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Options of Fast Start-Up of Partial Nitrification: Integration of Anammox with Mainstream Treatment

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Abstract—*The research on application of Anaerobic Ammonium Oxidation (Anammox) process for nitrogen removal from wastewater is under rapid investigations across the world since 1990s. For the mainstream application of anammox process, nitrite (NO_2^--N) availability in the wastewater is essential, an electron acceptor for anammox bacteria. Partial Nitrification (P/N) is crucial process for achieving proper concentration ofNO_2^--N, for the possibility of integration with anaerobic treatment processes. Three different strategies were evaluated: Continuous Aeration (Strategy 1), Nitrite Dosing (Strategy 2) and Intermittent Aeration-Anoxic (Strategy 3) modes. In Strategy 1, the startup of the P/N process was achieved using synthetic feed (~NH_4^+-N concentration:50 mg / L) to enrich Ammonium oxidizing bacteria (AOB) for a period of 30 d at low dissolved oxygen (DO) of 0.5-0.8 mg/L later replaced with Up-flow Anaerobic Sludge Blanket (UASB)effluent (NH_4^+-N: 50-60 mg/L; NO_3^--N: 0-5 mg/L; COD: 60-80 mg/L). The breakpoint of DO and ammonia was determined to find the P/N point by the variation of DO and ammonia profile during an entire cycle. Nitrite oxidizing bacteria (NOB) activity was dominant in strategy 1 as complete nitrification was observed. To achieve the P/N, the study further investigated the possibilities of nitrite dosing (~30mg/L) for 15d without feeding/decanting the reactor with continuous mixing. The granular sludge started to disintegrate as the days progressed in strategy 2 inhibiting AOB and NOB activity. The reactor was further operated under strategy 3 feeding with UASB effluent for enriching the AOB bacteria. Results of this study indicate that combination of strategy 1 and 2 is the best option for fast inhibition of NOB bacteria in the seed sludge. This study proposes an ideal strategy for the fast start-up of P/N under low DO concentration resulting in sufficient production ofNO_2^--N concentration required for anammox process.*

Keywords: *Nitrogen Removal, Partial Nitrification, Low Dissolved Oxygen, Nitrifier Biomass Activity.*

1. INTRODUCTION

Nitrogenous compounds present in water bodies deteriorated the ecology of the surrounding environment causing eutrophication. Anaerobic Ammonium oxidation (Anammox) process is a robust technology and is under rapid investigation across the world for the removal of nitrogen compounds from the mid-1990s. The application of anammox process can effectively play an important role in the removal of nitrogen (ammonium and nitrite) compoundsin the form of nitrogen (N_2) gas [1].However, the slow growth rate of anammox bacteria and susceptibility to fluctuating environment makes it a vulnerable process for implementation. Several studies have suggested the improved performance of anammox process at low strength wastewater [2].

The post treatment of anaerobically treated wastewater is essential to meet the disposal standards as it contains nitrogen compounds [3]. Anammox process can be an efficient system as a post treatment option for significant removal of nitrogen from anaerobically treated effluents. Though, there is need for an intermediate treatment process that can incorporate the nitrite (NO_2^--N)concentration in the anaerobically treated effluent, which is the electron acceptor for anammox bacteria. Partial Nitrification (P/N) process is a viable option for achieving NO_2^--N, converting NH_4^+-N into NO_2^--N [4]. The application of partial nitrification- anammox (PN/A) process need no carbon source and can reduce the requirement of aeration up to 60% in comparison to conventional nitrification and denitrification process [5]. In order to achieve the P/N process, it is important to improve the abundance of ammonium oxidizing bacteria (AOB) and inhibit the nitrite oxidizing bacteria (NOB) inside the reactor to prevent complete nitrification [6].

The main objective of this study was to investigate the possible effective strategies and solution for fast start up of the partial nitrification process for achieving nitrite in the anaerobically treated effluent for further treating nitrogen by anammox process under low dissolved oxygen (DO).

