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# Biological treatment of a low strength domestic wastewater in a membrane bioreactor

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**Abstract:** Apart from facing eutrophication, wastewater treatment is a major environmental issue, due to the exhaustion of human resources and the enforcement of stricter legislation limits. Limited economic resources and land availability as well as the high cost of conventional wastewater treatment plants led us to find alternative sustainable methods to treat wastewater, such as membrane bioreactor technology. In this work, we evaluated the depuration of a low strength domestic wastewater derived from a coagulation-flocculation process. An MBR system was operated under alternating aeration and periodic feed, where membrane cleaning was achieved by periodic pumping. MBR performance was examined with and without external carbon source addition, whereas either raw urban wastewater or glycerol from the biodiesel production served as the external carbon source. In all cases, $BOD_5$, COD, TKN and $NH_4^+$-N removal rates were greater than 86% and their effluent values were below the legislation limits. However, denitrification efficiency was low in the absence of external carbon source or during addition of the raw effluent (<16.9% and 25.6%, respectively) and only glycerol addition as the external carbon source resulted in complete denitrification. In particular, TN removal efficiency was above 85%, with effluent $NH_4^+$-N and TN concentrations being below 1.7 and 11.7 mg/L, respectively. Indeed, glycerol addition improved system performance, fulfilling the disposal limits set by the law.

**Key words:** Domestic wastewater, low strength, MBR

## 1. INTRODUCTION

Due to the constantly increasing population and to the fact that modern societies become more consuming than ever, there is a need to expand wastewater treatment plants capabilities. Activated sludge systems, which are commonly used, are costly to construct and most important, have high carbon footprint demands. Many alternative methods to treat wastewater have been developed, one of which is membrane bioreactor technology. The advantages of these configurations in comparison to activated sludge systems are their excellent flow quality, the smaller carbon footprint and the operation flexibility (Visvanathan et al., 2000; Melina et al., 2006). Submerged MBRs need half land area than activated sludge systems and sludge production is half amount (Gander et al., 2000).

A MBR system includes a bioreactor, where all biological processes for nutrients removal are taken place. Inside the bioreactor, the separation of activated sludge from the treated water is achieved through membrane filtration, without the need for sedimentation tank, which is required in conventional activated sludge systems (Judd et al., 2006). The membrane acts as a barrier, permitting passed through the pores some components of mixed liquor and retaining the others (Tchobanoglous et al., 1998).

In order to protect the environment and subsequently the human health, every country enforces criteria for the quality of the treated wastewater. Regulations on wastewater reclamation and reuse are essential, because they protect public health, increase water availability by saving water resources, prevent coastal pollution and deal with water drought problems (Angelakis et al., 1999). Reuse of wastewater in Greece complies with the disposal limits set by the Joint Ministerial Decree 145116/2011.

The aim of current work is to investigate the removal efficiency of a lab-scale MBR system, treating a low strength wastewater. Wastewater was derived from a chemically enhanced primary treatment pilot-scale unit, located in the wastewater treatment plant of the city of Xanthi. The main factor to classify a wastewater as high, medium or low strength is the C/N or the COD/TKN ratio (Carrera et al., 2004; Ryu and Lee, 2009). Microbial growth in wastewater treatment plants relies on various nutrient requirements and operating conditions, with organic content being a major growth factor (Ma et al., 2009). Therefore, an efficient sewage treatment process should be applied in order to achieve high nutrient removal efficiencies from a wastewater with low C/N ratio (Wang et al., 2015).

## 2. MATERIALS AND METHODS

A membrane bioreactor system, shown in Figure 1, was set up and operated under alternating aeration and periodic feed. The unit consisted of a storage tank containing the low strength wastewater, which was derived from the chemical treatment of a domestic wastewater. A pump was supplying wastewater inside a buffer tank in order to feed system at once. The bioreactor comprised of a 25 L tank and a submerged microfiltration membrane of 0.1 μm pore size and 1.5 $m^2$ area. A blower was placed inside the tank for supplying air, while a submersible mixer was used to avoid solid particles sedimentation. The filtrate was pumping through the membrane and stored in a tank for chemical analysis. A second tank was also included for providing external carbon source (glycerol from biodiesel production) to improve denitrification.

