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Anaerobic MBR Technology for treating Municipal Wastewater at Ambient Temperatures

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Abstract

An innovative way to treat municipal wastewater and produce energy at the same time is anaerobic treatment. Anaerobic processes are traditionally used for high-strength wastewater or municipal sludge treatment and only recently have been applied for the treatment of low strength municipal wastewater. To investigate the performance of anaerobic wastewater treatment through the incorporation of membrane technology, a 40 L laboratory scale Anaerobic Membrane Bioreactor (AnMBR) with a flat sheet submerged membrane along with a 40 L reservoir for trapping and measuring the biogas produced have been installed and set in operation. The operation of the AnMBR unit with real wastewater is an important step for data generation, since most of the studies related to AnMBR have been performed with synthetic wastewater offering no insight to problems that a real-world unit might face. This paper presents the start-up of the unit and operating results from the first phase of laboratory scale experiments, conducted at temperatures between 14-18^{o}C. More experiments will be held in the near future at different temperatures and also different operating conditions in order to examine the efficiency of the reactor under realistic conditions, by identifying the possibility of integrating the technology into WWTPs.

Keywords: anaerobic treatment; AnMBR; circular economy; biogas production

1. Introduction

Water reuse has been identified as one of the five top priorities of the European Innovation Partnership (EIP) on Water. According to EC, the EU potential for wastewater reuse is estimated to be six times greater than the existing one (approximately 6 billion m^3). Traditional municipal wastewater management in many European countries is mostly addressing public health and environmental issues related to waste storage and disposal. As a result, in many cases municipal wastewater management has been practiced in a non-sustainable way, employing treatment schemes that exert a high energy demand, have a large carbon footprint and contribute significantly to climate change. Examples of these management schemes are easily found in Greece in wastewater treatment that are mainly based on aerobic biological processes that are energy intensive and result in high sludge production, are characterized by a high energy footprint, produce high quantities of greenhouse gases (GHG) and have high operating costs (Mamais et al, 2015). Therefore, the energy portfolio should aim to the minimization of carbon-based energy consumption and the increase of the renewable energy production.

Anaerobic processes are traditionally used for high-strength wastewater or municipal sludge treatment (Lin et al., 2013). Recently, it has been efficiently applied for the treatment of low strength municipal wastewaters as well (An et al, 2009). The main advantages of the anaerobic treatment compared to the conventional aerobic treatment methods are: a) the low structural and operational cost, b) the production of small volumes of well stabilized excess sludge and c) the production of methane which is a useful source of energy (Show & Lee, 2016).

One emerging technology that can improve the efficiency of anaerobic processes is anaerobic membrane bioreactors (AnMBR), which combine biological treatment with membrane filtration for secondary wastewater treatment. The full biomass retention achieved by the AnMBR results in a higher concentration of suspended solids compared to conventional active biomass systems and at very low concentrations of suspended solids in the outlet. Therefore, the low growth rates of anaerobic microorganisms are compensated and high-quality reclaimed water is produced, free from suspended solids and pathogens and rich in nutrients, making it an ideal fertilizer in agriculture.

High-quality biogas production is another feature that puts the AnMBR into a sustainable option for municipal wastewater treatment. In particular, the composition of the gas under optimal conditions can extend up to 90% in methane (Liao et al, 2010).

In view of the above, the objective of the present study is to provide credible data on performance of AnMBR under ambient temperatures and to derive guidelines for optimized operation of the reactor.

2. Materials and Methods

2.1. Description of the AnMBR reactor

To investigate the performance of anaerobic wastewater treatment with AnMBR, a 40 L laboratory scale reactor with a flat sheet submerged membrane along with a 40

L reservoir for trapping and measuring the biogas produced have been installed in the R&D department of the Athens Water Supply and Sewerage company (EYDAP). The operation of the pilot unit with real wastewater is an important step for data generation, since most of the studies related to AnMBR have been made with synthetic wastewater (Lin et al., 2013), offering no insight about problems that a real-world unit might face.

The system operated at ambient temperatures between 14-18^{o}C. To regulate temperature at values similar to the ones recorded to the Greek WWTPs an external heated bath was used. Moreover, temperature, REDOX and Transmembrane Pressure (TMP) sensors have been installed in the unit for the control of the anaerobic processes. Start-up occurred using biomass from a digester of Volos WWTP, which has been adapted from mesophilic to psychrophilic conditions.

Cleaning of the membranes is performed via biogas through a biogas pump that recirculates the biogas produced and stored in the reservoir. The biogas was then collected from the head space of the AnMBR back to the reservoir. Chemical cleaning has not yet been applied to the system because the membranes have not shown any signs of fouling yet.

2.2. Operating parameters

The AnMBR started its operation in March 2019. During start-up the temperature varied from 14 to 18^{o}C. The treatment capacity of the unit was set to 20 L/d and the organic loading rate was 0.25kgCOD/m^3/d. The HRT was 2d while the sludge was removed from the reactor only for the needs of sampling. The concentration of mixed liquor suspended solids (MLSS) in the AnMBR tank was controlled around 6 g/L and the membrane Flux was around 1.6 LMH.

3. Results and Discussions

Figure 1 presents a summary of COD profiles in the influent, effluent and the COD removal rates.

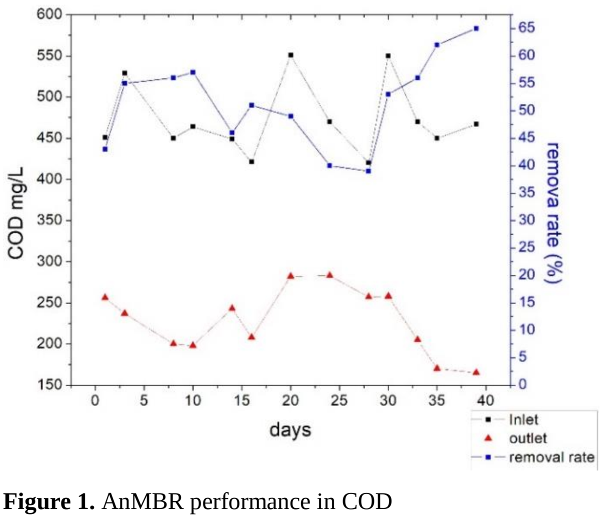

Figure 1. AnMBR performance in COD

The removal rates of COD have an average value of 52% ±8. These rates are rather moderate at the time being, but it should be noted that the system has been set in operation for less than 2 months and the ambient temperatures were low at the time that the start-up was occurred. In addition, FISH analysis was performed on mixed liquor samples to determine the microbial content of the anaerobic reactor biogenesis.

The average pH to both the inlet and the outlet of the reactor was 7.5 ±0.3 and 7.1±0.1 respectively. Total Suspended Solids in the outlet are totally removed being always below the limit of detection of the analytical method. The transmembrane pressure appears to be stable and the daily measure of the outlet capacity proves that no fouling has yet occurred. The produced biogas was daily monitored and the results showed that the average methane yield was up to 0.35 L CH_4/g COD removed (0.25 L CH_4(STP)/g COD removed, the volume of methane produced at 15^{o}C Standard Temperature and 1 atm Standard Pressure).

In the near future, more experiments will be held at different temperatures and different operating conditions in order to examine the efficiency of the reactor.

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