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Short Communication

Intensified nitrogen and phosphorus removal by embedding electrolysis in an anaerobic–anoxic–oxic reactor treating low carbon/nitrogen wastewater

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ABSTRACT

A modified anaerobic–anoxic–oxic (AAO) reactor embedding electrolysis was constructed for treatment of low carbon/nitrogen (C/N) wastewater. The effect of different current conditions on the performance of reactor was investigated in this study. When the current ranged from 0 mA to 200 mA, the removal efficiency of total nitrogen (TN) increased from 61.25% (0 mA) to 75.60% (200 mA), and that of total phosphorus (TP) increased from 72.24% (0 mA) to 93.93% (200 mA). In addition, the removal efficiencies of chemical oxygen demand (COD) and NH_4^+-N were not affected. The results indicated that AAO reactor coupling electrolysis was an effective way to strengthen the removal of nitrogen and phosphorus for treatment of low C/N wastewater.

1. Introduction

Eutrophication, which caused by nitrogen (N) and phosphorus (P) pollutions, is widely recognized to be origin of the decline of water environmental capacity in China. Anaerobic–Anoxic–Oxic (AAO) process is widely utilized for simultaneous N and P removal. However, it has an inherent drawback for treatment of urban sewage owing to the lack of carbon source. Several ideas have been proposed to improve the operation of wastewater treatment plants (WWTPs) for reducing the consumption of carbon source (Wang et al., 2017b). The two-sludge process is a promising technology for nutrient removal from low carbon/nitrogen (C/N) wastewater (Wang et al., 2017a). Moreover, enhanced biological phosphorus removal (EBPR) is often discounted for the insufficient carbon source in influent (Yang et al., 2017).

Compared with EBPR, the P-removal by chemical precipitation is more efficient, simple and reliable. Metal salts, such as aluminum salts and iron salts, are the most common medium used to achieve the P-removal (Morse et al., 1998). However, the presence of residual aluminum ions might increase the risk of alzheimer's disease, resulting in the limitation of the use of aluminum salts (Zatta et al., 1988). On the other hand, there are few side effects of iron salts on environment, and the cost is also low. In recent years, iron salts have been extensively applied in the field of chemical P-removal of sewage (Oikonomidis et al., 2010). However, it is worth noting that the hydrolysis of iron ions can deplete the alkalinity of sewage (de Haas et al., 2001). As a result of alkalinity decrease, the reduction of pH could inhibit the nitrification process when fed with low alkalinity municipal sewage.

The electrochemical method is a new way for removal of N with different anode (such as Al, Cu and Fe). However, Cu can inhibit the process of ammonia oxidation and EBPR (Ge et al., 2015; Zheng et al., 2014). In addition, the Fe anode has been proven to be suitable for nitrate reduction (Li et al., 2010) and iron salts are the most wildly used coagulants for chemical P-removal (Li et al., 2014). In the electrochemical process with iron as anode, the Fe^0 converted to iron ion in the anode, and then the iron ion could be used to achieve P-removal in wastewater (Gao et al., 2017). In the cathode, the microorganism in the system could use the electron and H^+ to realize the reduction of nitrate (Kelly and He, 2014). In the whole process of electrolysis, the H^+ consumed in the cathode could counteract the alkalinity consumed by the hydrolysis of iron ions, and the alkalinity in sewage would not decrease. The inhibition on nitrifying bacteria caused by pH reduction would also be avoided. To date, electrolysis has been successfully applied to treatment of municipal wastewater and industrial wastewater (Gao et al., 2016). However, few researches focused on embedding electrolysis in biological process, such as AAO process. Meanwhile, the present researches on electrolysis mainly assessed on simulated wastewater (Gao et al., 2017). The performance of electrolysis-integrated AAO reactor was needed further research to treatment of actual wastewater.

A modified AAO reactor embedding electrolysis of iron anode was constructed for treatment of low C/N wastewater. The purpose of this study was to investigate the effect of current on the performance of this process.

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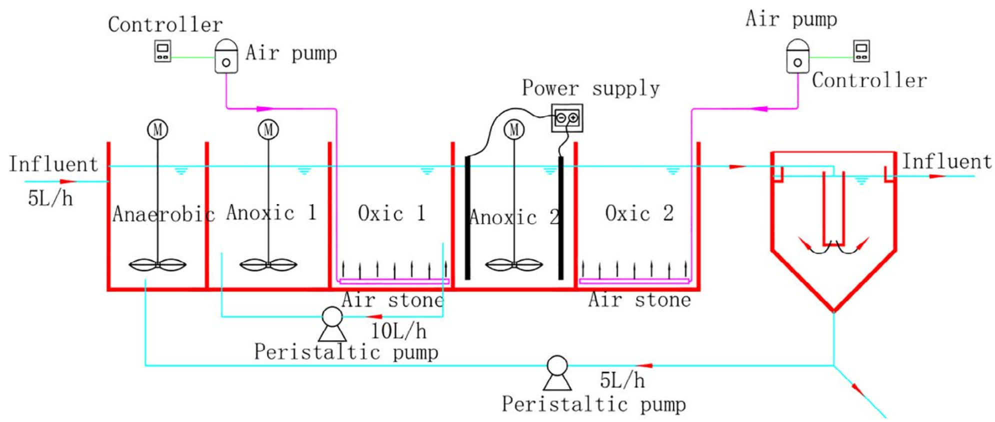

Fig. 1. Schematic diagram of the anaerobic–anoxic–oxic reactor embedding electrolysis.

