Research on Water Treatment Technology of Low-energy Membrane Bioreactor Based on Computer Automation

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Abstract. Compared with traditional sewage treatment technology, it has the advantages of good effluent quality, high treatment efficiency, and automation. This article analyzed the mechanism of causing membrane fouling during its operation and proposed control strategies relying on computer automation technology, introduced several new membrane bioreactors and methods for process improvement, and finally looked forward to its future development trend.

Keywords: Membrane Bioreactor, Sewage Treatment, Membrane Fouling, Process Improvement

1. Introduction
Membrane bioreactor (MBR) is a new type of high-efficiency sewage treatment technology that combines traditional biological treatment units and membrane separation technology. Compared with traditional sewage treatment technology, it has greatly improved the treatment efficiency and economic benefits [1]. Membrane separation technology for sewage treatment originated in the late 1960s. Researchers used membrane separation technology to replace the secondary sedimentation tank for sewage treatment, which formed the prototype of the membrane bioreactor. The problem cannot be effectively solved, so the membrane bioreactor has not received widespread attention [2]. In the 1980s, with the development and utilization of membrane materials, increasing maturity of membrane cleaning and regeneration technology, MBR technology is substantially developed. In Asia, Japan first included membrane technology for water treatment and reuse in the national scientific research plan, and made breakthroughs in the anaerobic membrane-biological combination process, further promoting the development of the MBR process. Membrane bioreactor technology ushered in the golden age of its development in the 1990s, various countries have joined in the development and research of MBR technology in succession, the research on the membrane fouling, microorganism metabolic characteristics, process flow and optimization of operating conditions has been continuously deepened [3]. In order to save energy consumption, some scholars proposed to put the membrane module directly in the aeration tank for the first time, and carried out the research of the integrated membrane bioreactor for sewage treatment [4]. In recent years, MBR combined technology has received more and more attention, and has become a new research trend to couple MBR with other technologies to develop new membrane bioreactors. With the continuous deepening of membrane fouling research, people have also made some achievements in the research of membrane modification and the development of new membrane materials. In addition, other scholars have used pervaporation technology to synthesize a highly permeable polymer membrane material under normal pressure,
which has broad applications in wastewater treatment. This article analyzed the mechanism of causing membrane fouling during its operation and proposed control strategies, introduced several new membrane bioreactors and methods for process improvement, and finally looked forward to its future development trend [5-6].

China's research on membrane bioreactors for sewage treatment started up late, but developed rapidly. In the 1990s, domestic universities and scientific research institutions were committed to the development and research of membrane bioreactors, and the MBR technology has made great progress with the support of the Ministry of Science and Technology. In recent years, China's MBR technology has made in-depth development, and a series of research results have been achieved in the areas of MBR combined process, MBR economic research, and the impact of metal ions on membrane pollution. With the increasing scarcity of global water resources and increasing pollution of water, membrane bioreactor technology is receiving more and more attention. It is expected that through the improvement of sewage treatment technology to achieve the recycling of water resources. This article analyzed the mechanism of causing membrane fouling during its operation and proposed control strategies, introduced several new membrane bioreactors and methods for process improvement, and finally looked forward to its future development trend.

2. MBR process

2.1. MBR principle
Membrane bioreactors combine modern membrane technology with bioreactors. The principle is that microorganisms adhere to the surface of a specific carrier in the reaction system. When sewage flows through the reactor, microorganisms will adsorb and degrade the pollutants in the reactor. A more complete microbial degradation system will be formed. The interception effect of the membrane can retain microorganisms with a long generation cycle and greatly improve the efficiency of sewage treatment and the quality of the effluent water.

MBR is mainly composed of three parts: bioreactor, membrane module and control system. According to the aerobic need, it can be divided into aerobic membrane bioreactor and anaerobic membrane bioreactor. According to the role of membrane module, it can be divided into solid-liquid separation membrane bioreactor, extraction membrane bioreactor and membrane aeration membrane bioreactor. According to the combination of membrane module and bioreactor, it can be divided into two types: external and integrated. The external membrane separation device is placed outside the biological reactor, the sludge mixed liquid is separated by the membrane and the sludge is intercepted and flowed back into the bioreactor. The integrated membrane bioreactor organically combines membrane separation technology and biotechnology, and the membrane module is placed in the reactor. The membrane separation device is used to intercept the activated sludge and organic matter in the reaction tank, replacing the traditional secondary sedimentation tank, greatly improving the biomass in the reaction tank, and achieving separate control of the sludge residence time and hydraulic residence time.

2.2. Process characteristics
The quality of effluent water is high. After the sewage is processed by the membrane bioreactor, the amount of COD and BOD and the turbidity of the water is significantly reduced, and the water quality meets the water quality standards for domestic water.