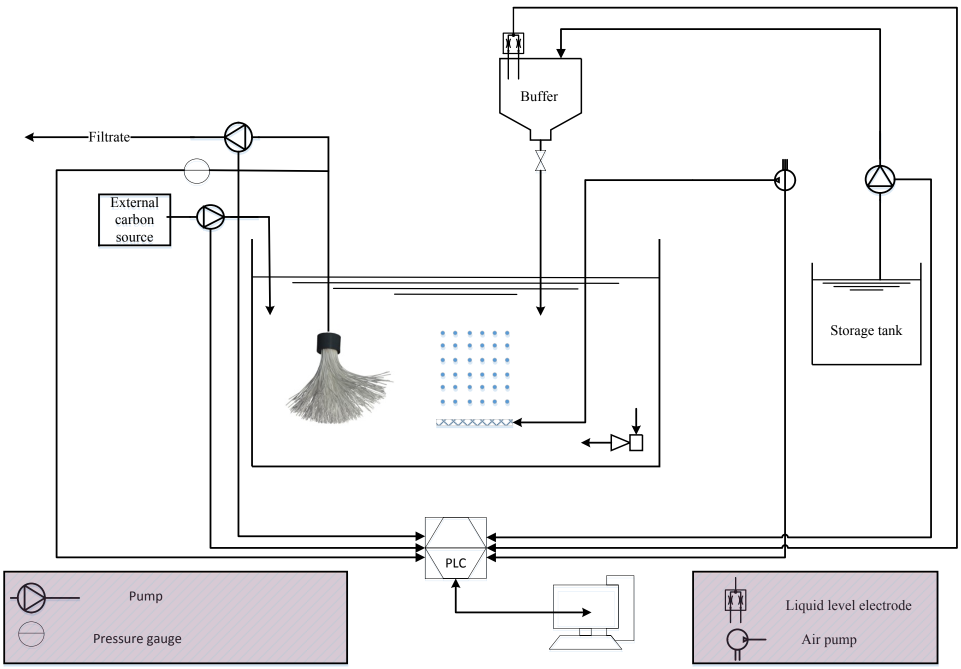


*Figure 1. MBR system chart flow*

A Programmable Logic Controller (PLC) was used for unit control and operation. Every operating cycle consisted of two phases, an aerobic and an anoxic, which were successively changing during the whole experimental period to achieve denitrification. At the beginning of each cycle, i.e. at the beginning of the anoxic phase, wastewater was entering inside the bioreactor tank. Aerobic and anoxic phase duration, filtration period, wastewater and external carbon source pumping were controlled by the PLC system.

Each operating cycle consisted of a 30 min aerobic and 30 min anoxic phase duration. The influent and permeate flow was equal to 0.5 L/h, which corresponded to an HRT of 1.25 d and an working volume at 15 L. Samples were withdrawn from the influent, the effluent and the storage tank in order to evaluate system performance.

## 3. RESULTS AND DISCUSSION

Organic carbon removal rates were sufficient during unit operation. $BOD_5$ and COD removal efficiency was over 96% and 93%, respectively. Similar results were concluded in another MBR system, reporting overall BOD and COD removal efficiencies of 96% and 95%, respectively (Lim et al., 2007). Effluent quality was also comparable with that of Melin et al. (2006), who achieved 97% BOD removal efficiency during wastewater treatment. In any case, effluent was characterized by a low organic content, with BOD and COD concentrations being equal to 4 and 25 mg/L, respectively. Such values were much lower than the legislation limits set in Greece for wastewater reuse.

Nitrification was also efficient, resulting in high ammonia nitrogen and total Kjeldahl nitrogen removal efficiencies of 95% and 87%, respectively. Similar performance showed a MBR unit, operating under the alternating aeration mode (Chaize and Huyard, 1991), measuring effluent TKN concentrations less than 10 mg/L, which corresponded to an average TKN removal efficiency of 85%. In a pilot-scale MBR treating municipal wastewater (Monclus et al., 2010), TKN removal efficacy was 81.3%, with effluent TKN concentration being equal to 10 mg/L. The ammonia nitrogen removal efficiency in an MBR equipped with a submerged microfiltration membrane was 80-83%, with effluent $NH_4^+$-N concentration being equal to 5.6 mg/L (Rosenberger et al., 2002), which is higher than the respective value determined in this study (effluent $NH_4^+$-N was below 3 mg/L).

