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Feasibility of Olive Mill Wastewater treatment by Multi-Soil-Layering Ecotechnology

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Abstract
This work aims to examine for the first time, the treatment of olive mill wastewater (OMW) by Multi-soil-Layering (MSL) ecotechnology. OMW studied is a very acidic (pH 4.44) and highly concentrated of organics (25.15 g $L^{-1}$of COD) and toxic phenolic compounds (1.496 g L^{-1}). Moreover, OMW contained low concentrations of Electrical conductivity and Total Suspended Solids (4895 µS cm^{-1} and 1.454 g L^{-1} successively). The MSL system is composed of soil mixture blocks (soil-sandy texture + sawdust + metal iron + charcoal) arranged in a brick-like pattern and surrounded by permeable gravel layers to avoid clogging. In our study, OMW diluted by urban wastewater was loaded to the system, at continuous Hydraulic Loading Rate (HLR) of 100 L $m^{-2}day^{-1}$. During the experiment, the percentage of OMW was gradually increased from 10% to100%.Results showed that, between 10% and 50% of OMW in the feeding of MSL induced a pH alkalizing (from 7.9 to 8.5) of the treated water and reduced successfully TSS (from 95.73% to 99.06%), COD (from 85.03% to 91.76%), BOD (from 54.39% to 82.63%), total phosphorus (from 55.46% to 90.06%), NH_4^+ (from 69.25% to 98.58%) and phenolic compounds (from 91.47% to 100%).The Total oxygen demand for organic matter biodegradation and Nitrogen oxidation was completely satisfied in the MSL and residual dissolved oxygen still high at the outlet. However, when exceeding 60% of OMW in the inlet, the efficiency of the MSL system decreased for all parameters and a clogging starting sign (acidic pH, very low residual oxygen in the outlet) appeared although stability of outflow. Therefore, the MSL ecotechnology could be a good option for OMW treatmentwhen mixing of OMW to urban wastewater was less than50% corresponding to a maximum superficial organic load feeding of 1.068 kg COD $m^{-2}day^{-1}$ and 0.516kg BOD_5 m^{-2} day^{-1}.

1. Introduction
The uncontrolled release of olive-mill wastewater (OMW) represents one of the most important environmental problem in the Mediterranean region. The application of olive mills wastewater on agricultural soils has generally positive effects on crop productivity and soil characteristics [1,2], because of its high organic load [3] and mineral salts richness. However, phenolic compounds are responsible for phytotoxic and antimicrobial effects [4-6]. These organic load can be degraded by microorganisms [7-9]. Bacteria of the genera *Pseudomonas*, *Achromobacter*, *Aeromonas* and *Serratia* are capable of degrading phenolic compounds [10,11].
Moreover, Aissam et al. [12] showed that two fungi (*Aspergillusniger* and *Penicillium sp.*) and two yeast (*Geotrichumterrestre* and *Candida boidinii*) were successful for the assimilation of phenolic and lipid compounds. These strains have reduced the COD to 40.3% after a treatment of olive-mill wastewater.However, the time required for a total degradation can be considerable.
The treatment of OMW was already tested using several techniques; forced evaporation [13], coagulation-flocculation [14,15], electro-coagulation [16,17], aerobic treatment [18-20], anaerobic treatment [21,22],

membrane bioreactor [20], advanced oxidation [23-25,9] and infiltration-percolation on a sand filter [26]. Other studies have envisaged the spreading of OMW in the soil as a means of treatment [27,28].
Wakatsuki et *al.* [29] developed in Japan a low-cost technology of multi-soil-layering (MSL) for the treatment of domestic wastewater. The operational principle of this system is based on the infiltration and percolation using the soil and local materials as purification means.This technology was then used successfully in Japan, China, Thailand, USA, Taiwan and Morocco for the treatment of domestic wastewater [30-36]. Moreover, this system has been tested for the treatment of polluted river water, livestock wastewater, food processing waste [30], dairy effluents [37], leachate [38], turtle aquaculture effluents [39], textile wastewater [40]and domestic wastewater [31,32].However, to our knowledge, no work has been tested the MSL technology for olive-mill wastewater treatment. The present study aims to examine the feasibility and the performance of MSL technology in removing phenolic compounds, suspended solids and organic matter from olive-mill wastewater.

