Startup of $A^2/O$ Combined with Microbial Fuel Cell and Influencing of C/N on the System

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Abstract. Aiming at treating domestic wastewater and producing electricity in the same time, the efficiency of microbial fuel cell (MFC) combined with conventional $A^2/O$ system was studied. The system reached the maximum average voltage of 574 mV after batch feeding 37 days with 1000 $\Omega$ external resistance. The average COD and ammonia removal efficiencies were 92.9% and 72.1%, respectively. In order to examine the effects of C/N on the electricity production and wastewater treatment efficiency, external resistance was changed to 100 $\Omega$ with continuously feeding after starting up. Three C/N with 3, 4.2 and 6 were compared in this study. The results showed that the system reached the maximum average voltage of 534 mV when the C/N was 4.2. At the same time, the COD removal rate reached 96.1%~97.1%. It was observed that C/N had not discernible effects on ammonia removal rate.

Introduction

$A^2/O$ has played a significantly important role in modern municipal wastewater treatment as a key technology. Recently, it has been a focus on how to reduce the high energy consumption during treatment. There are a lot of organic compounds in urban domestic wastewater which were estimated to holding 9.3 times more energy than those contained in treating process[1]. Microbial fuel cell (MFC) is an equipment using microorganisms as a catalyst to transform organic chemical energy into electricity directly[2,3] and it is able to accomplish organic matter degradation and electron transfer effectively through microbial metabolic activity. Thus, MFC has caught an extensive attention in treating wastewater and generating electricity[4].

Experiments investigating performance of MFC demonstrated that the increase in volume of the reactor can cause an increase of volume resistivity and lower the power production. Its potential commercial value and application was self-evident although it was still in the laboratory stage. Wang et al.[5] designed a reflux membrane-less MFC on the basis of conventional $A^2/O$ aiming at strengthening nitrogen removal and the results showed that the removal efficiency of TN increased by 8.17% compared with reference $A^2/O$ system. Wang at al.[6] constructed a new system capable of inhibiting membrane pollution and recycling energy power when treating wastewater through MFC combined with MBR. It indicated that the integrated system could remove COD and ammonia with an efficiency of 94% and 92% respectively. At the same time, it acted well in alleviating membrane pollution. Existing investigations demonstrated that many factors can affect the performance of MFC, such as volume, pH, electrode spacing, substrate concentration, C/N of inflow, etc.[7,8]. Among these, C/N is a significant parameter both to MFC and $A^2/O$[9]. However, little investigation has been conducted towards the influence of C/N to MFC and $A^2/O$.

We applied an integrated system combing $A^2/O$ with MFC to investigate its performance in treating municipal wastewater and generating electricity. In this study, we mainly studied the start-up regulation and the influence of C/N to wastewater treatment and electricity generating performance, meanwhile searched for the best C/N[10,11] which could be a reference to combing $A^2/O$ and MFC.
Materials and Methods

Experimental Set-up

A modified A2/O device made up of organic glass was used as the reactor with an effective volume of 0.01m³. The anode of MFC was put into the anaerobic tank of A2/O while the cathode in the anoxic tank. Both the anaerobic tank(anode) and anoxic tank(cathode) were sealed by organic glass to keep an anaerobic environment. The effective volume of the anaerobic tank(anode), anoxic tank(cathode), aerobic tank were 2 L, 2 L, 6 L, respectively. Two aerators were installed at the bottom of aerobic tank to provide sufficient oxygen and promote the well blend of matrix. Anode and cathode connected by copper wires formed a closed loop with an external resistance of 1000 Ω during start-up and the outer resistance was altered into 100 Ω subsequently. Graphite brush used as cathode was linked to a computer with a data acquisition card(DAC).

Experimental Conditions

Batch mode feeding was applied during start-up period in this study. The system was successfully started after stably operating for 3 cycles and the feeding mode changed into continuous mood subsequently. The temperature was maintained at (25±3) ℃ during operation while pH remained between 7~8 with an inflow rate of 9.2mL/min and HRT of 18h. The internal reflux ratio was maintained at 300%. DO in anode chamber and anoxic tank were maintained at 0.15~0.2 mg/L and 0.3~0.5 mg/L respectively in order to ensure an anaerobic environment when DO of aerobic tank was 2~3 mg/L through sufficient aeration. With the purpose of running stably we used artificial wastewater in which sodium acetate served as carbon source, ammonium chloride served as nitrogen source, KH2PO4 and Na2HPO4 served as pH buffer. There are still some trace elements and nutrition. The concentration of inlet COD and NH₄⁺-N were 1121~1170 mg/L and 98.4~104.7 mg/L respectively while the volume loading was kept at 1.3~1.4 KgCOD/(m³•d).

Analysis and Measurements

Conventional indicators and measurements used in this study are as follows. COD: potassium dichromate method, NH₄⁺-N: nesssler’s reagent spectrophotometry method, NO₃-N: thymol spectrophotometry method, NO₂-N: N-(1-naphthyl)-ethylenediamine spectrophotometry method, DO: portable DO tester, pH: electronic tester, voltage: data acquisition card connected with computer. Water sample indicators were measured every two days and the voltage was recorded per minute on computer[12].

