Pilot-scale Study of River Sewage Treatment by Aerobic-anaerobic Reactor

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Abstract: The work conducted a pilot-scale study of sewage treatment of a certain river in the Yuquan District of Huhhot by aerobic-anaerobic fixed-bed bioreactor constructed by Kaldnes carriers. After the reactor started off to work, the biological film on the stuffing increased the thickness to about 1 mm a week later. It is shown from the results after a continuous operation of 30 d that the ammonia nitrogen will become 5-10 mg/L when the water ingress COD is 60-150 mg/L and will get lower than 2 mg/L when the effluent COD is under 40 mg/L. If the concentration of effluent suspended solid without precipitation is below 10 mg/L and the chroma is inferior to 1,00 after the device is of stable operation, it can be indicated that the reactor is effective for the removal of organic matter, ammonia nitrogen and chroma. The pilot-scale experiment in the work verifies the feasibility and advantages of river sewage treatment in use of this reactor, which proposes the new concepts and methods for the river sewage treatment.

1 INTRODUCTION

At present, the seven largest rivers of China are all facing pollution of different degrees. Especially in the 138 urban rivers, the vast majority that flow through the prosperous areas are polluted in varying levels, among which 38% are under the national surface water quality standard V grade. Thus, it clearly reflects based on the facts above that China is now suffering severe water pollution and obvious deterioration trend. Currently, there are mainly three kinds of river sewage control technologies already in use or tested both at home and abroad: physical, chemical and biological methods. But the chemical methods are not applicable here due to the large amount of waste water and relatively low pollutant concentration. With regard to river purifying technology, so far in China, only physical methods, such as water dilution and desilting, have been put into realistic application. However, physical methods are always palliatives that treat the symptom but not the underlying problems.

Biological methods are the mostly studied by the reasons that the organic matter, nitrogen and phosphorus can be effectively dislodged from the waste water by this method. Thereinto, most of the research aims at the biofilm technology, but the disadvantage is that the excess sludge produced in the process of waste water treatment is easy to cause secondary pollution. In particular, the excess sludge will increase the sediment quantity. Prolonged pollutants degradation is bound to exert a potential adverse effect on the function of rivers. In order to remove pollutant and reduce sludge, it is effective to add stuffing into the aeration tank, or enhance the biomass and the residence time of microorganism. One of the most common biofilm technologies is the Moving Bed Biofilm Reactor (MBBR). Kaldnes stuffing is added to the aeration tank and anaerobic tank so as to enhance the biomass and reduce the sludge. On account that the carrier, having a cutting effect on bubble, is added to the reactor, the aeration rate will be inferior to that by the conventional biological methods. For this reason, it can finally increase the unit concentration of microorganism and decrease the construction and operation costs. MBBR has been widely adopted in the upgrading and rebuilding of sewage treatment plants in Europe. While in China, the method is only experimented in the Lucun Wastewater Treatment Plant in Wuxi and has achieved satisfactory results.

With the accretion of population, the Heihe River in the Yuquan district of Huhhot suffers severe contamination. Most parts of the river are classified under V grade or worse than V grade 1, with the pollution characteristics as synthetic organic pollution. Ammonia nitrogen and total phosphorus are the main pollutants, and the

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domestic runoff is the primary pollution source, followed by industrial waste, poultry and stock farm, farmland and surface runoffs. The research utilized aerobic-anaerobic biointerval moving bed reactor (hereafter referred to as reactor) to dispose the sewage. In this way, it is conducive to maintaining microorganism inside the reactor in high concentration and enhance the unit processing load. There is no need of nitrification liquid reflux to cut down energy consumption. Moreover, the diverse aerobic and anaerobic environment inside the reactor can reduce the productivity of excess sludge in the process of sewage treatment. Thus, the goal can be achieved that the excess sludge is decreased or even eliminated at the same time of treating the waste water. This reactor adopts the Kaldnes carrier that is extensively used in the market. The Kaldnes carrier is known for the characteristics of large specific surface area, big quantity of biofilm formation and fast biofilm forming speed.

In order to further explore the effects and feasibility of the reactor on removing the organism and nitrogen in the water courses of Huhhot, the pilot-scale test was carried on to study the process of river sewage treatment. This, as a result, accumulated abundant engineering data for the popularization and application of this technology.

