STUDY OF NITROGEN CONSUMPTION BY NITRIFICATION PROCESS

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ABSTRACT: Biological processes are being applied to nitrogen removal from wastewater. The conventional process is based on nitrification followed by denitrification. In nitrification process the ammoniacal nitrogen is oxidized to nitrate and it is strongly influenced by availability of dissolved oxygen. In this context, kinetics studies are an alternative used to evaluate the microorganisms activity by defining substrate (NH_3-N) consumption and the influence of others parameters, like oxygen and substrate. The present study aims to evaluate the ammonium consumption rate by nitrification process at three different ammonia concentrations (100, 200 and 300 mg NH_3-N L^{-1}) at air flow rates of 20, 30, 50, 100, 200 and 500 mL_{air} min^{-1} $L^{-1}_{reactor}$. The kinetics were made by batch tests in an EGSB reactor at temperature of 25ºC for 2h30min. It was visualized that with 100 and 200 mg N-NH_3 L^{-1} the substrate concentration was fully consumed. However, at the substrate concentration of 300 mg NH_3-N L^{-1} an increase of substrate consumption was observed but ammonia was not entirely consumed. Furthermore, for the three initial ammonia concentrations, the behavior of substrate consumption was similar in function of air flow rate. Additionally, it was possible to conclude that as the supply of oxygen increased, the nitrogen ammoniacal consumption rate also increased.

Keywords: ammoniacal nitrogen, kinetics, nitrifiers.

INTRODUCTION

Nitrogen compounds present in wastewater must be under concern because of the potential of environmental pollution and health problems, such as water bodies eutrophication and human methemoglobinemia disease (AKPOR & MUCHIE, 2011).

Recent studies have been developed aiming to improve treatment efficiency and to reduce operational costs. It is possible to remove high wastewater nitrogen loads by optimizing the treatment strategies (CASAGRANDE et al., 2013).

Biological processes are being applied to nitrogen removal from wastewater and a conventional process used is nitrification followed by denitrification. The nitrification in aerobic conditions consists of ammonium oxidation in two phases. Firstly, occurs the oxidation of ammoniacal nitrogen to nitrite by ammonia oxidizing bacteria (AOB) and, subsequently the nitrite is oxidized to nitrate by nitrite oxidizing bacteria (NOB) (PRÁ et al., 2012).

In general, this is the limiting for subsequently processes that removes nitrogen because nitrite and nitrate are substrate to them. Better conditions to nitrifiers selection and growth at the nitrification process establishment are being investigated (CHINI et al., 2016).

Therefore, kinetics evaluations are an alternative used to study the microorganisms performance by defining substrate consumption. Kinetics studies are a good tool for testing biological reactors efficiency allowing greater predictability and process design (PRÁ et al., 2016).

The present study aims to evaluate the ammonium consumption rate by nitrification process at three different ammonia concentrations at air flow rates of 20, 30, 50, 100, 200 and 500 mL_{air} $min^{-1}L^{-1}_{reactor}$.

MATERIAL AND METHODS

Studies of kinetics were done in batch tests using a cylindrical reactor with internal diameter of 5 cm and 60 cm height, 1 L of working volume, operated as an EGSB (expanded granular sludge bed) reactor. Aeration was provided using an air pump (A230, Big Air) connected to an air EPDM diffuser and measured by an air flowmeter (Gilmont, GF-9260). Temperature was kept constant at 25ºC.

To evaluate the effect of substrate in the microorganisms consumption rate, tests were performed using concentrations of 100, 200 and 300 mg NH_3-N L^{-1}, according to Magrí et al. (2012).

Inoculum containing bacteria with nitrifying activity was obtained from a lab-scale reactor which had been operated for over a year. A volume of 80 mL of biomass were used and the air injected in each test was 20, 30, 50, 100, 200 and 500 mL_{air} $min^{-1}L^{-1}{}_{reactor}$ and. Samples were collected at time 0 and then after 30 minutes, during 2h30min, successively. For each collected sample, pH, dissolved oxygen (DO) and temperature were immediately measured. After it, samples were analyzed for NH_3-N, NO_3^--N, NO_2^--N and alkalinity determination. At the end of the batch test, volatile suspended solids (VSS) were determined. All samples were analyzed according to APHA (2012).

Nitrite and ammonia consumption rate (r) and specific nitrite and ammonia consumption rate (μs) were determined from substrate concentration versus time linear regression obtained in batch tests (LI et al., 2014).

RESULTS AND DISCUSSION

A comparison of the initial, final and consumed ammoniacal nitrogen is presented in Table 1. The initial concentration of 100 mg NH_3-N L^{-1} had an ammonia consumption from 43% up to 100%, as the air flow rate was increased from 20 until 500 mL_{air} min^{-1} $L^{-1}{}_{reactor}$. At the same air flow variation, for the ammonia concentration of 200 mg NH_3-N L^{-1} consume of 32% to 100% was observed. On the other hand, using substrate concentration of 300 mg NH_3-N L^{-1} the maximum ammonia consume was 71% using air flow of 500 mL_{air} min^{-1} $L^{-1}{}_{reactor}$. In addition, the pH in all batches remained between 7.5 and 8.5.

