Aeration strategies to improve nitrogen removal using deammonification process in EGSB reactor

Angélica Chini[1], Airton Kunz[1,2], Deisi Tápparo[3], Lucas Antunes Scussiato[1]

[1] PGEAGRI/CCET, UNIOESTE – Cascavel, PR, Brazil. angechini@gmail.com
[2] Embrapa Swine and Polutry – Concórdia, SC, Brazil.
[3] UnC – Concórdia, SC, Brazil

Abstract: Anaerobic digestion technology for stabilization and organic matter removal from swine slurry is widely used and long known, but this method not degrades nitrogen compounds present in abundance in the digestate. So, deammonification is being studied as an alternative for post treatment. In this process, two groups of bacteria nitrifying bacteria (aerobic microorganisms) and anammox (anoxic microorganisms) have to cooperate to complete ammonia remove. In this process, the ammonia oxidation by partial nitrification (PN) generate substrate to anammox activity, so there must have PN control to prevent nitrite accumulation. This way making the dissolved oxygen (DO) supply an important key to control and stabilization process. The present study aimed to test the aeration effect on the nitrogen removal using deammonification process in an EGSB reactor. The results show the use of DO control to avoid nitrite accumulation in a deammonification single reactor is a good strategy to increase anammox activity.

Keywords: Anammox, dissolved oxygen, partial nitrification.

Introduction

Anaerobic digestion technology for stabilization and organic matter removal from swine slurry is widely used and long known (Holm-nielsen, et al. 2009). The drawback of this method is the nitrogen compounds present in abundance in the digestate, which are not degraded under anaerobic conditions.

Recent studies have been developed aiming to improve treatment efficiency and reduce operational costs, optimizing the treatment strategies available or pursuing development of new processes capable to remove high nitrogen loads of wastewater (Casagrande, et al. 2013). Several alternative processes have been developed in recent years, such as partial nitrification (PN), anaerobic ammonium oxidation (anammox) and their combined system (Vanotti, et al. 2013).

Deammonification is a completely autotrophic nitrogen removal in a single reactor, in which two groups of bacteria, nitrifying bacteria (aerobic microorganisms) and anammox (anaerobic microorganisms), have to cooperate during the process (Magrí, et al. 2012). As a result, the ammonia oxidation by PN creates generate substrate to anammox activity.

Therefore, there must have PN control, by preventing nitrite accumulation and the possible nitrite oxidation to nitrate by nitrite-oxidizing bacteria (NOB), this way making the dissolved oxygen (DO) supply an important key to control and stabilization process (Chung, et al. 2005).

In this way, expanded granular sludge bed (EGSB) reactor performance as post-treatment for anaerobic effluent can be an interesting strategy due to higher oxygen mass transference in the reactor allowing to work at more restricted process air flow rates (Fang, et al. 2011).

Considering this, the present study aimed to test the aeration effect on the nitrogen removal using deammonification process in an EGSB reactor.

Material and methods

An EGSB reactor (1L) containing: nitrifying biomass (r-NH_3-N= 100.4 mgN.L^{-1}.h^{-1}), anammox biomass (r-NH_3-N= 17.7 mgN.L^{-1}.h^{-1}; r-NO_2^--N= 25.1 mgN.L^{-1}.h^{-1}), biofilm plastic carrier (55g w/v) operating at HRT of 9 h. The reactor was operated under intermittent aeration 30 minutes per cycle (15 min on / 15 min off) at 25ºC, fed during aeration time, with synthetic medium containing 300 mgNH_3-N.L^{-1} and nutrient solution (Magrí, et al. 2012). The N-compounds and alkalinity were daily analyzed according the methodology describe at Apha (2012). pH (Hanna, pH 21) and DO (YSI 55) were monitored at aerobic and anoxic phases.