2. Materials and methods

2.1. Structure and components of the MSL system

Figure 1 shows the structure of the laboratory-scale MSL system with a plastic box measuring 36 cm in widthby 30 cm in depth by 65 cm in height that was used in the present study. The MSL system was composed of soil mixture layers and gravel layers with a diameter of 3-5 mm.
Permeable gravel layers improve water distribution and dispersion and reduce the clogging risk. MSL structure facilitates the infiltration and distribution of wastewater and makes treatment of higher loading rates possible [41-43].

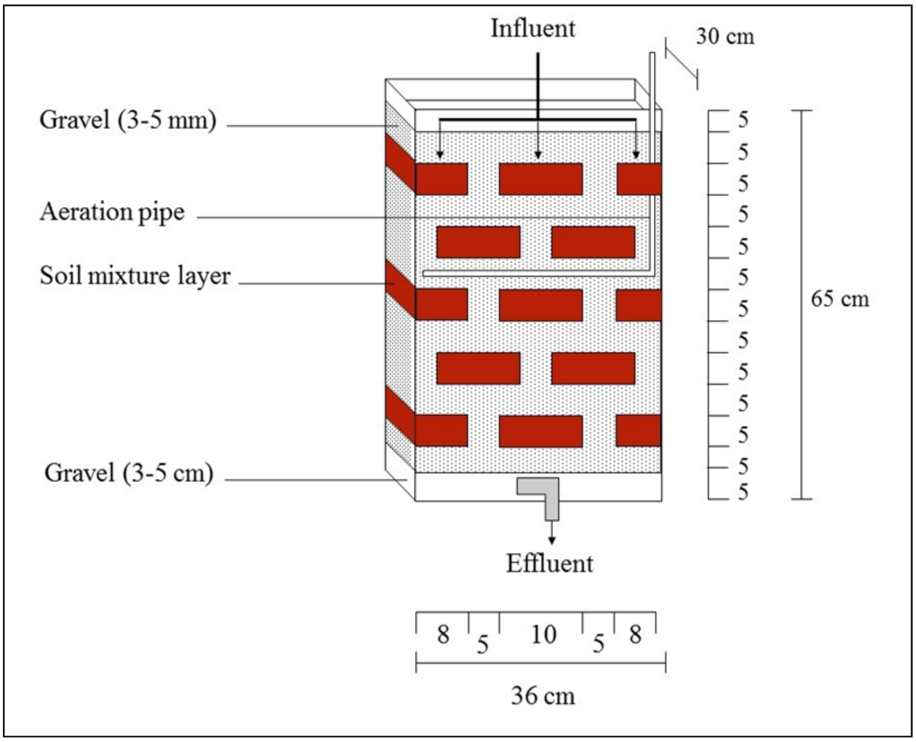

Figure 1: Structure and components of the MSL pilot for OMW treatment

The soil mixture layers consisted of soil sandy texture (pH= 8.13), sawdust (granulometry ≤ 2 mm), metal iron (granulometry ≤ 2cm) and charcoal at a ratio of 60%, 10%, 10% and 20% respectively. The layers were arranged in a brick-layer-like pattern surrounded by gravel layers. The physicochemical characteristics of soil are grouped in Table 1.
An influent emitter pipe (Ø= 30 mm) for olive mill wastewater was placed in the top layer of gravel. This pipe is connected with three adjustable drippers.
A natural aeration pipe was installed in the thirth gravel layer to ensure a uniform distribution of the air into the system. However, no artificial aeration was applied during the experimental period.

