Time of biofilm culturing
During the biofilm culturing, the removal efficiency of ammonia nitrogen pollution index was investigated and it is believed that the system is successful when the removal rate of ammonia nitrogen is more than 60\%\textsuperscript{5}. The removal of ammonia nitrogen by the system during the biofilm culturing is shown in Fig.2.

![Fig.2 Removal efficiency of ammonia nitrogen by biological contact oxidation during the biofilm culture period](image)

As can be seen from Fig.2, it takes about 3 weeks to culture biofilm successfully; at this time, the removal rate of ammonia nitrogen can be stable to more than 60\%. After the biofilm has been cultured successfully, there is a dense layer of biofilm on the packing surface, whose thickness is about 1~2mm(See Fig.3). The biofilm is slightly brownish and a large number of fungi, amoeba, bell worms and other bacteria, protozoa and metazoan animals can be observed under the microscope after the dissection(See Fig.4).
3.2. Removal efficiency of each pollutant
After the biofilm has been cultured successfully, the removal efficiency of pollutants such as organic pollutant, ammonia nitrogen, total nitrogen and turbidity were studied under the conditions of water inflow of 1.0 ~ 1.5m$^3$/h, gas-water ratio of 1:1 and hydraulic residence time of 35min~ 40min.

3.2.1. Removal efficiency of organic pollutant
Organic pollution in surface water is one of the main problems in drinking water treatment$^{[6]}$. Fig.5 shows the removal efficiency of organic pollutant by the system.

![Fig.5 Removal efficiency of organic pollutant by biological contact oxidation during the stable period of run](image)

It can be seen from Fig.5 that it is limited to remove organic pollution of surface water through the biological contact oxidation process filled with modified suspending biochemical packing, the
maximum removal rate is 13.88% and the average removal rate is 10.94%. The removal rate of organic pollutant is slightly higher from April to September and the removal rate is above 10%. However, the removal rate in other months is less than 10%. In other words, the removal efficiency of organic pollutant in the month of high temperature is slightly higher than that in the month of low temperature. The reason for above phenomenon may be the concentration of organic matter in surface water is low, and the limited organic matter in surface water aggravate the competition of nitrobacterium, nitrite bacteria and heterotrophic bacteria and the competition inhibits the growth and reproduction of heterotrophic bacteria which mainly consume organic matter. In addition, it is slightly warmer than other months from April to September, the higher temperature increases the biological activity of heterotrophic bacteria, promote the growth and reproduction of heterotrophic bacteria, thus shows a better removal effect on organic pollutant.

3.2.2. Removal efficiency of ammonia nitrogen

The removal rate of ammonia nitrogen in conventional water treatment process is very low and is only 18.9%[7]. The pretreatment effect of biological contact oxidation process filled with modified suspending biochemical packing on ammonia nitrogen of surface water was studied in the experiment and Fig.6 shows the removal effect of the system.

Fig.6 Removal efficiency of ammonia nitrogen by biological contact oxidation during the stable period of run

It can be seen from Fig.6 that the removal rate of ammonia nitrogen gradually increases from March to August, and it gradually decreases after September. During the entire trial period, the highest removal rate appears in August and the removal rate is up to 80.26%, while the lowest rate of removal appears in March and December and it is about 48%. It is because the temperature gradually increases from March to August, which increases the activity of nitrobacterium and nitrite bacteria and promotes its growth and reproduction, thus the process improves the removal efficiency of ammonia nitrogen. On the contrary, the temperature of indoor and outdoor environment shows a downward trend from September to December, the decreasing of water temperature reduces the activity of nitrobacterium and nitrite bacteria, inhibits its growth and reproduction, and weakens its nitrification, so the removal effect of ammonia nitrogen is worse.

3.2.3. Removal efficiency of total nitrogen

Fig.7 shows the removal effect of biological contact oxidation process filled with modified suspending biochemical packing on total nitrogen.

It can be seen from Fig.7 that the removal effect of the system on total nitrogen is significantly lower than that on ammonia nitrogen, but it still has certain removal ability and average removal rate can reach 39.82%. The reason for this is that the removal of total nitrogen includes three stages (ammonification, nitrification and denitrification) in the process of biological denitrification, the denitrification stage is the final part of total nitrogen removal; the success of denitrification stage
depends on the number and activity of denitrifying bacteria and the completion of the ammonification and nitrification stages. However, in the process of biological contact oxidation, it is mainly aerobic environment, which is not conducive to the growth and reproduction of denitrifying bacteria that mainly exist in the innermost layer of biofilm, the nitrate nitrogen transfer is constrained by the outer layer of biofilm, which affects the denitrification. In addition, ammonification and nitrification are the preconditions of denitrification, and the denitrification is also restricted to some extent.

![Graph](image1.png)

Fig. 7 Removal efficiency of total nitrogen by biological contact oxidation during the stable period of run

It can be also seen from Fig. 7 that the effect of the system on total nitrogen from April to October is better than that in other months and the removal rate is above 40%. This may be mainly due to the high temperature from April to October, which is conducive to the growth and reproduction of microorganism and promotes its biological activity, and leads to higher removal rates.

3.2.4. Removal efficiency of turbidity

Fig. 8 shows the removal effect of biological contact oxidation process filled with modified suspending biochemical packing on turbidity.

![Graph](image2.png)

Fig. 8 Removal efficiency of turbidity by biological contact oxidation during the stable period of run

It can be seen from Fig. 8 that biological contact oxidation process filled with modified suspending biochemical packing used for pretreatment surface water has certain effect on the removal of turbidity and the removal rate is relatively stable. During the nearly 10-months trial period, the maximum removal rate, the lowest removal rate and the average removal rate of turbidity are 24.8%, 14.7% and 19.87% respectively. In addition, the removal effect on turbidity from May to September is slightly worse than that in other months. The average removal rate of two time quantum is 16.91% and 22.82% respectively, and the average removal rate of the former is 5.91% lower than that of the latter.
The reason for above phenomenon may be the subtle organic matter, which are suspended in the original water, and colloidal state will be adsorbed and degraded by suspended packing when the original water flows through the contact oxidation reactor. Therefore, the system shows a certain removal effect. However, the amount of biodegradable organic matter in original water is relatively small, and the adsorption capacity of suspended packing is also limited. In general, the removal ability of the system to turbidity is not high. In addition, the higher temperatures from May to September accelerates microbial metabolism and promotes the rapid reproduction and aging of microorganisms, and a large number of aging and peeling biofilms lead to lower turbidity removal rates during this period.

4. Conclusion
1. It takes about 3 weeks to culture biofilm successfully when the natural culture method of biofilm is adopted. After the biofilm is successfully cultured, the structure of mature biofilm is stable, the microbial population appears diversity, and the system has better removal effect on ammonia nitrogen.
2. During the stable period, biological contact oxidation process filled with modified suspending biochemical packing used for pretreatment of surface water has better removal effect on ammonia nitrogen and average removal rate reaches 65.16%, the removal efficiency of organic pollutant, total nitrogen and turbidity is relatively low and average removal rate are 10.94%, 39.82% and 19.87% respectively.
3. In warmer months, the system has better removal effect on organic pollutant, ammonia nitrogen and total nitrogen, while the removal of turbidity is better in colder months.

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