2 TEST MATERIAL AND METHOD

2.1 The Water Samples Were Collected in the River near Yuquan District in Huhhot.

The quality of waste water was tested with pH between 7.0 and 8.2, ammonia nitrogen between 5 and 10 mg/L, TP between 0.2 and 1 mg/L, COD between 60 and 150 mg/L and chroma between 200 and 500. The water temperature during this period was between 18 and 24□.

2.2 Testing Apparatus and Process Flows

The pilot plant and process flows in the sewage treatment are shown as follows. The pilot plant has a height of 1.2 m (effective height of 1m), width of 0.33 m and length of 3 m. Interrupted by the clapboard, the plant can be divided into nine zones. The volume of the whole reactor is 1 m3. Inside the reactor, there is 65% of Kaldnes stuffing, with a diameter of 2 cm, thickness of 1 cm and specific surface area of 450 m2/m3, placed in the reactor. The void fraction of the reactor is 95%. Through placing perforated aerator pipe at different positions inside the reactor, the aerobic zone and anaerobic zone are alternatively formed. The gas water ratio is kept within 15:1 and the residence time of waste water in the reactor is 10 h. By this method, the sewage is pumped into the reactor from the river with no need for primary settling tank or regulating reservoir. Besides, the waste water can directly be drained after reactor processing with no use for secondary settling tank and can flow in the way of baffling in the reactor. The amount of daily water treatment reaches 2.4 tons.

2.3 Test Methods and Plant Operating Conditions

Before the test, the activated sludge by filter pressing should be collected from the nearby sewage treatment plant and inoculated to the reactor in the front. The inoculum concentration should be controlled within the range between 10% and 15% of the reactor volume. At the back of the reactor, two aerobic zones should inoculate microorganisms domesticated in the lab to remove the nitrogen-containing compounds. Such microbial populations contain quite a few nitrifying and denitrifying bacteria, by which they can effectively remove the nitrogen-containing compounds. Then the inoculated reactor begins to input water continuously. After a week, the microorganisms inside gradually adapt to the characteristics of river sewage. The biofilm on the carrier has a thickness of 1 mm and is khaki in color. Owing to the aeration that makes the Kaldnes stuffing keep tumbling, the internal biofilm of Kaldnes stuffing at the aerobic zone gains a higher thickness than the external surfaces. While in that the Kaldnes stuffing at the anaerobic zone stays static, the sludge stacks between the inner side and outer side interspaces and is black in color. When the reactor can outlet water stably, it is time for data detection. Samples should be collected in both the entrance and exit of reactor. During this period, the test mainly explored the effects of reactor under a certain residence time on the removal of organism, ammonia nitrogen, SS, turbidity and phosphorus as well as the variations of dissolved oxygen (DO) inside. Based on a series of laboratory research on the residence time for river sewage of different concentrations, the pilot-scale test controls the time within 10 h.

2.4 Analysis Methods

The test adopted the analysis methods including potassium dichromate method for COD

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measurement, Nessler's reagent colorimetric method for chroma measurement, ammonium molybdate spectrophotometric method for determination of ammonia nitrogen content and laws of weight for determination of suspended sludge (SS) and the concentration variations of microorganisms on the stuffing. Portable dissolved oxygen instrument (Hash DO6+) was used to test the concentration of dissolved oxygen (DO) at different positions of the reactor.

3 RESULTS AND DISCUSSION

3.1 Removal Efficiency of Reactor on the Organism

After a week or so, the reactor can perform stably after some debugging. With a continuous operation for 30 days, the reactor is able to effectively remove the organism from the waste water. Even if the concentration of organic pollutants fluctuates wildly, the exit COD of reactor can still keep stable, all under 40 mg/L. This reflects that the reactor can steadily wipe out the organic pollutants from the river sewage. The main reason lies in the biofilm suspended on the Kaldnes carrier that enhances the monolithic microorganism concentration. By weighing the microorganism on the stuffing after elution, the concentration can reach 6 to 8 g/L, which is conspicuously higher than that with the conventional activated sludge method.