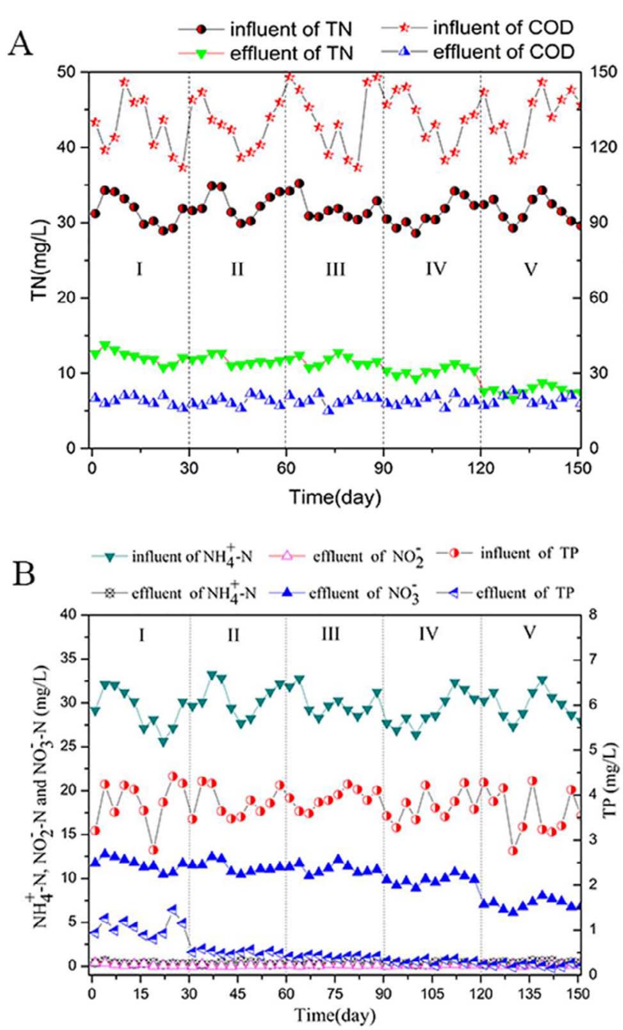

Fig. 2. Nitrogen, total phosphorus and chemical oxygen demand removal over 150 days of operation.

2. Materials and methods

2.1. AAO reactor

The AAO reactor was shown in Fig. 1. The reactor was made of plastic, which included an anaerobic zone (200 mm × 250 mm × 250 mm, effective volume was 10 L), two anoxic zones (250 mm × 250 mm × 250 mm, effective volume was 12.5 L), two oxic zones (250 mm × 250 mm × 250 mm, effective volume was 12.5 L) and a sedimentation tank (effective volume was 10 L). The influent of reactor (5 L/h), sludge recycling (5 L/h) and inner recycling (10 L/h) were controlled by peristaltic pump (baoding longerpump, BT100-1F, 0–25 L/h). The electrolytic cathode consisted of four carbon brush (50 mm in diameter, 150 mm in length). The electrolytic anode consisted of an iron wire mesh (Fe content was higher than 99.99%, 200 mm × 150 mm). Current of the electrolytic process was controlled by a DC regulated power supply (KORAD, KA3005D, 0–30 V, 0–5 A).

2.2. Experimental conditions

The inoculated sludge was obtained from a municipal WWTP with AAO process in Chongqing, China. Initial mixed liquor suspended solids (MLSS) was about 3600 mg/L. During the whole experiment, the MLSS was controlled at 3500–4500 mg/L by discharge of sludge from sedimentation tank. The raw wastewater was derived from the effluent of preliminary sedimentation tank in the municipal WWTP. During the whole experiment, the chemical oxygen demand (COD), biochemical oxygen demand for five days (BOD_5), total nitrogen (TN), NH_4^+-N and total phosphorus (TP) concentrations in the influent were measured as 112–149 mg/L, 38–72 mg/L, 28.4–35.2 mg/L, 25.6–33.3 mg/L and 2.7–4.5 mg/L, respectively. The BOD_5/TN was only around 2. The temperature was maintained at room temperature. The dissolved oxygen (DO) of aerobic zone was controlled at 2–3 mg/L. During stage one (1–30 d), the electrolysis was not integrated in AAO reactor. During stage two (31–60 d), the electrolysis was integrated with current 20 mA in AAO reactor. The current was gradually increased to 40 mA, 100 mA and 200 mA, in 61–90 d (stage three), 91–120 d (stage four) and 121–150 d (stage five), respectively.

2.3. Measurements

Liquid samples were sampled every day and concentrations of COD, NH_4^+-N, NO_3^--N, NO_2^--N, PO_4^{3-}-P, TP and MLSS were measured with standard methods (APHA, 1998). DO and temperature were monitored by a DO detector (Hach, HQ30d, USA) and pH was monitored by a pH detector (Hach, sension2, USA). The iron wire mesh of the electrolytic anode was replaced at the beginning of each stage except stage one.

3. Results and discussions

3.1. C, N and P removal in the AAO reactor

The modified AAO reactor was operated for 150 days, and the removal efficiencies of COD and TN were shown in Fig. 2(a). When the current ranged from 0 mA to 200 mA, the effluent COD concentration consistently stabilized at 15–25 mg/L, indicating that the removal of