2.2. Operating conditions

OMW used in this experiment was collected from a modern triphasic unit in Marrakech region. The feeding of the system was realized by diluted OMW with urban wastewater (concentration: 10%, 20%, 30%, 40%, 50%, 60%, 70%, 80%, 90% and 100%) through the influent emitter pipe with a Hydraulic Load Rate (HLR) of 100 L $m^{-2}day^{-1}$. This type of alimentation used allows to maintain aerobic conditions inside the system and to avoid clogging of the system. The experiment was run from February 9th to August 4th, 2015 (177 days).

Table 1: Soil physicochemical characteristics (mean ± standard deviation n= 3)

Parameters	Content
pH	8.13 ± 0.27
Coarsesand (%)	61.86 ± 0.66
Fine sand (%)	28.23 ± 1.52
Clay (%)	5.51 ± 0.46
Fine silt (%)	2.81 ± 0.04
Coarse silt (%)	1.92 ± 0.01
Total organic carbon (mg g^{-1})	13.10 ± 0.71
Total Kjeldahl Nitrogen (mg g^{-1})	1.06 ± 0.08
Ca^{2+} (mg g^{-1})	79.10 ± 0.02
Phenolic compounds (mg g^{-1})	Not Detected

The dilution of OMW by urban wastewater was carried out to stimulate the biological activity in the MSL system. The sampling was conducted 3 to 4 times per week at the MSL influent and effluent. The samples were collected in plastic bottles for chemical analyzes. Each sample of 1 L was kept at 4°C before analysis.

2.3. Analytical methods

Influent and effluent samples were analyzed for pH, electrical conductivity and dissolved oxygen, using a multiparameter probe type WTW multi 340i/set (WTW Büro-weilheim, Germany). Total Suspended Solids (TSS) concentration was determined by filtration method AFNOR T90-105 [44].

BOD_5 was analyzed according to the Warburg method, and Total COD was analyzed based on dichromate open reflux method [45]. Dissolved COD was determined by the same method after filtration of the sample through Millipore membrane (0.45 um porosity).

Ammonium nitrogen (NH_4^+) concentration was determined by the indophenols method, Nitrate nitrogen (NO_3^-) by diazotization methodafter their reduction through a cadmium-copper column [46], and Total phosphorus (TP) concentration by molybdate and ascorbic acid method after potassium peroxodisulfate digestion [47],

Total polyphenols were measured using the method developed by Macheix et *al.*[48]. The coloration was measured by spectrophotometry at 395 nm.

The total oxygen demand (TOD) was calculated using the following formula given by Brissaud et *al.*[49] :

$$\textbf{TOD= dissolved COD + 4.57 TKN}$$

The Hydraulic Load Rate (HLR) was determined by measuring the volume in liter of the effluent during one hour. The HLR is expressed as follows:

$$\text{Volume (L)/surface in meter of MSL } (0.1\ m^2)\text{/day}$$

3. Results and discussion

3.1. OMW characterization

Table 2 presents the physico-chemical characteristics of the studied OMW. The pH is low (4.44) owing to the presence of compounds such as phenolic acids and fatty acids. In fact, during the storage period, auto-oxidation and polymerization reactions transform phenolic alcohols into phenolic acids. These reactions are manifested by a change in the initial color of OMW from brown reddish toward a very dark black [50]. Indeed, the OMW studied during this work is characterized by a very dark black coloration (12.45). The electrical conductivity is around4895 ± 7.07 µS cm^{-1} at 20°C which can be attributed to the salting used to preserve the olives until the grinding process. The OMW containedlower suspended solids of 1.454 ± 0.015 g L^{-1} than we expected. This can be explained by the origin of the OMW sampling. In fact, the OMW studied are taken from storage tanks, where there is settlement of the suspended matter.