2. METHODS

2.1 Wastewater characteristics and seed sludge

The synthetic wastewater was used have only NH_4^+ -N concentration (50 mg / L) and UASB effluent characteristics are NH_4^+ -N: 50-60 mg/L; NO_3^- -N: 5 mg/L; COD: 60-80 mg/L. The composition of synthetic wastewater as per (De Cocker et al. 2018) [7]. The sludge was taken from Okhla STP, New Delhi. The initial MLSS and MLVSS concentration of sludge where are 3136 mg/L and 2016 mg/l respectively. The experimental period of SBR was divided into three strategies. Continuous Aeration (Strategy 1) for 30 Days, complete nitrification was obtained by applying synthetic wastewater having only NH_4^+-N concentration of 50 mg/l with additional macro as well as micro nutrients for enriching Ammonium Oxidizing Bacteria (AOB). Nitrite Dosing (Strategy 2) for 15 Days, during which the synthetic wastewater feed was stopped and the wastewater in the reactor was continuously stirred with intermittent nitrite dosing. That is, on Day 31, 35, 39, 45, the $NaNO_2$ stock solution was added into the SBR to get initial nitrite concentration of 30 mg/L. In Intermittent Aeration-Anoxic (Strategy 3), the SBR was started with UASB Effluent (NH_4^+ -N: 50-60 mg/L; NO_3^- -N: 0-5 mg/L; COD: 60-80 mg/L) for enriching the AOB bacteria.

2.2 Reactor Configuration

The experiments were performed in sequential batch reactor (SBR). The reactor was made of Plexiglass with a working volume of 12 L (30x25x16 cm). The volume exchange ratio (VER) was maintained at 33%.The seed sludge was inoculated about 30% of the total volume of the reactor. The aeration was supplied by an air pump through ceramic diffusers inside the reactor to maintain desired dissolved oxygen (DO). Uniform mixingwas given at 100 rpm using a mechanical stirrer (RQ 1400, REMI).One cycle was of 3h with 15 min feeding, 45 min mixing and aeration, 105 min settling, 2 min decanting, and 13 min starvation.The DO concentration was varied within a range of 0.4–1.1 mg/Lin each aerobicreaction phase.

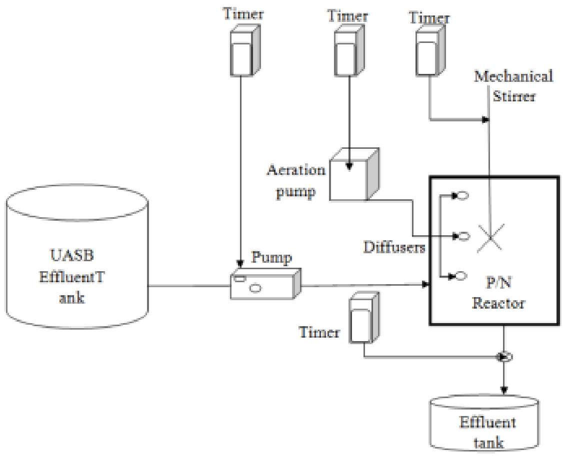

Fig. 1: Experimental setup used in the study

2.3 Calculation of NAR and SND efficiency

The calculation of Nitrite accumulation ratio (NAR) are as follows:

$$\text{NAR} = \frac{\text{NO2−N}}{\text{NO2−N+NO3−N}} \text{X } 100\%....... \quad (1)$$

The efficiency of Simultaneous nitrification and denitrification (SND) are as follows:

$$\text{SND Efficiency} = \frac{NH4-N\ (oxidized) - NOx-N\ (produced)}{NH4-N\ (oxidized)} \text{x } 100\%...... \quad (2)$$

$$\text{Specific SND rate (mgN/mgMLSS/hr)} = \frac{NH4-N\ (oxidized) - NOx-N\ (produced)}{MLSS * t}...... \quad (3)$$

3. RESULTS AND DISCUSSION

3.1 Process performance of Partial Nitrification at low DO

The profile of DO, NH_4^+-N, NO_2^--N and NO_3^--Nare shown in Fig.2. The nitrification process initiated immediately as the aeration period started. Above 90% NH_4^+-N oxidation was occurred within 52 min during the aeration phase with a corresponding rise in NO_2^--N. Later, the DO gradually increased indicating the completion of nitrification process which also been confirmed by the conversion of NO_2^--N into NO_3^--N. More than 80 % of ammonium was converted to nitrite which shows that AOB is dominant while NOB is suppressed.