The forms NO_3^--N, N_2 and O_2 stoichiometric coefficients were calculated based in equations 1, 2 and 3 respectively.

$$Coef.NO_3^-N = \frac{(NO_3^-Nout - NO_3^-Nin)}{(NH_3Nin - NH_3Nout)} \qquad \textbf{Equation 1}$$

$$Coef.N_2 = \frac{(1-((NO_2^-Nout - NO_2^-Nin)\ /(NH_3Nin - NH_3N\ out)) + (Coef.NO_3^-N))}{2} \qquad \textbf{Equation 2}$$

$$Coef.O_2 = \frac{\left((\mathrm{Coef.}NO_3^-N\times 3)+\left(\frac{(\mathrm{NO^{2-}Nout - NO^{2-}Nin})}{(\mathrm{NH^3Nin - NH^3Nout})}\times 2\right)+\frac{\left(4-\frac{(\mathrm{Ca}CO_3\mathrm{in}-\mathrm{Ca}CO_3\mathrm{out})}{\mathrm{NH^3Nin - NH^3Nout}}\right)\times\frac{14}{50}}{2}\right)}{2} \qquad \textbf{Equation 3}$$

The EGSB reactor was operated for 33 days and divided in two phases. Phase 1 it was operated air flow rate of 30 mL.min^{-1} (DO around 0.9 mg.L^{-1}) until the 10th day. Phase 2 air flow rate was reduced to 20 mL.min^{-1} at the 10th day (DO stayed 0.5 mg.L^{-1}).

Results and discussion

In the phase 1 (Fig. 1), the nitrogen loading rate (NLR) was 0.8 kgN.L^{-1}.d^{-1} and nitrogen removal rate (NRR) were 0.3 kgN.L^{-1}.d^{-1} achieving maximum NH_3-N removal efficiency of 53%. During the phase 1, nitrite and nitrate start to accumulate in the reactor indicating the influence nitrificating process.

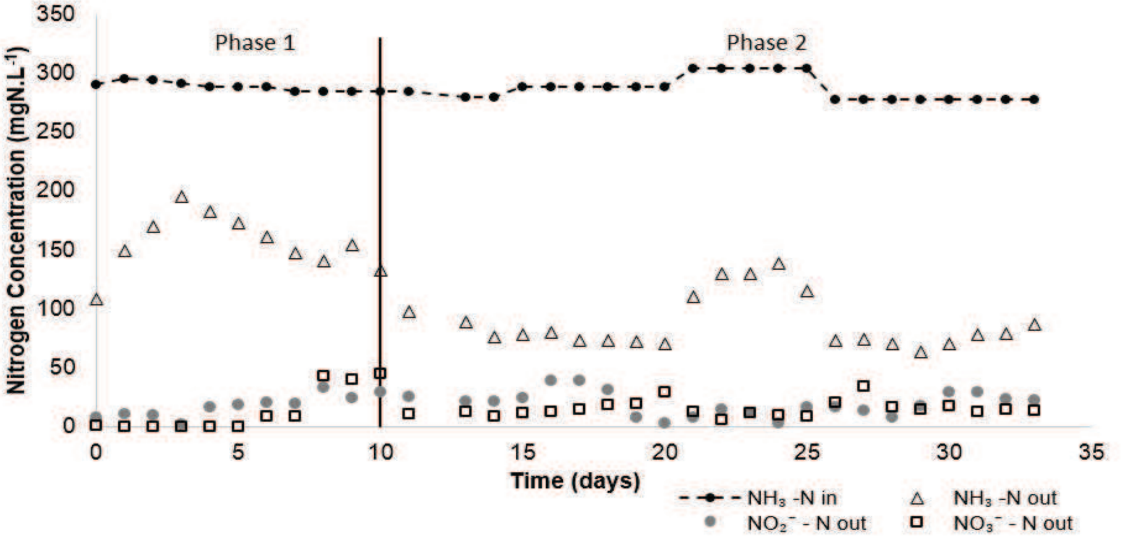

Figure 1 - Variation of influent and effluent nitrogen concentration along operation time.