The organic matter expressed in terms of COD and of BOD_5 presented relatively high values. The average values are 25.152 g L^{-1} and 10.448 g L^{-1} respectively. The concentration of nitrogenous elements (TKN: 1.28 g

L^{-1}; NH_4^+ : 17.16 mg L^{-1}; NO_2^- : 0.321 mg L^{-1}; NO_3^- : 0.340 mg L^{-1}) and phosphate elements (PO_4^{3-} : 22.8 mg L^{-1}; Total P : 57.8 mg L^{-1}) in the raw OMW are relatively high. The concentration of phenolic compounds is relatively high (1.496 g L^{-1}) compared to other studies which have also used modern OMW characterization [15,51]. The composition of phenolic compounds of OMW varies according to the oil extraction procedure and the variety of olive treated [52].

Table 2: Physicochemical composition of the raw OMW

Parameters	Mean ± standard deviation (n=3)
pH	4.44 ± 0.03
Electrical conductivity (µS cm^{-1} at 20°C)	4895 ± 7.07
Total Suspended Solids (g L^{-1})	1.454 ± 0.015
Coloration (Abs)	12.45 ± 0.80
Total COD (g L^{-1})	25.152 ± 0.16
BOD_5 (g L^{-1})	10.448 ± 0.10
Total Kjeldahl Nitrogen (g L^{-1})	1.28 ± 0.04
Ammonium (mg L^{-1})	17.16 ± 0.09
Nitrite (mg L^{-1})	0.321 ± 0.011
Nitrate (mg L^{-1})	0.340 ± 0.057
Orthophosphates (mg L^{-1})	22.836 ± 0.020
Total phosphorus (mg L^{-1})	57.826 ± 0.049
Phenolic compounds (g L^{-1})	1.496 ± 0.046

3.2. Urban watewater characterization

Table 3 summarizes the characteristics of wastewater used in our experience. The obtained results indicated high values of pH (7,55), electrical conductivity (2784 µS cm^{-1}), Total Suspended Solids (262 mg L^{-1}), organic matter and nutrients. Moreover, the analysis of wastewater showed the total absence of phenolic compounds.

Table 3: Physicochemical composition of urban wastewater

Parameters	Mean ± standard deviation (n=3)
pH	7.55 ± 0.01
Electrical conductivity (µS cm^{-1} at 20°C)	2784 ± 6.93
Total Suspended Solids (mg L^{-1})	262 ± 2.646
Total COD (mg L^{-1})	661.267 ± 3.027
BOD_5 (mg L^{-1})	387.667 ± 2.517
Total Kjeldahl Nitrogen (mg L^{-1})	99.667 ± 1.14
Ammonium (mg L^{-1})	47.675 ± 0.629
Orthophosphates (mg L^{-1})	6.437 ± 0.39
Total phosphorus (mg L^{-1})	9.484 ± 0.501
Phenolic compounds (mg L^{-1})	Not Detected

3.3. Evolution of hydraulic loading rate (HLR)

Figure 2 shows the temporal evolution of HLR at the inlet and the outlet of the multi-soil-layering system according to the time. The system was fed with a HLR of 100 L $m^{-2}day^{-1}$(24hrs continuously). The effluent rate measured was slightly less than or equal to that of the influent with a mean value of 98.94 L $m^{-2}day^{-1}$. This suggests that almost all volumes of OMW influent are recovered at the MSL system outlet, with an average rate of effluent loss of only 1.06%. However, the water loss by investigated MSL system was slightly increased in high concentration of OMW (100%).

In fact, the rate of effluent loss of wastewater does not exceed 2% for the MSL system [42].This seems to show the capability of the MSL system to treat OMW without clogging sign, under an HLR of 100 L $m^{-2}day^{-1}$.

