# UASB reactor effluent nitrogen removal in an aerated-facultative pond at a poultry slaughterhouse

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**Abstract**

This paper investigates the removal of nitrogen from UASB effluent in an aerated-facultative pond (AFP) at a poultry slaughterhouse wastewater treatment system. The AFP presented COD, BOD, NTK and ammonia removal efficiencies of 63%, 71%, 68%, and 79%, respectively at surface loading (SL) of 301 ± 109 kg BOD/ha.d and HRT of 18 ± 2 d. HRT in the aerated section of the pond was 4.5 ± 0.4 d. Nitrification and denitrification tests conducted with biomass collected at three AFP points indicated that it is capable of both nitrification and denitrification. The highest ammonia and nitrite oxidation rates as well as the highest nitrate and nitrite denitrification rates were obtained in tests using biomass from the mechanically-aerated section (PA). The density of ammonia- and nitrite-oxidizing bacteria was higher at PA. In all tests, the ammonia-to-nitrite oxidation rate was higher than that of nitrite-to-nitrate oxidation, corroborating the accumulation of nitrite found in the pond effluent. Nitrification and denitrification tests showed that the nitrogen removal observed in the aerated pond followed the biological pathway. The nitrification and denitrification rates found in this study were similar to those observed in conventional nitrogen removal systems, pointing to the potential of aerated ponds to remove nitrogen from anaerobic reactor effluents.

**Keywords**

Denitrification; nitrification; post-treatment; poultry slaughterhouse wastewater; UASB reactor

## INTRODUCTION

Poultry slaughterhouse wastewater is characterized by high loads of suspended solids, oil and grease, nitrogen, and phosphorus, which may vary from plant to plant, depending on the adopted industrial process and the water consumption per slaughtered bird (Del Nery *et al.*, 2007).

Anaerobic digestion is generally used as a core technology for treating food industry wastewater. In most cases, anaerobic reactor effluents fail to meet discharge legislation standards, so a post-treatment system to complete the removal of organic matter, nitrogen and phosphorus is required. Among the best alternatives is the use of ponds equipped with mechanic aeration as post-treatment of UASB reactor effluents, because of their capacity to reduce organic matter and nitrogen. Nitrogen reduction occurs in aerated ponds by several means, including algal uptake, nitrification/denitrification, and volatilization (Midelbrooks, 1995). The focus of this study was to assess nitrogen removal via biological processes at a partially aerated stabilization pond (aerated-facultative pond) based on the nitrification and denitrification potential of microbial populations.

## MATERIALS AND METHODS.

### Poultry slaughterhouse wastewater biological treatment system

The wastewater treatment system is composed of a UASB reactor (1,280 $m^3$) followed by an aerated-facultative pond (AFP) (13,000 $m^2$). The AFP inlet section (3,250 $m^2$) is equipped with 90 hp aeration. Monitoring parameters were determined once a month over 22 months of operation at P1, P2, and P3 sampling points (Figure1).

## Nitrification and denitrification tests

Nitrification and denitrification tests were performed in batch reactors (200 mL liquid volume). A culture medium containing macro and micronutrients was used, pH kept at 7.5-8.0. The batch reactors were placed in shakers at 30ºC ± 1ºC and 150 rpm rotation. Three tests were performed with biomass collected at three distinct AFP points as inoculum: PA (Test I, IV, and VII), PB (Test II, V, and VIII), and PC (Test III, VI, and IX) (Figure 1). In order to assess nitrification, a medium containing 30 mg/L ammonia-N was used. Fish tank aerators were employed to supply oxygen to reactors. Nitrate and nitrite denitrification tests were conducted with initial concentrations of 20 and 10 mg/L, respectively. For tests of nitrification and nitrate denitrification, samples were collected every hour. Ammonia, nitrite, and nitrate analyses were carried out. At the end of every test, VSS (volatile suspended solids) concentrations were determined and specific coefficients were estimated for each activity.

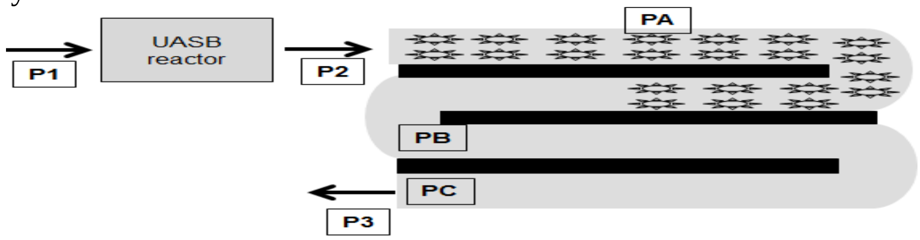

**Figure 1**: Biological units of the poultry slaughterhouse wastewater treatment system. Sampling points: P1 (UASB influent), P2 (UASB effluent), P3 (AFP effluent). Biomass sampling points: PA, PB, PC.