The separation effect is good and the sewage discharge ability is strong. In MBR technology, the separation of the membrane allows the system to effectively intercept free bacteria and pollutants, making the solid-liquid separation effect better than the traditional gravity sedimentation separation of the second settling tank, and will not deteriorate the effluent water quality due to sludge expansion. At the same time, the structure can be added according to actual needs, the number of modules can be increased, and the efficiency of sewage treatment can be improved.

High degree of automation. The equipment is easy to operate and maintain, can be automatically
controlled, has a small footprint and is easy to manage.

The formation mechanism and control measures of membrane fouling in MBR. In the process of continuous operation of MBR, pollutants will continue to deposit in the membrane module, causing membrane clogging to form membrane pollution. Some studies have shown that membrane pollution has become the most important factor restricting the development of MBR process. During MBR operation, membrane filtration resistance is divided into three stages with the change curve of filtration time: the first stage and the third stage are steep rise stages, and the second stage is a slow rise stage. During the period when the membrane bioreactor starts to operate, under the suction effect, colloids and other suspended particles move faster. When passing through the membrane module, some of the colloidal suspended particles will block the pores of the membrane, and some of the solutes in the sewage will be adsorbed on the membrane due to adsorption, causing the membrane filtration pressure to rise sharply. As the filtration time expands, the sludge flocs in the sewage will be adsorbed on the membrane surface, but the adsorption process becomes very slow due to its larger diameter. In the process of these sludge flocs forming a sludge layer on the membrane surface, these sludge flocs largely block the adsorption of colloidal particles and membranes, so the performance of the membrane filtration resistance in the second stage increases slowly with the increase of filtration time. Under the continuous action of the suction force, the sludge layer attached to the membrane surface will be continuously compacted, which in turn leads to a sharp increase in membrane filtration resistance, the third stage is formed.

3. Computer automated MBR combined process and its recent development

3.1. Automatic coupling system of membrane aeration membrane bioreactor

Membrane aeration membrane bioreactor (MABR) automation is a new type of water treatment technology that combines membrane technology and biochemical treatment technology for automation. The gas separation membrane can be used as a carrier for microbial growth and metabolism. It provides an oxygen source. Compared with traditional MBR, MABR has a higher oxygen utilization rate and has a good treatment effect on high-concentration organic wastewater. Some experiments have found that when the dissolved oxygen (DO) is 0.8mg / L, the removal rates of ammonia, nitrogen and COD reached 87.88%, 86.5% and 87.64%, respectively, which proves that MABR has good nitrogen removal ability and high load rate performance.

In recent years, the hybrid MABR process has become a new development trend of the MABR process. Iron-carbon microelectrolysis can decompose long-chain organic matter into small molecule organic matter. The Fenton reaction will use a mixed solution of hydrogen peroxide and divalent iron ions. Many known organic compounds such as carboxylic acids, alcohols, and esters are oxidized to an inorganic state to remove some difficult-to-degrade organic pollutants. Finally, in order to meet the requirements of water output, ozone oxidation is used as an advanced treatment to further remove COD. As a pretreatment, the Fenton reaction is a biochemical system, and the membrane aeration membrane bioreactor is a biochemical system. The ozone oxidation technology is for advanced treatment of chemical wastewater. The effect of operating conditions on the concentration of COD in the effluent is explored. The research results show that the reaction time of iron-carbon reaction is 1.5h, pH value 4, Fenton reaction n (H2O2): n (Fe2 +) and pH are 9 and 3, respectively, after the pretreated wastewater through MABR, the total COD removal rate is as high as 92.9%. After treatment, the effluent COD is less than 500mg / mL, which meets the requirements of entering the sewage treatment plant. Some scholars have designed a set of integrated MABR system consisting of hydrolysis / acidification pretreatment, MABR process and activated carbon adsorption post-treatment, which can effectively remove more than 90 percent COD and more than 98% ammonia, the effluent quality after treatment remains stable, COD is less than 200mg / L.

3.2. Reactor coupling system of anaerobic membrane biological automation

Anaerobic membrane bioreactor (ANMBR) is formed by coupling anaerobic reactor and membrane
separation. It is an automatic new efficient sewage treatment technology that effectively combines membrane separation technology and anaerobic biological treatment unit. In the ANMBR process, the anaerobic reactor can not only realize sewage purification, but also generate a large amount of biogas for energy use. The interception of the membrane realizes the complete separation of hydraulic residence time (HRT) and sludge residence time (SRT), which greatly increases the organic volume load. Compared with the traditional anaerobic biological treatment technology, it has the advantages of short start-up time, excellent effluent water quality, low sludge output, and recyclable biogas energy. Some scholars use ANMBR to treat bamboo industrial wastewater, making the final COD removal rate reach 91%, i.e., removing most of the organic matter.