The rate of ammonia consumption with the increase of air flow for the different initial tested concentrations is shown in Figure 1. It is possible to observe a similar behavior of ammonia consumption comparing the different concentrations studied in this work, where an increase of consumption occurred as higher air flow where applied.

Also, it was calculated the values for r and μ, as a function of the air flow increase to each ammonia concentration, the data had an increase tendency. It means that how much higher the flow rate highest was the substrate conversion rate.

According to Zoppas et al. (2016) the control of oxygen is crucial, since it defines which process will be predominant in the reactor. Considering that, low oxygen rate limits ammonia oxidation, and affects most significantly the growth rate of microorganisms responsible for oxidation of ammonia to nitrite. Therefore, data obtained in this study evidence the importance of control the air which is introduced into reactors, always aiming high efficiency with low energy cost.

It is knowledge that for 1 mol of ammonia, ammonia oxidizing bacteria (AOB) uses 1.5 mol of oxygen while nitrite oxidizing bacteria (NOB) uses 0.5 mol of oxygen. Complete nitrification requires 2 mol of oxygen per mol of ammoniacal nitrogen nitrified (RUIZ et al., 2003). So, nitrification kinetics is mainly affected by oxygen and substrate concentration, and two types of inhibition could occur, by substrate and microorganisms competition.

In this context, it can be considered that at concentration of 300 mg NH_3-N L^{-1} ammonia could have influenced in the oxidizing process because the maximum air flow tested was not enough for complete ammonia consumption.

CONCLUSIONS

For the three initial ammonia concentrations, the behavior of substrate consumption was similar in function of air flow rate. As the supply of oxygen increased, higher was the nitrogen ammoniacal consumption, but for concentration of 300 mg N-NH_3L^{-1} the maximum air flow tested was not enough for substrate consumption.

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Table 1. Substrate conversation rate (r), specific substrate conversation rate (μ), substrate initial, final and consumed concentration obtained at the batch tests.

Air Flow rate (mLair min⁻¹ L⁻¹reactor)	Substrate initial concentration (S) (mg NH_3-N L^{-1})	Substrate final concentration (mg NH_3-N L^{-1})	Substrate consumed concentration (mg NH_3-N L^{-1})	Substrate conversion rates (r) (mg NH_3-N L^{-1} h^{-1})	Specific substrate conversion rates (μ) (mg NH_3-N VSS^{-1} h^{-1})
20	100	56.20	43.80	-12.94	10.87
30		32.00	68.00	-22.39	18.82
50		2.25	97.75	-39.48	33.17
100		0.61	99.39	-61.51	51.69
200		0.23	99.77	-67.41	56.65
500		0.00	100.00	-81.83	68.76
20	200	128.00	72.00	-19.19	16.13
30		61.40	138.60	-20.96	17.62
50		58.00	142.00	-41.20	34.62
100		15.16	184.84	-68.86	57.87
200		1.34	198.66	-81.74	68.69
500		0.00	200.00	-86.73	72.88
20	300	201.00	99	-16.35	13.74
30		224.84	75.16	-19.94	37.63
50		200.00	100	-24.53	46.28
100		174.90	125.1	-36.71	69.26
200		135.60	164.4	-49.57	93.53
500		86.72	213.28	-100.37	102.42

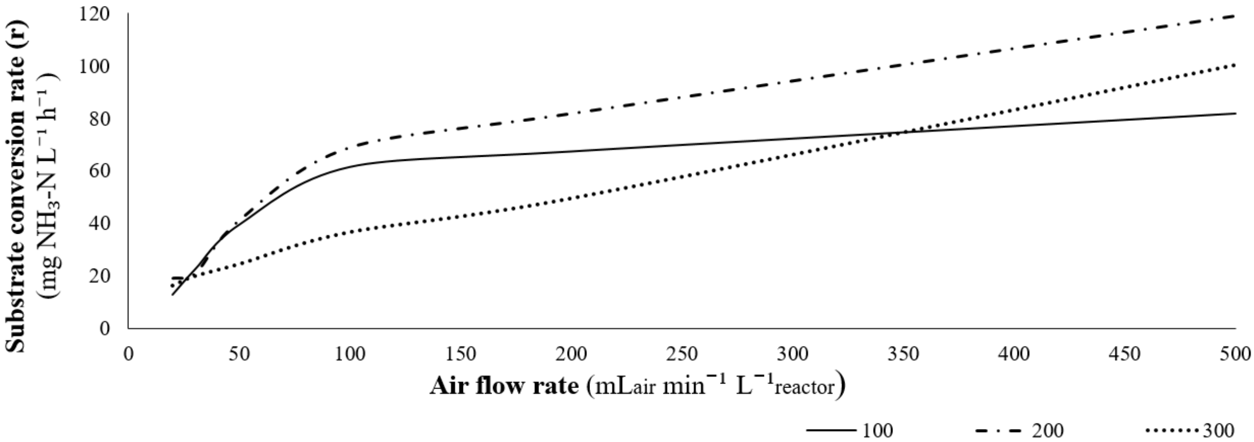

Figure 1. Comparative between substrate convertion (r) and air flow rate at three diferents ammonium concentrations (100, 200 and 300 mg L^{-1}).