During the first experimental period (without external source addition), a high $NO_3^-$-N concentration was determined in the effluent, indicating an insufficient denitrification process, due to the limited organic carbon availability. Thus, external carbon addition was needed to improve system denitrification process. In the next experimental period, raw wastewater was added to increase the COD/TKN ratio from 4.1 to 5. Although nitrate reduction was slightly improved, total nitrogen concentration in the effluent was still above the legislation limits. In the last experimental period, glycerol was added as external carbon source, resulting in an average COD/TKN ratio of 8.7. As shown in Figure 2, $NO_3^-$-N and total nitrogen concentrations in the effluent were equal to 3.6 and 11.7 mg/L, which are below the legislation limits.

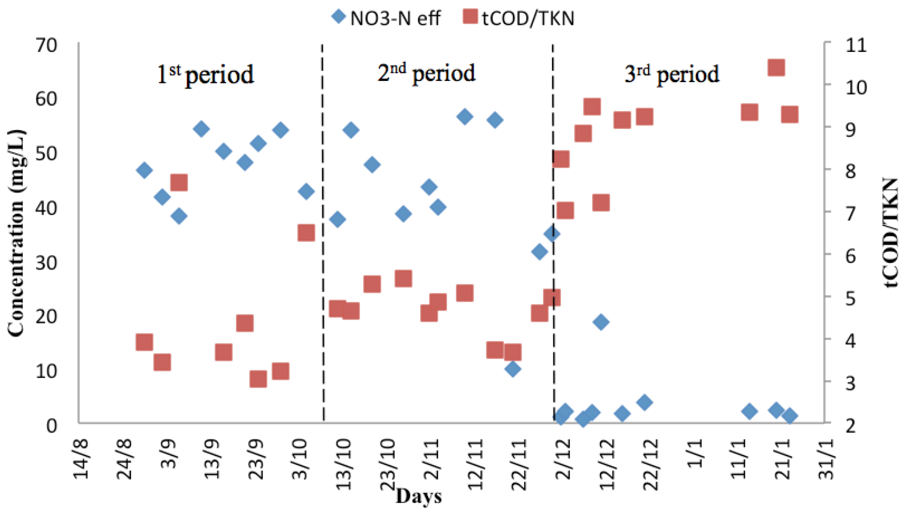


*Figure 2. $NO_3^-$-N effluent concentrations under different COD/TKN ratios*

Total suspended solids were not detected in the effluent during the whole experimental period, as a result of microfiltration membrane. Phosphorus removal efficiency almost reached 100%, especially during glycerol addition. Nutrients' concentrations in the effluent and the respective Greek legislation limits, according to the Joint Ministerial Degree (JMD) 145116/2011 for wastewater reuse, are presented in Table 1. Considering the Greek legislation, a low effluent $BOD_5$ concentration was achieved, which met the legislative limits for unrestricted irrigation and urban use. The effluent TN and ammonia nitrogen concentrations met the legislative limits for unrestricted irrigation, industrial use, urban and suburban green applications, and groundwater recharge. The suspended solids concentration complied with the required limits for unrestricted use.

*Table 2. MBR effluent characteristics and the respective Greek legislation limits*

| Parameter (mg/L) | **BOD** | **COD** | **TKN** | **$NH_4^+$-N** | **$NO_3^-$-N** | **TN** | **$PO_4^{-3}$-P** | **TSS** |
|---|---|---|---|---|---|---|---|---|
| MBR effluent | 3 | 13 | 7.9 | 1.7 | 3.6 | 11.7 | 0.1 | 0 |
| Legislation limit | 25 | 125 | - | 2 | - | 15 | 2 | 35 |

# 4. CONCLUSIONS

MBR unit resulted in high BOD, COD, TKN and $NH_4^+$-N removal efficiencies (96, 93, 86 and 95%, respectively) during treatment of a low strength wastewater. Partial addition of high strength wastewater, to enhance denitrification, did not affect the overall unit performance, determining BOD, COD, TKN and $NH_4^+$-N removal efficiencies of 97, 92, 87.5 and 95%, respectively. In the abovementioned experimental periods, total nitrogen removal was restricted and denitrification efficiency was low. Addition of glycerol increased C/N ratio over 8 and BOD, COD, TKN, $NH_4$-N and TN removal efficiencies were greater than 99.4, 97, 89 and 97%, respectively. Indeed, nitrate reduction highly improved and total nitrogen concentration in the effluent was equal to 11.7 mg/L. Addition of external carbon source also resulted in MLSS increase, without affecting system operation. MBR effluent characteristics fulfill with the disposal limits set by the Greek Joint Ministerial Decree, not only for wastewater discharge, but also for wastewater reuse for limited irrigation, industrial use and aquifer enrichment.

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