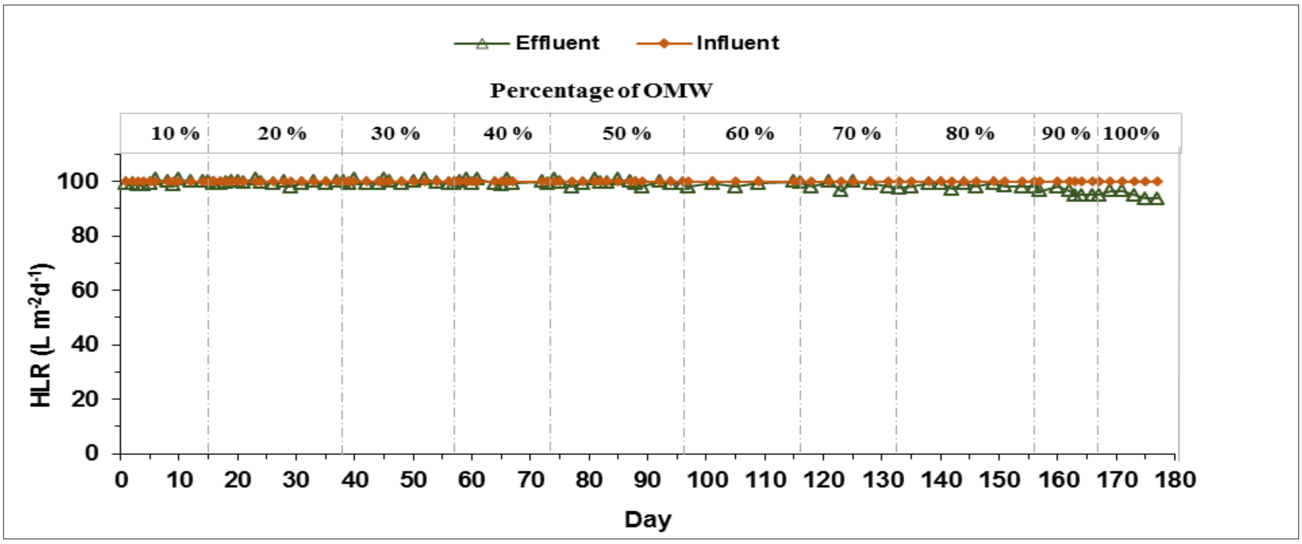

Figure 2: Temporal evolution of HLR of MSL influent and effluent

3.4. Evolution of physicochemical parameters

3.4.1. pH

The various results of figure 3 show an increase in pH value from acidic pH (5.1-6.9) to alkaline pH (7.9-8.51) between 10% and 50% OMW concentration. However, a sudden decrease of pH was noted when the MSL system receives more than 60% of OMW where values ranged from 4.5 for influent to 5.6 at the MSL system outlet.According to Mekki et al. [27] and Achak et al. [26], the OMW pH was increased when they spreadedOMW and passed it through a soil. This increase is probably due to the composition of the soil rich in limestone and the strong capacity of the soil to neutralize the acidic pH of the OMW. This may explain the increase of pH in the first phase (10%-50%).