### *Estimation of activity coefficients and density of nitrifying bacteria*

Kinetic modeling of nitrification tests was based on removal of nitrogen in the form of N-ammonia (ammonia oxidation test) and N-nitrate production (nitrite oxidation test). Denitrification was estimated from removal of nitrogen in the form of N-nitrate and N-nitrite using acetate as electron donor, C/N ratio kept at 10. Time profiles were obtained for substrate concentration in the liquid medium over time, and the integral method was employed to determine the reaction order. The nitrifying bacteria density was estimated according to the MNP technique (Schmidt & Belser, 1984) adapted to wastewater samples. PCR amplification with specific primers was also applied to confirm the presence of nitrifying bacteria.

## RESULTS AND DISCUSSION

## Applied loads and rates and UASB reactor and AFP performances

The characterization of the UASB and AFP influents and effluents are presented in Table 1. The organic loading rate (OLR) applied to the UASB reactor was 1.89 ± 0.56 kg COD/m$^3$.d and the hydraulic retention time (HRT) was 1.17±0.10 d throughout the period of study. The AFP presented COD, BOD, TKN, and ammonia removal efficiencies of 63%, 71%, 68%, and 79%, respectively, at surface loading (SL) 301±109 kg BOD/ha.d and HRT 18±2 d. The HRT values in the aerated section and in the nonaerated section of the pond were 4.5±0.4 d and 13.6±1.2 d, respectively. Nitrification and denitrification processes occurred simultaneously in the AFP.

**Table 1**. Wastewater characterization of biological treatment.

| Parameters | UASB influent (P1) | UASB effluent (P2) | AFP effluent (P3) |
|---|---|---|---|
| COD (mg/L) | 2163±534 | 739±212 | 272±82 |
| BOD (mg/L) | 1207±343 | 359±119 | 106±34 |
| TKN (mgN/L) | 206±41 | 177±28 | 56±40 |
| $NH_3$ (mgN-$NH_3$/L) | 100±17 | 149±19 | 31±33 |
| $NO_2$ (mgN-$NO_2$/L) | 0 | 0 | 10±8 |
| $NO_3$ (mgN-$NO_3$/L) | 9±2 | 4±1 | 6±4 |

## Nitrification and denitrification tests

Figure 2 shows profiles of kinetic tests conducted with biomass collected at the AFP sampling points PA, PB, and PC.

The highest ammonia and nitrite oxidation rates were obtained in Test I with biomass from PA (Table 2). In Tests II and III, ammonia and nitrite oxidation rates were similar. These results indicate that the oxygen supplied by mechanical aeration in the first section of the AFP (PA) promoted the growth of ammonia- and nitrite-oxidizing microorganisms. The density of ammonia- and nitrite-oxidizing bacteria was highest at PA followed by that found at PB and PC (Table 2), which is consistent with the nitrification rates estimated. PCR data corroborate these findings. In all tests, the ammonia-to-nitrite oxidation rate was higher than that of nitrite-to-nitrate oxidation, causing nitrite to accumulate (Table 2 and Figure 2). Lower nitrite oxidation rates may be related to poor development of nitrite-oxidizing microorganisms (Table 2) due to insufficient aeration at AFP and to the fact that stabilization ponds contain diverse microbial communities. Higher rates were obtained with specialized biomass. The ammonia and nitrite oxidation rates obtained by Villaverde et al. (1997) were 15 mgN.gSSV$^{-1}$.h$^{-1}$ and 15 mgN.gVSS$^{-1}$.h$^{-1}$ to 50 mgN.gVSS$^{-1}$.h$^{-1}$, respectively. Yuan & Gao (2010) and Reyes-Avila *et al.* (2004) obtained ammonia-to-nitrite nitrification rates in the order of 2.5 mgN.gSSV$^{-1}$.h$^{-1}$ and 6.25 mgN.gSSV$^{-1}$.h$^{-1}$, respectively.

The highest nitrite denitrification rates were obtained in Test VII with biomass collected at PA (Table 2). Nitrate denitrification rates were similar in Tests IV, V and VI, while denitrification rates decreased from Test VII to IX (Table 2) with biomass collected in PA, PB e PC, respectively. Reyes-Avila *et al.* (2004), using acetate as electron donor in a denitrification batch reactor obtained a denitrification rate of 12.55 mgN$_2$.gSSV$^{-1}$.h$^{-1}$. This indicates that the pond biomass is capable of employing oxidized nitrogen as final electron receptor when oxygen is lacking. On the other hand, the presence of nitrite in the pond effluent may be attributed to the pond not being capable of providing an environment suitable for denitrification, since it typical of facultative ponds to supply oxygen to the system through photosynthesis. Biological nitrification/denitrification depends on adequate environmental conditions for microorganisms to grow and is affected by several factors such as temperature, dissolved oxygen concentration, pH value, detention time, and wastewater characteristics. The extent of nitrogen removal depends on design and operating conditions (Metcalf & Eddy, 2003). However, design criteria for nitrogen removal in aerated ponds are very limited. Midelbrooks (1995) presented a minimum HRT of 45 days to accomplish nitrogen removal in aerated ponds and Houweling *et al.* (2008) indicate that the nitrification period could be prolonged by increasing aeration in the pond.

