

Comparison of aerobic processes for olive mill wastewater treatment

Y. Jaouad, M. Villain-Gambier, L. Mandi, B. Marrot
and N. Ouazzani

ABSTRACT

Membrane bioreactor (MBR) has been proven to be an efficient technology capable of treating various industrial effluents. However, the evaluation of its performances in the case of olive mill wastewater (OMW) over a conventional activated sludge (CAS) have not been determined yet. The present study aims to compare OMW treatment in two laboratory scale pilots: an external ceramic MBR and CAS starting with an acclimation step in both reactors by raising OMW concentration progressively. After the acclimation step, the reactors received OMW at 2 g_{COD}/L with respect to an organic loading rate of 0.2 and 0.3 $kg_{COD}/kg_{MLVSS}/d$ for MBR and CAS, respectively. Biomass acclimation occurred successfully in both systems; however, the MBR tolerated more OMW toxicity than CAS as the MBR always maintained an effluent with a better quality. At a stable state, a higher reduction of 95% chemical oxygen demand (COD) was obtained with MBR compared to CAS (86%), but both succeeded in polyphenols removal (80%). Moreover, a higher MLSS elimination from the MBR treated water (97%) was measured against 88% for CAS. Therefore, CAS was suitable for OMW treatment and MBR could be proposed as an alternative to CAS when a better quality of treated water is required.

Key words | acclimation, aerobic treatment, COD and phenolic compounds removal, conventional activated sludge process, external ceramic membrane bioreactor, olive mill wastewater

Y. Jaouad

L. Mandi

N. Ouazzani (corresponding author)

Laboratory of Water, Biodiversity and Climate Change (EauBioDiCC), Faculty of Sciences Semlalia,

University Cadi Ayyad,

Marrakech,

Morocco

and

National Center for Studies and Research on Water

and Energy (CNEREE), BP/511,

University Cadi Ayyad,

Marrakech,

Morocco

E-mail: ouazzani@uca.ma

M. Villain-Gambier

Université de Strasbourg, CNRS, UMR 7178,

F-67000 Strasbourg,

France

M. Villain-Gambier

B. Marrot

Marseille Univ, CNRS, Centrale Marseille, M2P2,

Equipe Procédés Membranaires (EPM),

Aix en Provence Cedex,

France

HIGHLIGHTS

- Olive mill wastewater (OMW) treatment by membrane bioreactor (MBR) and activated sludge (AS) were compared.
- Biomass acclimation and polyphenols degradation occurred successfully in both systems.
- At 0.2 and 0.3 $kg_{COD}/kg_{MLVSS}/d$, MBR showed higher efficiency at 95% than CAS (86%).
- MBR showed better performances (95%) than CAS (86%) for OMW COD treatment.
- Considering the Moroccan situation, the CAS could be more adapted for OMW treatment.

INTRODUCTION

Olive oil production is one of the main agro-industries in Mediterranean countries and the production of olive oil is increasing due to the nutritional benefits and economic interest of this substance. However, the activity generates significant amounts of olive mill wastewater (OMW), which represents a serious environmental problem in

many producing countries. The OMW volume produced during the process varied from 40 to 60 L for pressing method and it ranged from 100 to 120 L for triple phase centrifugation method per 100 kg of olives (Rahmani 2010). The OMW is one of the most contaminant effluent for the environment. The 5-day biochemical oxygen demand

(BOD₅) values are between 12 and 63 g/L and chemical oxygen demand (COD) values are between 80 and 200 g/L. These concentrations are around 200–400 times higher than those measured in typical municipal sewage. In addition, OMW contains phenolic compounds which are recognized with phytotoxic and antimicrobial properties.

Several methods are being used for the treatment of OMW such as electrochemical oxidation, stabilization ponds, thermal concentration, and other physicochemical treatments (Paraskeva & Diamadopoulos 2006). However, most methods are expensive and produce sludge and other secondary by-products which need to be further treated. The aerobic methods are recognized as economic alternatives to physicochemical methods for the treatment of a wide range of wastewater effluents. In most cases, conventional activated sludge (CAS) is used and preferred for large-scale application (Sipma *et al.* 2010). However, the feeding of this system by highly toxic OMW could be harmful and disturbing for its normal functioning. The inhibition of the biodegradation might occur because of the proper toxicity of OMW phenolic compounds towards microorganisms (Esmail *et al.* 2015).