These data with stoichiometric coefficients (Fig. 2), was also observed that the coefficients obtained in this phase were not closely linked to the literature stoichiometric coefficients (Vanotti, et al. 2012), mainly for O_2 corroborating prevalence of nitrification process.

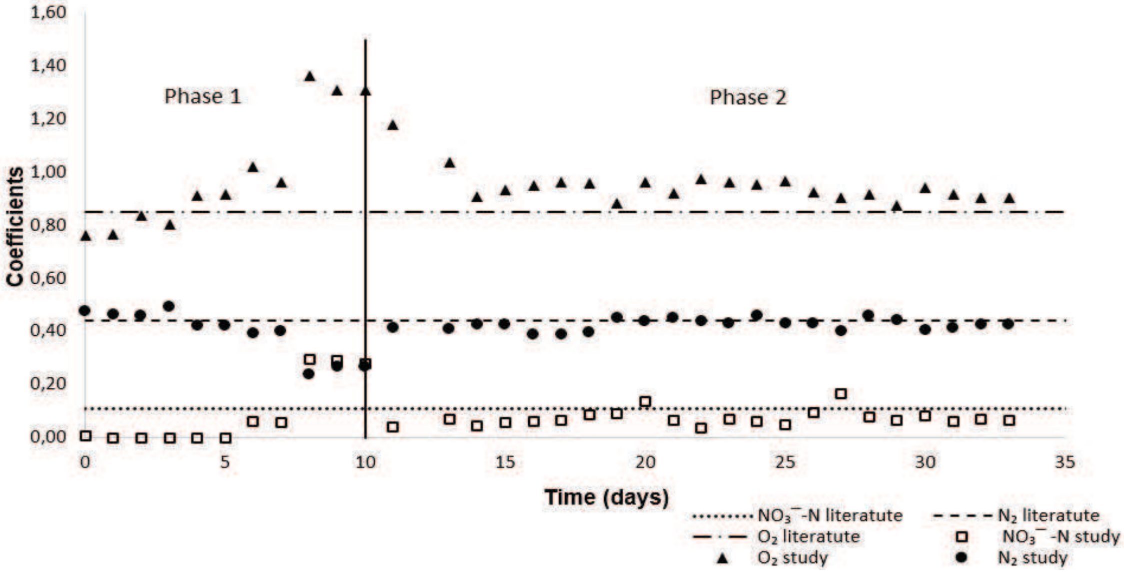

Figure 2 - Monitoring of the forms O_2, N_2 and NO_3^--N stoichiometric coefficients.

Thus, after aeration reduction, in phase 2, nitrite and nitrate accumulation in the reactor decreased but this process did not affect ammonia consumption, indication the increase of anammox activity. At this phase NLR was 0.8 $kgN.L^{-1}.d^{-1}$ and NRR reached 0.5 $kgN.L^{-1}.d^{-1}$ achieving y 77 % of NH_3-N remotion.

In this phase, the process was stable with stoichiometric coefficients remaining near by the reported in the literature (Fig. 2).

Therefore, compared deammonification process with nitrification/denitrification, that requires 2 mol of O_2 per mol of NH_4^+ removed (Bitton 2005), the results showed in this work point out that the oxygen requirement for ammonia removal can be reduced in 54%, a quantity of 0.93 mol of O_2 per mol of NH_4^+ removed.

The nitrifying and anammox bacteria groups in a single reactor create an effective consortium to remove ammonia that can contribute in the reduction of aeration costs for high strength nitrogen wastewater application as livestock effluents.

Conclusions

The use of DO control to avoid nitrite accumulation in a deammonification single reactor is a good strategy to increase anammox activity preventing the NO_2^- toxicity that can permanently inhibit the process.

Acknowledgements

The present research was supported by the Biogasfert Research Network from Embrapa/Itaipú grant nº 2.12.08.004.00.00. The first author thanks CAPES Foundation – Ministry of Education of Brazil for providing a master's degree scholarship. The four author thanks Araucaria Foundation – Scientific and technological support development support of Paraná for providing a master's degree scholarship.

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