**Table 2:** Nitrification and denitrification kinetic coefficients and MNP.

| Nitrification | Test I | Test II | Test III |
|---|---|---|---|
| Ammonia oxidation (mg N.gSSV$^{-1}$.h$^{-1}$) | 6.69 | 4.61 | 5.17 |
| Nitrite oxidation (mg N.gSSV$^{-1}$.h$^{-1}$) | 1.64 | 0.73 | 0.79 |
| Denitrification via nitrate | Test IV | Test V | Test VI |
| Denitrification (mg N.gSSV$^{-1}$.h$^{-1}$) | 7.73 | 7.47 | 8.47 |
| Denitrification via nitrite | Test VII | Test VIII | Test IX |
| Denitrification (mg N.gSSV$^{-1}$.h$^{-1}$) | 8.34 | 6.65 | 4.00 |
| MNP | PA | PB | PC |
| Ammonia-oxidizing bacteria (NMP/mg STV) | $7.10^6$ | $7.10^5$ | $26.10^4$ |
| Nitrite-oxidizing bacteria (NMP/mg STV) | $26.10^2$ | 980 | 480 |

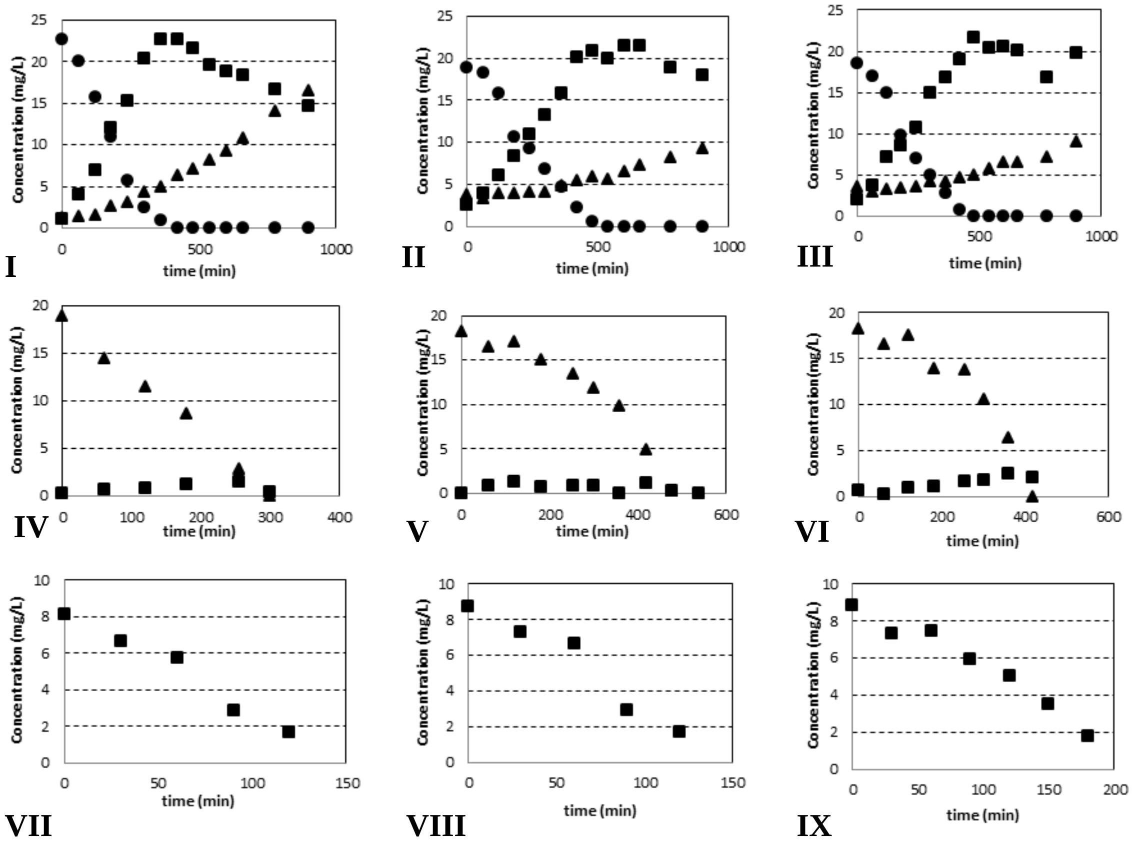

**Figure 2**: Kinetic test profiles: variation in concentration of N-NH4 (●), N-NO2 (■), and N-NO3 (▲) in tests conducted with biomass from PA (I, IV, VII), PB (II, V, VIII), and PC (III, VI, IX).

## CONCLUSIONS

The nitrification and denitrification tests carried out in this study indicate that nitrogen was removed from the AFP by biological processes. Moreover, the nitrification and denitrification rates found were similar to those observed in conventional nitrogen removal systems, which points to the potential of aerated ponds to remove nitrogen from anaerobic reactor effluents.

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