The lack of effective removal of nitrogen and phosphorus nutrients in urban sewage is a serious obstacle that restricts AnMBR's application in urban sewage treatment. Therefore, the development of a new sewage denitrification process by coupling AnMBR with anaerobic ammonium oxidation technology (Anaerobicam-monium oxidation analysis mmox, ANAMMOX). It has become a new research hotspot in recent years. ANAMMOX converts ammonia to nitrogen using nitrite (NO–N) as the electron acceptor under hypoxic conditions, and it is accompanied by a biological process during which the nitrite is used as the electron donor to fix CO2 and produce the nitrate (NO3–N). It has a greater advantage than traditional nitrification-denitrification denitrification. The comparison between anaerobic ammonia oxidation and traditional nitrification-denitrification is shown in Table 1.

### Table 1. Comparison between anaerobic ammonia oxidation and traditional nitrification-denitrification

| Condition / Type       | Traditional nitrification-denitrification | Anaerobic ammonia oxidation |
|------------------------|------------------------------------------|-----------------------------|
| Whether aerobic        | Need oxygen                              | No oxygen required          |
| Carbon source          | Organic carbon                           | Inorganic carbon            |
| CO2 production         | More                                     | Less                        |
| Ammonia removal rate   | Lower                                    | Higher                      |

The grid formula for sewage treatment is shown in equation (1):

\[ B = S(n - 1) + e \times n \]  

(1)

\( B \) is the width of the grid, \( S \) is the width of the grid, and \( e \) is the net clearance of the grid. The coarse grid \( e = 50-100 \text{mm} \), the medium grid \( e = 10-40 \text{mm} \), and the fine grid \( e = 3-10 \text{mm} \).

The head loss of the grid is shown in equation (2):

\[ H_l = k h_0 \]  

(2)

Among them, \( H_l \) is the head loss of the grid, \( h_0 \) is the calculated head loss, \( k \) is the coefficient, after the grid is blocked by pollution, the multiple of the head loss increases, generally 3.

It can be seen from the comparison that the new anaerobic ammonia oxidation denitrification process has the advantages of low oxygen consumption, energy saving, and lower process cost. For example, AnMBR is used as a reactor for enriching anaerobic ammonia-oxidizing bacteria, with ammonium chloride and nitrite as the substrate into water, realizing anaerobic ammonia oxidation by gradually shortening the hydraulic retention time. In the entire denitrification project, the removal rates of NO2–N and NH4 + -N were maintained above 90%, and the total nitrogen removal load (NRR) can reach a maximum of 0.49ks / (m3-d), which conforms to the anaerobic ammonia oxidation chemical reaction stoichiometry and achieves the expected nitrogen removal effect. In addition, the ANAMMOX-ANMBR coupling system was used to investigate pollutants in domestic sewage the treatment effect was calculated through the material balance calculation of the nitrogen removal path in the reactor at different stages. As a result, the total nitrogen removal load (NRR) was as high as 0.65ks / (m3d), the ammonia nitrogen in the effluent was less than 5mg / L, and the COD removal rate reached 87%. Achieved the ideal decontamination effect. In response to the slow growth of Anamox bacteria and membrane pollution, the domesticated nitrosating bacteria and anamox particles were put into an integrated air aeration full-process autotrophic denitrification-expanded particle sludge
bed-membrane bioreactor (CANON-EGSB-MBR). Using air aeration and continuous reflux the reactor was started, and the membrane performance and nitrogen removal performance of the reactor were investigated. The results showed that the membrane operation period was 5 times longer than that without aeration, and the total nitrogen removal rate reached 81%, therefore treating effectively the high-concentration ammonia nitrogen wastewater.

3.3. Moving bed biofilm reactor and its improved process
During the aeration process, the filler is in full contact with the sewage under the action of external force, so that the microorganisms in the sewage continue to grow on the surface of the filler. After a period of time, a biofilm will form on the surface of the filler, and the pollutants in the sewage will be adsorbed and degraded by the biofilm to purify the water body. Compared with the traditional MBR process, it has small space, easy expansion, no blockage, it has the advantages of simple operation and management, and is widely used in the treatment and recycling of sewage.

The ammonia nitrogen in MBBR is about 5mg/L, the ammonia nitrogen in the effluent is less than 1mg/L, and the ammonia nitrogen removal rate is 80% ~ 90%. Although the moving bed biofilm reactor has a good effect on the removal of COD and ammonia nitrogen, it still has the problems of easy shedding of biofilm, small amount of sewage treatment, and slow start-up speed in the actual application process.

4. Summary
In summary, we should continue to improve and optimize the MBR process, combine computer automation technology, and develop new MBR combined processes. We shall strengthen membrane pollution mechanism and prevention research, develop new high-throughput pollution-resistant membrane materials, explore and collect the experimental parameters of sewage treated by membrane bioreactors in various industries, perform the optimization of MBR process flow and operating conditions, continue to promote the development of the application of MBR in sewage treatment.

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