Enhancement of nitrogen removal in a novel anammox reactor packed with Fe electrode

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1. Introduction

The anammox (anaerobic ammonium oxidation) process is a novel and promising technology for treating high nitrogen-containing wastewaters such as aquaculture wastewater, anaerobic digester supernatant and landfill leachate (Vlaeminck et al., 2009). The anammox bacteria oxidize ammonia to nitrogen gas using nitrite as an electron acceptor under anaerobic conditions according to the following equation (Strous et al., 1999)

$$\begin{align*}
\text{NH}_4^+ + 1.32\text{NO}_2^- + 0.066\text{HCO}_3^- + 0.13\text{H}^+ & \rightarrow 1.02\text{N}_2 + 0.26\text{NO}_3^- + 0.66\text{CH}_2\text{O}_{0.3}\text{N}_0.15 + 2.03\text{H}_2\text{O}
\end{align*}$$

(1)

Compared to conventional nitrification and denitrification, anammox process has some unique advantages such as high nitrogen removal, low energy consumption, no need of the external carbon source and low sludge yield. However, up to now, the anammox process is still difficult for large-scale application. The anammox bacteria, as autotrophic anaerobes, are of slow growth with a doubling time of about 11 days. The anammox bacteria need a strict anaerobic condition and are sensitive to environmental changes such as dissolved oxygen, temperature, pH and organic matter. Inappropriate operation often reduced anammox activity, even led to anammox process collapse (Liu et al., 2008a; Tang et al., 2010).

It was reported that the anammox bacteria could be cultivated and enriched from anaerobic/aerobic sludge, mixed activated sludge (Bae et al., 2010; Date et al., 2009) and granular sludge (Tang et al., 2011). Reactor types including up-flow anaerobic sludge bed reactor, upflow blanket filter reactor and membrane bioreactor were also investigated to reduce the washout of biomass to retain the anammox bacteria in the reactors. Besides, Liu et al. (2008b) reported that anammox process could be accelerated through applying a static magnetic field.

Fe is an essential element for the growth of almost all microorganisms. Some important protein classes, such as hemachrome, iron-sulfur protein, et al., are related to participation of Fe. Iron particles proved to be bacterioferritin were also found in anammoxsome which were the important sites for anammox reaction (Van Niftrik et al., 2008). The bacterioferritins, such as haem-containing bacterioferritins, are iron storage proteins. Iron storage usually occurred under iron-limiting conditions (Andrews, 1998). Van Niftrik et al. (2008) believed that anammox bacteria absorbed and stored iron to meet the needs for hemoglobin synthesis.

Anammox bacteria belong to obligate anaerobes, which require an obligatorily anaerobic environment with a low oxidant-reductive potential (ORP) level. Truong et al. (2008) observed that specific anammox activity was increased by about 50% as the ORP of the treating system decreased from 0 to −110 mV. However, it is actually not so easy to maintain the reaction system in a completely anaerobic condition. This is because nitrite used as the substrate and nitrate produced in the anammox reaction (see