The membrane bioreactor (MBR) has attracted attention concerning its high ability for the removal of a large type of contaminants including phenolic compounds (Baresel *et al.* 2019). The integrated membrane in the MBR replaces the clarifier in CAS process with settling ability problems. The MBR treatment of industrial wastewater has become attractive for the robustness of the process to treat high organic load and inhibitory compounds (Fazal *et al.* 2015). The main problem associated with MBR process is membrane fouling, therefore, it has to be managed in order to guarantee the development of a sustainable process. Soluble microbial products (SMP) are currently considered as the main part of extra polymeric substances (EPS) which are responsible for membrane fouling. Due to the lack of information about the

characteristics of SMP in MBR and CAS treating OMW, one of the main objectives of this study is to assess the feature and appearance of SMP in both reactors and to link their production to the operating conditions. The treatment of OMW in MBR was successfully performed in previous studies with a preliminary acclimation step. The COD and phenolic compounds removals in the range of 80–95% and 80–90% were respectively reached (Dhaouadi & Marrot 2008; Jaouad *et al.* 2018). As the effluent treatment with MBR was reported to be more expensive than CAS treatment (Bertanza *et al.* 2017), the objective of the current study is to investigate and compare the performances of two pilots, MBR and CAS, operating simultaneously for the treatment of OMW. The COD and phenolic compounds removal efficiencies and the quality of the treated water were principally assessed during the running of both pilots. A strategy of OMW treatment in Morocco was then proposed. The purpose of this strategy is to demonstrate which one of the reactors is effective in OMW wastewater treatment considering the Moroccan context.

MATERIALS AND METHODS

MBR and CAS pilots set up

A laboratory scale MBR system (30 L) (Polymem, France) was used in this study. The membrane was placed outside of the bioreactor and operated under a cross flow velocity of 4 m/s to reduce membrane blockage. Diagrams of the pilot plants are presented in Figure 1.

The aerobic tank was supplied by 30 L activated sludge and the aeration was provided by small bubble diffusers (6–8 mgO₂/L). Recirculation of activated sludge from the aeration tank to the membrane was accomplished by recirculation pump. The temperature was maintained at 25 °C

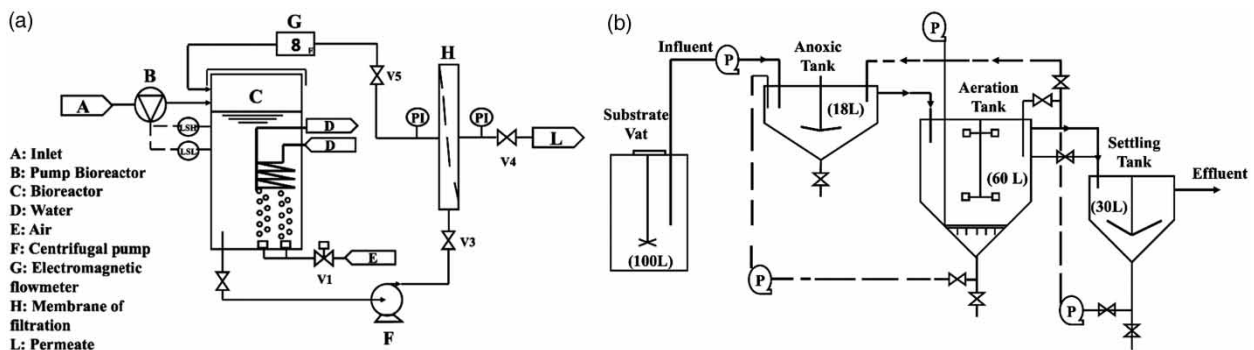


Figure 1 | Schematic diagram of MBR (a) and CAS (b) installations.

inside the bioreactor using a cooling coil system. Initially, the experiment was conducted by an ultrafiltration (UF) membrane to retain specific enzymes involved in phenolic compounds removal. Afterwards, the UF membrane was replaced by a microfiltration (MF) membrane to guarantee a constant flow rate of the permeate with less membrane fouling. Both of the used membranes (UF and MF) were tubular mono-channel ceramic types (Novasep-Orelis, France) with an effective filtration area of 0.02 m², initial water permeability of 100 L/h/m²/bar. The pore size of UF membrane was 150 kDa while it was 0.1 μm for the MF membrane. Transmembrane pressure (TMP) increase was controlled with two manometers set at the inlet and outlet of membrane module (alimentation and retentate). Both permeate and feed flows were kept constant at 0.75 L/h.

