Anaerobic digestion of olive mill wastewater using a static granular sludge reactor followed by a plant remediation eco-system

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Keywords: OMWW, anaerobic digestion, phytoremediation.
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Introduction

Olive oil production is generally connected to the generation of adverse environmental problems making its further operation problematic. Olive Mill Wastewater (OMWW) is produced only from the pressed and 3-phases olive oil production processes and its major characteristics from an environmental point of view are its high organic content as well as its high concentration in lipids and phenolic compounds. In Greece, due to the distribution of olive oil production in a large number of small to medium olive mills, the seasonality of the olive oil production and the low and competitive price of olive oil, the viability of any wastewater treatment technique becomes limited (Vlyssides et al., 2017). The construction of any wastewater treatment facility, in order to be economical viable, should result in the production of marketable side products. Methane production from anaerobic digestion and plant biomass production rich in protein from tertiary treatment facilities are two final products that can be produced under an integrated treatment process based on clean technologies (El-Shafai, 2006).

Materials and methods

In this study, an integrated wastewater treating system was examined at lab-scale using OMWW from a III-phase olive oil mill plant including an anaerobic digestion unit and a phytoremediation unit. Initially, the OMWW is diluted 10 times and filtrated to remove any solids before entering into a 2 L Static Granular Anaerobic Sludge Bed Bioreactor (SGASBB). The initial COD of the diluted and filtrated OMWW was 2500 mg/L and the hydraulic retention time into the SGASBB was 1.5 days. The effluent from the SGASBB is first entering into a reed bed of a total surface 470 cm^2 and 14 cm height and then into a plant bioreactor of a total surface 300 cm^2 and 13 cm height. The first phytoremediation stage consists of a lab scale constructed wetland where *Arundo Donax* was cultivated followed by a second phytoremediation stage of a water pond covered with the floating aqua plant of sp *Lemna minor*.

Results and Discussion

OMWW is a high toxic waste and it is not amenable to biological degradation, specifically due to its high content of phenolic compounds (16-20 g/L) and olive oil residues (1-1.5%). In this study, the toxic inhibition of OMWW was reduced prior to the anaerobic digestion by 1:10 dilution and filtration. The overall degradation yield from the three stage treatment facility (one anaerobic digestion stage and two phytoremediation stages) was above 90% for COD, TOC, TKN και TP. Therefore, we can safely suggest that the water for diluting the initial OMWW can be provided by recirculating the treated waste. The disadvantage of diluting the OMWW is that we need to increase the volume of the anaerobic digester. To overcome this problem, a Static Granular Anaerobic Sludge Bed reactor has been studied which has significant advantages for high hydraulic loads and medium organic loads.

The anaerobic digestion has three main disadvantages: (1) the inability to nitrificate the organic nitrogen in the anaerobic digester; (2) due to the requirement of strong reductive conditions, the yield of anaerobic digestion cannot exceed 85% of the initial TOC and (3) due to the removal of carbon through the production of biogas and the low digestion of the organic nitrogen, the TOC/TKN ratio of the effluent is low, hindering the possibility of implementing a further aerobic nitrification process (Vlyssides et al., 2017). The major problem of TKN treatment after the anaerobic digestion can be solved by using the aquatic plant *Lemna minor* which utilizes the ammoniacal nitrogen in order to produce proteins. However, the high concentration of COD and phosphorus contained in the effluent is an inhibitory factor for the growth of *Lemna minor* plant. This problem was successfully overcome by introducing an additional stage between the anaerobic digestion process and the hydroponic cultivation of *Lemna minor*. This stage involves the cultivation of *Arundo Donax* reed which has the ability to remove significant amounts of carbon and phosphorus (Iatrou, 2015; Tanaka, 2010).

The results of the lab-scale process (anaerobic digestion followed by two stages of phytoremediation) have shown significant reduction of the organic load of the waste. Results from the SGASBB indicated that COD was decreased more than 70% producing methane in parallel. Moreover, the combination of the two stage phytoremediation unit has the advantage not only to reduce further the COD to very low concentrations (<100 mg/L) but also to decrease the phosphorus and nitrogen content from the final effluent due to the production of

plant biomass and plant protein. The COD content was reduced from 2500 mg/L to 20 mg/L when the maximum permissible limit for effluent discharge is 120 mg/L.

Conclusions

In this study, we present an integrated system for the successful treatment of OMWW that includes an anaerobic digestion process using a SGASBB and a two-stage phytoremediation unit. More than 90% of the initial COD was degradated by using the above lab-scale facility producing biogas and plant biomass. The latter will be used in the near future as nitrogen source in the anaerobic digestion process.

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