Instruments and Reagents

Peristaltic pump: BT100-1F, Baoding Longer. data acquisition card: 7660B, 48 channels data acquisition card, zhongtaiyanchuang. portable DO tester: HANNA-HI9146N-portable DO tester. spectrophotometer: 5B-3BV, uv-vis multi-parameter water quality tester. pH and water temperature: HANA HI8424pH/ORP/T-tester. Reagents used in this study were all of analytical grade and chemical grade under the national standard.

Experimental Design

When started up, 1L activated sludge was inoculated to the anaerobic zone(anode). The system operated intermittently with an external resistance of 1000 Ω during starting period which was transformed into 100 Ω after continuously operated for one month in order to promote electricity production. Reactor was re-fed when the voltage decreased below 30mV. And continuous inflow was applied after repeatedly running for 3 cycles.

The aim of this study was to analyze the electricity generating performance of integrated system coupling A2/O and MFC and water quality improvement, identify the best operating parameter.

After producing electricity stably, C/N of the inflow was set at 3, 4.2, 6, making the COD/N of 8, 11 and 16, respectively. In order to demonstrate the performance change of A2/O combined with
MFC more accurately, the concentration of COD, NH$_4^+$-N, NO$_2^-$-N, NO$_3^-$-N of each sample was measured when the system stably operated for 24 h under each voltage.

Results and Discussion

Owing to the batch feeding mode of the system and the inflow duration depended on the effect of electricity generation, effluent quality also presented a periodic changing trend. Just as Figure 1 showed, COD and NH$_4^+$-N of inflow remained 1121~1170 mg/L and 98.4~104.7 mg/L, respectively. Although COD and NH$_4^+$-N of inflow is very high at the beginning, it showed a decline as the reaction proceeding just as Figure 1(a) and (b) showed. A stable concentration around 103.2 mg/L and 39.8mg/L of COD and NH$_4^+$-N was achieved on 10 th day with a removal efficiency of 91.4% and 62%, respectively. Fed one more time, outlet COD and NH$_4^+$-N decreased rapidly and tended to be stable soon with a final concentration of 89.5mg/L and 30.4mg/L and increasing removal efficiencies of 92.9% and 72.1%. Essential agreement between treatment and electricity generating cycle could show the successful start-up from the sides.

Figure 1. The treatment effect for wastewater during start-up of A2/O combined with MFC.

Figure 1(c) shows the evolution of NO$_2^-$-N and NO$_3^-$-N in the system. It can be observed that the accumulation of nitrate and nitrite is a slow process. During start-up, there was scarcely NO$_2^-$-N and NO$_3^-$-N in effluent. Nitrite accumulation occurred after 6 days operation. Ten days later, nitrate occurred and increased gradually and achieved its maximum along with a stable condition after 20 days. At this moment, the concentration of nitrate in the system was 16.41mg/L while the maximum of nitrite even reached to 4.41 mg/L.

Effect of C/N to the System

Various electricity generation under different C/N after 30 days continuous operation was showed in Figure 2. When C/N was 4.2, the voltage began to rise at the day of 10 and achieved its maximum of 550mV on day 22. Its startup time was 4 days shorter when compared with C/N of 3 and 3 days longer compared with C/N of 6. It was indicated that higher C/N contributes to the enrichment of microorganisms and abundant carbon source can make microbes grow and breed faster[13]. At the same time, the metabolism of anaerobic electrogenesis bacteria could be promoted which may speed up the electronic generating rate. When C/N was 3 and 6, the maximal voltage obtained were 265 mV and 406 mV, respectively, showed a 51.8% and 26.2% decline compared with that during C/N was
Thus, it is demonstrated that 4.2 is the best value of C/N that can enrich electogenesis bacteria to a large extent, promote the electrons generation and transfer efficiency during organic decomposition and elevate the voltage.

Figure 2. Voltage output of the system at different C/N.

Figure 3. Variation with time of COD and NH$_3$-N removal efficiency of different C/N.

Variation with time of COD removal efficiency of different C/N was shown in Figure 3. When C/N reached to a certain threshold exceeding the systematic organic loading, the removal efficiency of organics fell. So it can be realized that the system could operate with the optimal condition when C/N was 4.2. Different microorganisms exhibited various C/N requirements which is consistent with the investigation of Huang et al.[13].

Kept the inlet COD unchanged and altered the addition of NH$_4$Cl, we got the diagram as is shown below(Figure 3). No obvious variation of outlet ammonia removal efficiency was observed with the change of C/N addition. It showed a positive correlation between outflow ammonia and inflow ammonia with a removal efficiency remained above 70%. This demonstrated that ammonia removal in this system was mainly influenced by volume loading of inflow ammonia rather than C/N.

Conclusions

We applied a batch mode to start the A$^2$/O coupling with MFC. After 37 days culture, the system started up successfully and obtained the maximum average voltage of 574mV with a 1000Ω external resistance. The removal efficiency of COD and NH$_3$-N reached to 92.9% and 72.1% accompanied by the accumulation of 4.41mg/L and 16.41mg/L for NO$_2$-N and NO$_3$-N, respectively. The maximum voltage of 550 mV was gained when C/N was 4.2 after 30 days continuous culture which is 51.8% and 26.2% higher than that of C/N of 3 and 6. It can also be concluded that the startup time shortened with the increase of C/N. The best removal of 96.1%~97.1% of COD was achieved when C/N was 4.2 consistent with the maximum voltage obtained under the same condition. So it can be seen that C/N
of 4.2 is the best operating condition. Different C/N did not show much influence on ammonia removal with a constant removal efficiency above 70%.

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References


