Nitrification-Denitrification of Raw Municipal Wastewater without Recirculation, Using Encapsulated Microbial Systems

M. Farazaki* H. Marakas* and P. Gikas*

* School of Environmental Engineering, Technical University of Crete, Chania, Greece
(E-mail: *petros.gikas@enveng.tuc.gr*)

Abstract
A novel nitrification-denitrification process using encapsulated nitrifiers and denitrifiers has been tested for the treatment of real municipal wastewater. The process consists initially of nitrification at low Hydraulic Retention Times (HRT), so to preserve BOD for the downstream denitrification stage (at the same HRT). HRTs of 8, 4 and 3 h were tested with encouraging results, as TN was measured below 1, 5 and 12 mg/L, respectively.

Keywords
nitrification, denitrification, wastewater, Lentikats

INTRODUCTION

In most municipal wastewater treatment plants there is a need for the removal of nitrogen, which usually takes place using the combined nitrification – denitrification process. Nitrification refers to the biological oxidation of ammoniac nitrogen to nitrate, and takes place under aerated conditions, while denitrification refers to the reduction of nitrate to gaseous nitrogen. The later process takes place under anoxic conditions and requires the addition of organic carbon. The most common approach in wastewater treatment is the employment of denitrification upstream of nitrification, combined with strong recirculation (2 to 4 times influent flow rate) of the downstream nitrified wastewater, in order to take advantage of the inlet BOD which is used a carbon source. The above process involves high pumping costs. Alternatively, nitrification can take place upstream of denitrification, however in such case there is need for the addition of organic carbon, at high cost.
The scope of the present work is to investigate the possibility for nitrification-denitrification process in once-through systems (e.i.: without recirculation), without the need for addition of extra carbon source (e.i. using the BOD in wastewater as carbon source), on real wastewater. As BOD oxidation progresses along with nitrification in the aeration tank, and taking into account that BOD oxidation rate is faster than ammoniac nitrogen oxidation, it is important to increase the overall nitrification rate beyond the BOD oxidation rate. The latter is achievable if retained nitrifiers are used in the aeration tank, while the hydraulic retention time is below the doubling time of the heterotrophic biomass (Farazaki et al., 2015); with the above configuration hetertrophic microorganisms will fail to reproduce in the aeration tank (Gikas and Livingston, 2006), leaving a significant fraction of BOD intact to flow into the following anoxic tank. Then, the remaining BOD can be used as carbon source for nitrate denitrification in the anoxic process.

EXPERIMENTAL SETUP

Experiments have been carried out in two continuous stirred tanks (CSTB), for nitrification and denitrification, respectively. Raw municipal wastewater collected from the WasteWater Treatment Plant (WWTP) of Chania, Greece, has been used. Wastewater was initially flocculated (using polyaluminium chloride) so a large fraction of suspended solids was removed. Encapsulated nitrification and denitrification microorganisms by Lentikats SA (Czech Republic) were used (Buskova et al., 2011). The activity of nitrifying (N_{LB}) and denitrifying (D_{LB}) Lentikats biocatalyst was measured between 300-500 mg/(kgN_{LB}·h) and 500- 600 mg/(kgD_{LB}·h), respectively. Following the initial experiments, the reactors then operated in series, with the outlet of the nitrification reactor used as inlet to the denitrification reactor. In both reactors, the pH was controlled to 7.1±0.1, while temperature was maintained at 25 °C. The nitrification tank was continuously aerated and dissolved oxygen was controlled between 2-3 mg /L. In each reactor, the volume of liquid was 1.7 L while 250 g of nitrifying biocatalyst were added in the aerated tank, and 250 g of denitrifying biocatalyst were added in the anoxic tank. Three different Hydraulic Retention Times (HRT) at 8, 4 and 3 h (calculated for each reactor) were tested. Ammonia, nitrate and BOD concentration in the feed tank were measured between 52-60mg($N\text{-}NH_4^+$)/L, 0.5-1mg($N\text{-}NO_3^-$)/L and 190-230mg/L, respectively.

RESULTS AND DISCUSSION

Based on the experimental results (Fig. 1), at HRT 8 h, almost all $N\text{-}NH_4^+$ is converted to $N\text{-}NO_3^-$ in the aerated reactor, while TN is below 1 mg/L at the exit of the system. At HRT of 4 h a slight increase in $N\text{-}NH_4^+$ is observed at exit of the aerated tank (up to 4 mg/L), the concentration of which remains almost intact at the exit of the system, while $N\text{-}NO_3^-$ concentration at the exit of the system is about 1mg/L. At the lowest HRT (3 h), $N\text{-}NH_4^+$ has been measured to about 10 mg/L, both at the exit of the aeration tank and at the exit of the system; however, $N\text{-}NO_3^-$ does not exceeds 2.5mg/L at the exit of the system. On the other hand, BOD removal in the aeration tank decreases with the decrease of the HRT. BOD was measured between 20-30mg/L for HRT 8 h or 4 h, while it was measured between 40-60 mg/L at HRT 3 h.

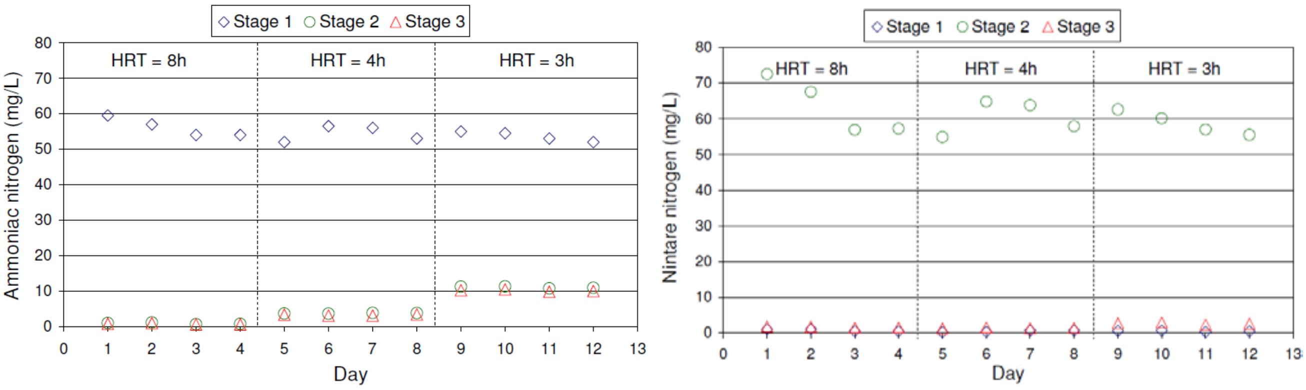

Figure 1. Ammoniac nitrogen (Left) and nitrate nitrogen (Right) concentrations in the influent of nitrification tank (Stage 1), the effluent of nitrification tank – influent of denitrification tank (Stage 2) and the effluent of denitrification tank (Stage 3)

CONCLUSSIONS

Once through, nitrification-denitrification system for municipal wastewater treatment is achievable. Using Lentikats biocatalyst the concentration of nitrification/denitrification microorganisms can be up to 5000 $g_{microorganisms}/m^3$, compared to less than 300 $g_{microorganisms}/m^3$ used in conventional activated sludge plants. Thus, the volume of nitrification/denitrification tanks may be reduced at about 16 times (Gikas et al. 2015), with parallel reduction in recirculation pumping costs.

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