The second reactor was a pilot-scale automated activated sludge plant (TAE/3000) (Figure 1(b)). The pilot is composed of three tanks: feed wastewater tank (100 L), aerobic tank with a working volume of 60 L and containing flocculated activated sludge. The settling tank (30 L) is the final module where the flocculated activated sludge is separated from the treated water. A part of sludge in the settling tank was regularly recirculated into the bioreactor to ensure the presence of a significant biomass amount inside the biological reactor. Ambient temperature was maintained at approximately 25 °C. In the aeration tank, the oxygen was provided by an air pump and diffused inside the bioreactor using a large diffuser at a concentration of 2–3 mgO₂/L.

Operating conditions

Initially, the pilots were filled with activated sludge. In the case of MBR, the activated sludge was supplied from a submerged MBR treating municipal wastewater of the village Le Rousset (France, 12,000 inhabitants equivalent, 1,800 m³/d flow rate, organic load 0.1 kg_{BOD5}/kg_{MLVSS}/d). For the CAS plant, the biomass was taken from a full-scale municipal wastewater treatment (WWTP-AS) of Marrakesh (Morocco, 1,300,000 inhabitants equivalent, 120,000 m³/d flow rate). Initial mixed liquor suspended solids (MLSS) concentrations were around 4 g_{MLSS}/L for CAS and 8 g_{MLSS}/L for MBR process. Then, the biomass was pre-adapted in both pilots to a synthetic substrate containing glucose as carbon source: C₆H₁₂O₆ (2.1 g/g_{MLVSS}), KH₂PO₄ (0.2 g/g_{MLVSS}), NaHCO₃ (0.3 g/g_{MLVSS}), MgSO₄ (0.1 g/g_{MLVSS}) and CaCl₂ (0.02 g/g_{MLVSS}). Afterwards, the biomass was acclimated to gradual concentrations of OMW following the acclimation procedure described by Jaouad *et al.* (2016). During the acclimation step, the food

to microorganism ratio (F/M) was kept around 0.3 kg_{COD}/kg_{MLVSS}/d with a starting ratio of 20% OMW/ 80% glucose (v/v). Then the volume of OMW increased progressively as the biomass growth was noticed for several days.

Based on the finding from Jaouad *et al.* (2016), the maximum biomass growth (1.8/d) can be obtained with OMW using a COD concentration of 2 g_{COD}/L and tended to decline after further augmentation of OMW concentration (superior to 2 g_{COD}/L). Therefore, at the end of the acclimation step, the dilution of the raw OMW effluent until 2 g_{COD}/L was necessary to avoid substrate inhibition effect. The acclimation phase was performed under an infinite sludge retention time (SRT) for both reactors and different hydraulic retention time (HRT) of 16 h for AS and 24 h for MBR. At steady state, for the microfiltration step (MF-MBR), the F/M ratio and the mixed liquor volatile suspended solid (MLVSS) were fixed at 0.2 kg_{COD}/kg_{MLVSS}/d and 8 g/L, respectively. The MBR alimentation was done continuously with a constant OMW loading, previously pre-filtered (cut off of 200 μm). In addition, a daily purge was performed in order to keep a constant value of MLVSS concentration of 8 g/L in the MBR and to minimize membrane fouling. For the CAS pilot, the bioreactor was fed only by OMW at a fixed F/M ratio of 0.3 kg_{COD}/kg_{MLVSS}/d. In addition, a frequent purge was performed to maintain 4 to 5 g_{MLVSS}/L in the CAS bioreactor and to ensure a high water clarification. The stabilization of the system was obtained a few days later. The SRT were fixed at 20–25 days for both pilots.

The OMWs used in this experience were sampled at two different periods (in 2013 for OMW1 and in 2014 for OMW2) from a discontinuous extraction unit from Marrakesh, southern Morocco (Table 1). To obtain comparable results, the alimentation of the two pilot plants by OMWs was performed using similar F/M ratio of 0.3 kg_{COD}/kg_{MLVSS}/d.

Table 1 | Physical and chemical composition of OMW1 and OMW2

Parameters	OMW1 (MBR)	OMW2 (CAS)
pH (25 °C)	5	4.1
Conductivity (mS/cm)	9.3	16
Total suspended solids (TSS) (g/L)	2.1 ± 0.3	4.5 ± 0.2
COD (g/L)	96 ± 2	170 ± 5
Total nitrogen (TN) (g/L)	0.46	2.6 ± 0.1
Total phosphorus (TP) (g/L)	0.1 ± 0.03	0.3 ± 0.02
Total polyphenols (g/L)	3.2 ± 0.01	8.1 ± 0.4
Proteins (g/L)	0.04	0.004