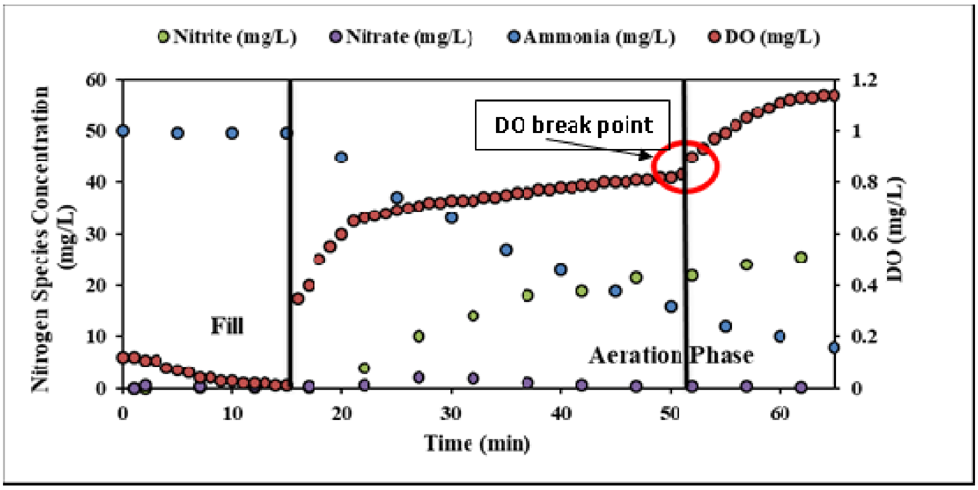

Fig. 2: Nitrogen variation in a cycle under low DO

The Fig 3 shows the variation of NAR, SND and SND rate during an entire cycle. The removal efficiency of ammonium was achieved more than 80%. The average SND efficiency was more than 20 %. The Total Nitrogen (TN) removal efficiency and SND efficiency difference mainly contribute to different DO concentration. At low DO, TN efficiency and SND removal efficiency both have positive effect as compared with high DO [8] because of the anoxic zone present in the reactor. As compared with other literatures our SND efficiency and specific SND rate were low, which may be because of lower poly-β-hydroxybutyrate (PHB) production in wastewater. It has been observed that DO have major effect on NAR.

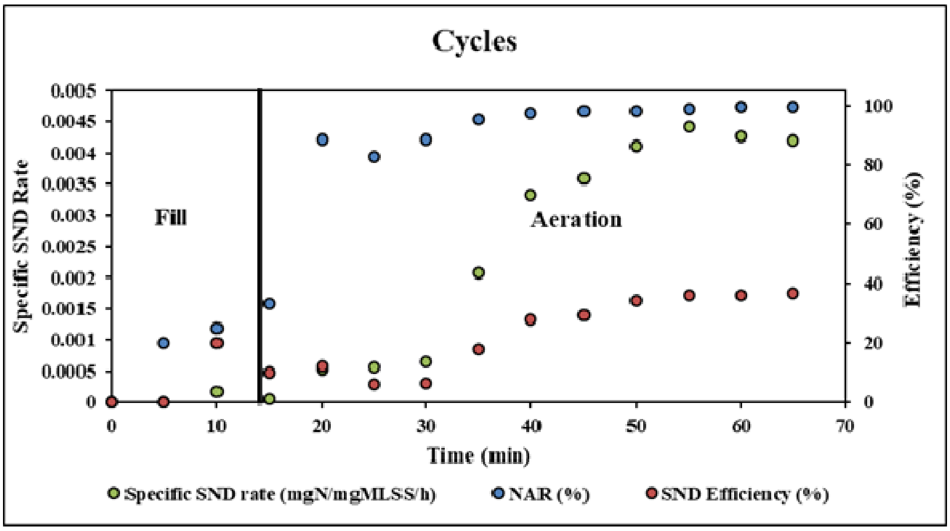

Fig. 3: Variation of Nitrogen efficiency at low DO in SBR

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4. CONCLUSIONS

The possibilities for achieving NO_2^--Nwas investigated under low DO conditions. Low DO results in low sludge production and energy efficient for partial nitrification. However, dominant NOB activity in the reactor confirmed complete nitrification failing the study. The study recommends further investigation of inhibiting NOB for achieve partial nitrification using effective strategies such as nitrite dosing and anoxic/oxic phase. It is feasible to use in ANAMMOX process as a unit for nitrite production which act as electron acceptor in ANAMMOX reactor.

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