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DEAMMONIFICATION REACTION IN DIGESTED SWINE EFFLUENTS

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ABSTRACT: Farmers that would like to implement biological nitrogen (N) removal from the effluent of anaerobic digesters (AD) – for example to comply with regional surplus nitrogen regulations or to take advantage of environmental nutrient credit programs – are often limited by the low amount of endogenous carbon available for traditional denitrification, since the carbon is consumed in the biogas production. The deammonification process is a completely autotrophic nitrogen removal approach that eliminates the carbon needs for denitrification. Thus, it can be a promising approach for the biological removal of ammonia (NH_4^+) from anaerobic digester effluents that are low in carbon and high in ammonia concentration. We obtained rapid deammonification reaction by mixing a high performance nitrifying sludge, HPNS (NRRL B-50298) with anammox bacterial sludge, Brocadia caroliniensis (NRRL B-50286) in single, aerated reactors. The reactors contained biofilm plastic carriers (30-40% v/v) that were fluidized by the aeration. The process water temperature was 23±2°C. The single-tank reactors were tested with digested swine wastewater. The reactions obtained were consistent with deammonification process. Compared with traditional N removal, the deammonification process reduced 56-57% of the aeration. It removed the nitrogen in a single-tank, further reducing equipment costs. Therefore, deammonification can be a key technology for development of more economical and energy efficient biological ammonia removal systems in the near future.

Keywords: ammonia treatment, anammox, deammonification, swine wastewater, manure.

INTRODUCTION

This file describes model and standards to be used for publication in the Proceedings of the III Sigera. Leave a blank line after Introduction Farmers that would like to use nitrification/denitrification (NDN) to remove N from the effluent of anaerobic digesters (AD) – for example to comply with surplus nitrogen regulations or to take advantage of environmental nutrient credit programs – are often limited by the low amount of endogenous carbon available for traditional denitrification, since the carbon is consumed in the biogas production. Two solutions could be implemented: 1) to add supplemental carbon (i.e., MeOH), or 2) to use some of the raw manure directly into NDN. In the first case, the cost increases because chemicals need to be purchased, and in the second case, the benefit decreases because less manure is being used to produce biogas. For example, in an on-farm treatment plant in a swine operation in Brittany (France) that used AD/NDN, as much as 30% of the raw manure bypassed AD directly into NDN to obtain optimal denitrification (F. Beline, pers. comm., 5/22/2012). A better approach would be to use biological deammonification. Deammonification is a completely autotrophic nitrogen removal approach that combines partial nitritation and anammox (Fig. 1). Our objective was to test the deammonification concept for swine wastewater using a one-stage process (partial nitritation and anammox in a single tank).

MATERIAL AND METHODS

Bacterial cultures: For partial nitritation, we used a high performance nitrifying sludge (HPNS) developed for treatment of high ammonium concentration and low temperature wastewater (Vanotti et al., 2011a). The anammox bacteria used was Candidatus *Brocadia caroliniensis* with accession number NRRL B-50286 (Vanotti et al., 2011b). Characteristics of these bacterial cultures are provided by Vanotti et al. (2012).

Deammonification Reactors. We tested two single-tank reactors: a 5-L aerated vertical vessel and a 1-L aerated conical vessel (Figures 2 and 3). Both vessels contained biofilm plastic carriers (1200 m^2/m^3) at 30-40% v/v packing ratio that were fluidized by the aeration. The reactors were started by mixing 230-800 mL of anammox bacterial sludge Brocadia caroliniensis (NRRL B-50286) and 80-400 mL of nitrifying sludge HPNS (NRRL B-50298). The process water temperature was 23±2°C. The aeration rate applied varied from 300 to 850 mL/min as N loading rate increased from 0.8 to 1.4 kg N/m^3-reactor/day in the 5-L reactor. The aeration rate in the 1-L reactor was 40-100 mL/min. The process was optimized with interrupted aeration cycles (23 min ON/7 min OFF). During aeration, the DO was generally below 0.6 mg/L.

RESULTS AND DISCUSSION

Figure 4 shows a typical batch test in the 5-L reactor conducted to determine the rate of N removal and the stoichiometry of the single-tank deammonification process. The rate of ammonia removal was 1.03 kg N/m^3-reactor/day with ammonia removal efficiency of 100% and total N removal efficiency of 89%. The stoichiometry was derived from the concentration profiles of ammonia, nitrite, nitrate, and carbonate alkalinity (Eq. 1):

5-L reactor (Eq. 1): $NH_4^+ + 0.87\ O_2 \rightarrow 0.45\ N_2 + 0.11\ NO_3^- + 1.41\ H_2O + 1.18\ H^+$

Consistent results obtained with swine wastewater in the 1-L reactor. In continuous flow, the ammonia removal efficiency was 97% with N loading rates of 0.69 kg N/m^3-reactor/day and swine wastewater NH_4-N concentration of 568 mg/L. The stoichiometry was derived from the changes of ammonia, nitrite, nitrate, and alkalinity between influent and effluent (Eq. 2):

1-L reactor (Eq. 2): $NH_4^+ + 0.85\ O_2 \rightarrow 0.44\ N_2 + 0.07\ NO_3^- + 0.04\ NO_2^- + 1.40\ H_2O + 1.19\ H^+$

The results indicate that the reactions obtained in the single-tank process in both reactors (Eq. 1 and 2) were consistent with the theory of the deammonification process combining partial nitritation and anammox with regards to alkalinity and oxygen consumption (Eq. 3).