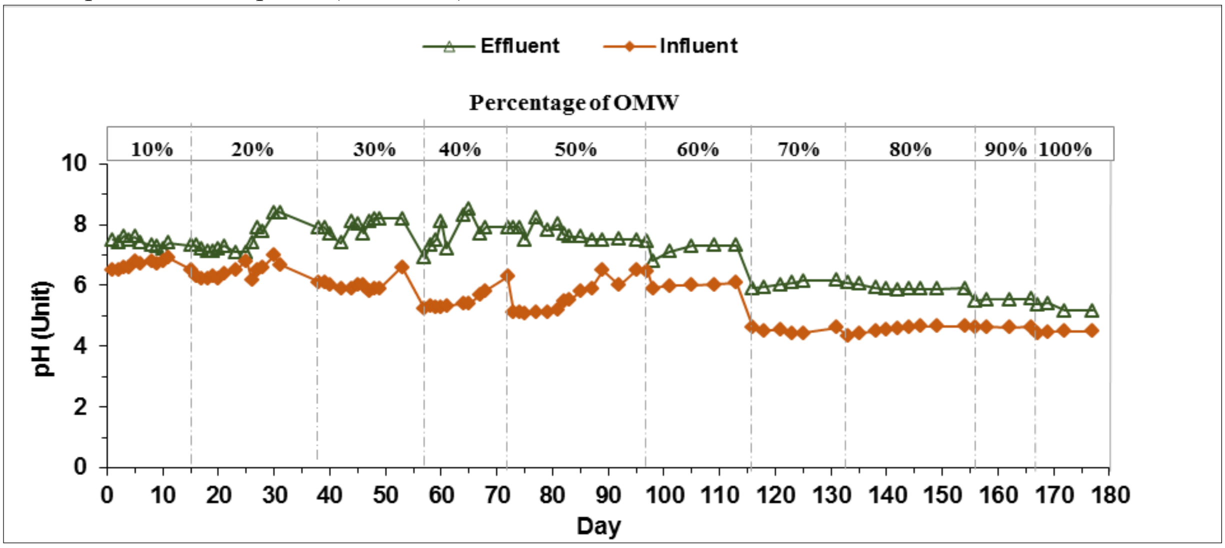

Figure 3: Temporal evolution of pH of MSL influent and effluent

However, the significant decrease of the effluent pH in the second phase (60%-100%) can be explained by the high acidity of the influent that exceeds the buffer capacity of soil.

The influent pH is decreasing according to the increase of percentage of OMW. However, the difference of the magnetitude of the pH variation between input and output could also be linked to nitrification/denitrification processes inside MSL system [31]. Furthermore, the continuous operation of upgrading OMW concentration in the feeding induce an organic overload of MSL system and could exceed its aeration capacity that induce a beginning development of anaerobic conditions in MSL system.

3.4.2. Total Suspended Solids removal (TSS)

Figure 4 shows an important reduction of the TSS (99.06%) at the starting of the operation (10%). This reduction remains always very high until concentration 50%with a maximum of 95.73% which exceeds the percentage found by Achak et *al.*[26]using a sand filter.