3.2 Removal Efficiency of Reactor on the Ammonia Nitrogen

It is shown that the concentration of ammonia nitrogen is approximately 8 to 10 mg/L from the variation of ammonia and nitrogen in the entrance and exit of the reactor. This indicates that the river is suffering very serious pollution and eutrophication. After treating the waste water through the reactor, the concentration of ammonia nitrogen in the exit becomes lower than 2 mg/L and the plant keeps a stable performance in removing the ammonia nitrogen. The reactor constructed in this research contains a repeated alternation from being aerobic to being microaerobic, then to being anaerobic. On this account, the nitrate and nitrite produced at the aerobic zone can be used for denitrification at the next anaerobic zone. In this case, there is no need of nitrification liquid reflux to accomplish denitrification, which is quite helpful to save energy. Compared with the A20 technology frequently used in the urban sewage treatment plants at present, this reactor makes it easier to operate and saves the transportation expenses since nitrification liquid reflux is no longer required.

3.3 Variation of Phosphorus in the Reactor

The removal efficiency on phosphorus is not apparent because the excess sludge production is not sufficient in the operation process. But the concentration of phosphorus is rather low in the river, basically around 0.8 mg/L. After being treated by the reactor, the phosphorus concentration in the exit can reach 0.5 mg/L or so. With regard to other water courses, if the phosphorus content is pretty high in the river, then there is a need to add medical flocculation precipitation at the exit of the reactor to wipe out the phosphate so as to reach the discharge standard.

3.4 Removal Efficiency of Reactor on SS

It can be seen from the SS variations at the entrance and exit of the reactor that the SS of water inflow is about 30 to 60 mg/L while the SS of the exit is lower than 10 mg/L with mean of 5 mg/L. This reveals that the reactor has a very good effect on sludge reduction. The main reason lies that the porous Kaldnes stuffing placed in the reactor can effectively intercept the SS at the anaerobic zone. Then the intercepted SS can resolve at the anaerobic zone and the organism released can be used as the carbon source of denitrification. Studies have shown that the aerobic, microaerobic and anaerobic alternative environment in the reactor is prone to separate the anabolism from catabolism of microorganisms and drop down the productivity of sludge. Therefore, it is believed that the environment which is collectively aerobic, microaerobic and anaerobic can reduce the SS in its favor, especially conducive to the sewage treatment in the heavily polluted rivers. In addition, after analyzing the concentration of dissolved oxygen (DO) at different positions by means of DO instrument, it can also be discovered that the DO concentration at the aerobic zone is 3 to 4 mg/L and goes up as the travel distance increases while the DO concentration at the anaerobic zone is only 0-0.5 mg/L. This result can explain that the alternation phenomenon of being aerobic and anaerobic happens at the direction of reactor horizontal flow.

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3.5 Removal Effect of Reactor on Chroma

The original chroma of the river is dark and seriously polluted. Seen from the appearance, the water is almost black with peculiar smell. The chroma of sewage tested is between 200 and 500. And after being treated through the reactor, the muddy water gets transparent with the chroma reduced to 50 to 100. This manifests that the reactor is able to steadily and efficiently clear the pollutant and chroma in the sewage.

4 CONCLUSIONS

(1) It can be concluded that the aerobic-anaerobic repeatedly alternative moving bed biofilm reactor (abbreviated as the reactor) is able to treat the river sewage effectively according to the results gained from the continuous sewage treatment after the stable operation of the reactor in 30 days. When water inflow is between 60 and 150 mg/L and the hydraulic retention time is 10 h, the exit COD can be maintained at about 40 mg/L.

(2) This technology has a certain resistance to COD impact and a strong adaptability to the concentration variations of organism in the waste water. Thus, there is no need of regulating reservoir and secondary settling tank. The exit SS is inferior to 10 mg/L.

(3) The resistance to COD impact is displayed in this technology. The Kaldnes stuffing inside the reactor enhances the concentration of microorganisms to the twice of biomass with the normal activated sludge method. Moreover, the plug-flow reactor is conducive to blending the sewage and microorganism so that the reactor shows a stronger adaptability.

This reactor can form an aerobic and anaerobic environment in the flow direction. This environment can effectively remove the ammonia nitrogen in the waste water. When the concentration of ammonia nitrogen at the entrance reaches 8 to 10 mg/L, the concentration of ammonia nitrogen at the exit will drop down to less than 2 mg/L. After the reactor performs steadily, the SS of the water outlet keeps below 10 mg/L with a mean concentration of 5 mg/L. This reflects that the coefficient of sludge production in the reactor is pretty low, so no secondary settling tank is needed for sewage treatment. Such is also regarded as one of the remarkable advantages of this technology.

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