Single-stage theory (Eq. 3): $NH_4^+ + 0.85\ O_2 \rightarrow 0.44\ N_2 + 0.11\ NO_3^- + 1.43\ H_2O + 1.14\ H^+$

Compared with nitrification/denitrification (that requires about 2 mol of O_2 per mol of NH_4^+ removed), our results obtained with the deammonification process (Eq. 1 and 2) reduced the oxygen required to remove the ammonia by 56-57%.

CONCLUSIONS

We evaluated deammonification treatment using single, fluidized, aerobic reactor tanka by mixing a high performance nitrifying sludge and anammox bacteria. Based in our previous experience with deammonification using separate reactors (one for PN and another for anammox), the single-tank approach was much easier to manage. The two bacteria groups were able to associate quickly and effectively in a single tank providing a streamlined ammonia removal process. Thus, the single tank configuration offers the potential to further reduce the cost of treatment of ammonia in livestock wastewaters containing high ammonia.

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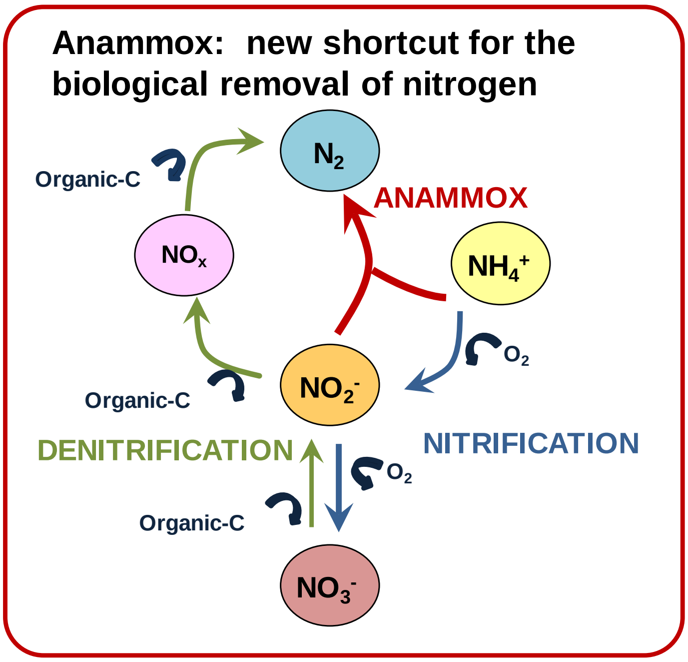

Figure 1. Deammonification involves ammonia oxidizing bacteria that convert about half of the wastewater ammonia (NH_4^+) into nitrite (NO_2^-) (partial nitritation), and anammox bacteria that utilize the remaining ammonia (NH_4^+) and nitrite (NO_2^-) to produce N_2.

Figure 2: Deammonification treatment using single-tank to perform partial nitritation and anammox in a fluidized continuous flow aerated reactor. A) 5-L reactor set-up, B) Mixing of HPNS with anammox, and C) Reactor detail with plastic carriers inside.

Figure 3: A) Deammonification treatment of swine wastewater using single-tank (1-L conical reactor), and B) Detail of fluidized reactor.

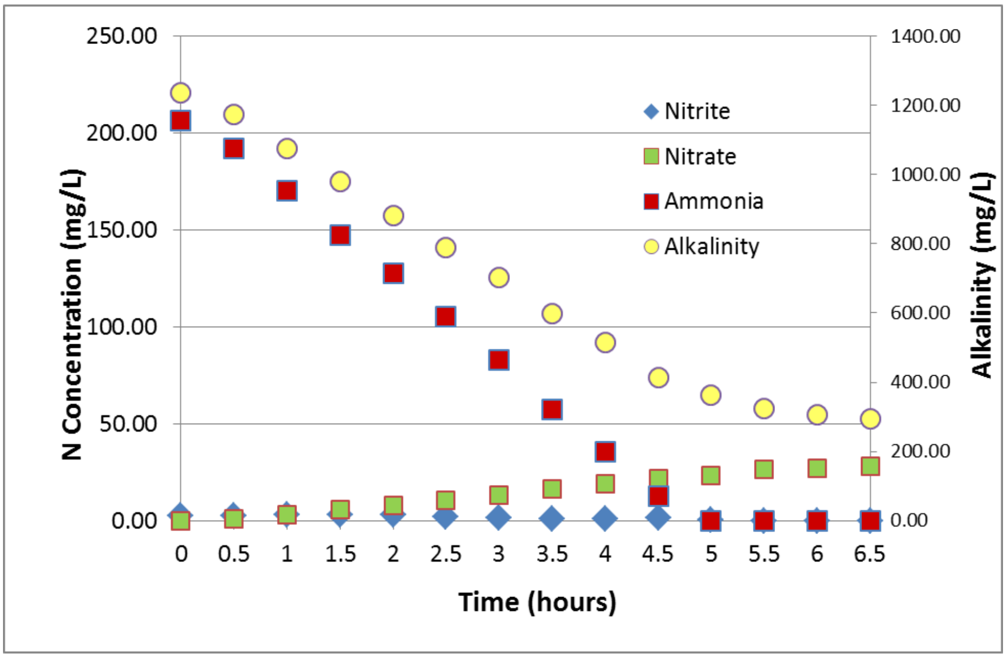

Figure 4: Deammonification treatment of digested swine wastewater in batch conditions.