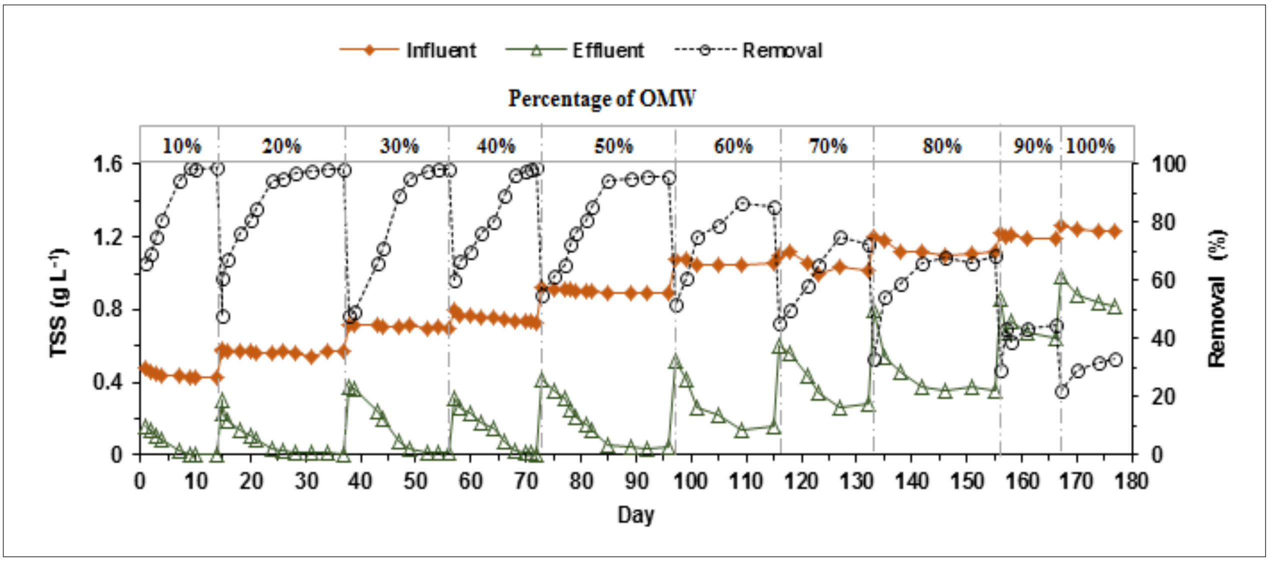

Figure 4: Temporal evolution of influent, effluent and removal efficient of TSS

However, from the concentration 60%, it was noted a significant decrease in the reduction rate of the suspended matter by the MSL system. TSS concentration decreased from 1.26 g L^{-1} to 0.82 g L^{-1} when the MSL was fed totally by OMW (100%) which corresponds to a reduction of only 33.33%.

The high reduction rate of TSS can be explained by the composition of the MSL system containing gravel and soil mixing layers serving as primary barriers to solids in the medium. Moreover, this high rate can be linked to the development of a good biofilm when using mixtures of urban wastewater and OMW, which reduced the porosity of the MSL system and subsequently improved the physical filtration processes.

However, the reduction rate of the suspended matter recorded from the concentration 60% can probably be related to the increase of some colloidal fraction of organic matter brought by the increase of OMW rate [53] which is not retained by the MSL.

3.4.3. Dissolved Oxygen, COD and BOD5 evolution

The Figure 5 shows the evolution over the time of the dissolved oxygen concentration and of the total COD and BOD_5 reduction. The unit (Kg m^{-2} day^{-1}) quantify the quantity of contaminant applied per unit system area.

The evolution of the three parameters was divided on two distinct phases:

Phase 1 (10%-50%): where dissolved oxygen concentrations were increased at the system outlet with a maximum of 3.76 mg L^{-1} (Figure 5a). Moreover, the maximum rates of reduction of dissolved COD,total COD and BOD_5 in this phase are 81.46%, 91.76% and 82.63% respectively (Figure 5). At the end of this phase, the important removal rateof the total COD decreased slightly to 85.03% which exceeded that found by Achak et *al.*[26]using a sand filter treating OMW at 50% dilution.

Phase 2 (60%-100%): dissolved oxygen concentrations of effluents were decreased (0.05-0.11 mg L^{-1}) comparing with those of influent (0.12-0.33 mg L^{-1}) (Figure 5a). In addition, a remarkable decrease of dissolved COD, total COD and BOD_5 reduction were noted during this phase with a maximum removal rate of 51.71%, 57.10% and 49.60% respectively (at concentration 60% of OMW) and a rate of 0.69%, 21.48% and 5.15% respectively at the end of the treatment (at concentration 100% of OMW) by the MSL system (Figure 5). The high residual dissolved oxygen in the first phase is indicating a good oxygenation of the MSL system that allows a high degradation of the organic matter. Nevertheless, the sharp downfall of outlet dissolved oxygen noted from percentage 60% can be explained by the high organic matter load of the OMW which requires a high concentration of oxygen to be degraded.

Organic matter is reduced by a combination of biological degradation, filtration and adsorption. According to Sato et al. [43], organic matter degradation by microorganisms occurs in the uppers MSL layers where oxygenated conditions are generally dominated.

Therefore, while percolating through the MSL system, particulate organic matters are removed by surface filtration, when dissolved organic matters are degraded by the fixed bacteria developed within the MSL system.

The mechanisms of treatment of diluted OMW in MSL are vulnerable to changes in one or several operating parameters such as pH [31], fluctuation of organic loads [54]and the availability of oxygen inside the filter, which affect the overall performance of treatment. Therefore, the decrease of pH and of oxygenation may explain the decrease of degradation of organic matter in the 2^{nd} phase of the treatment by the MSL system.

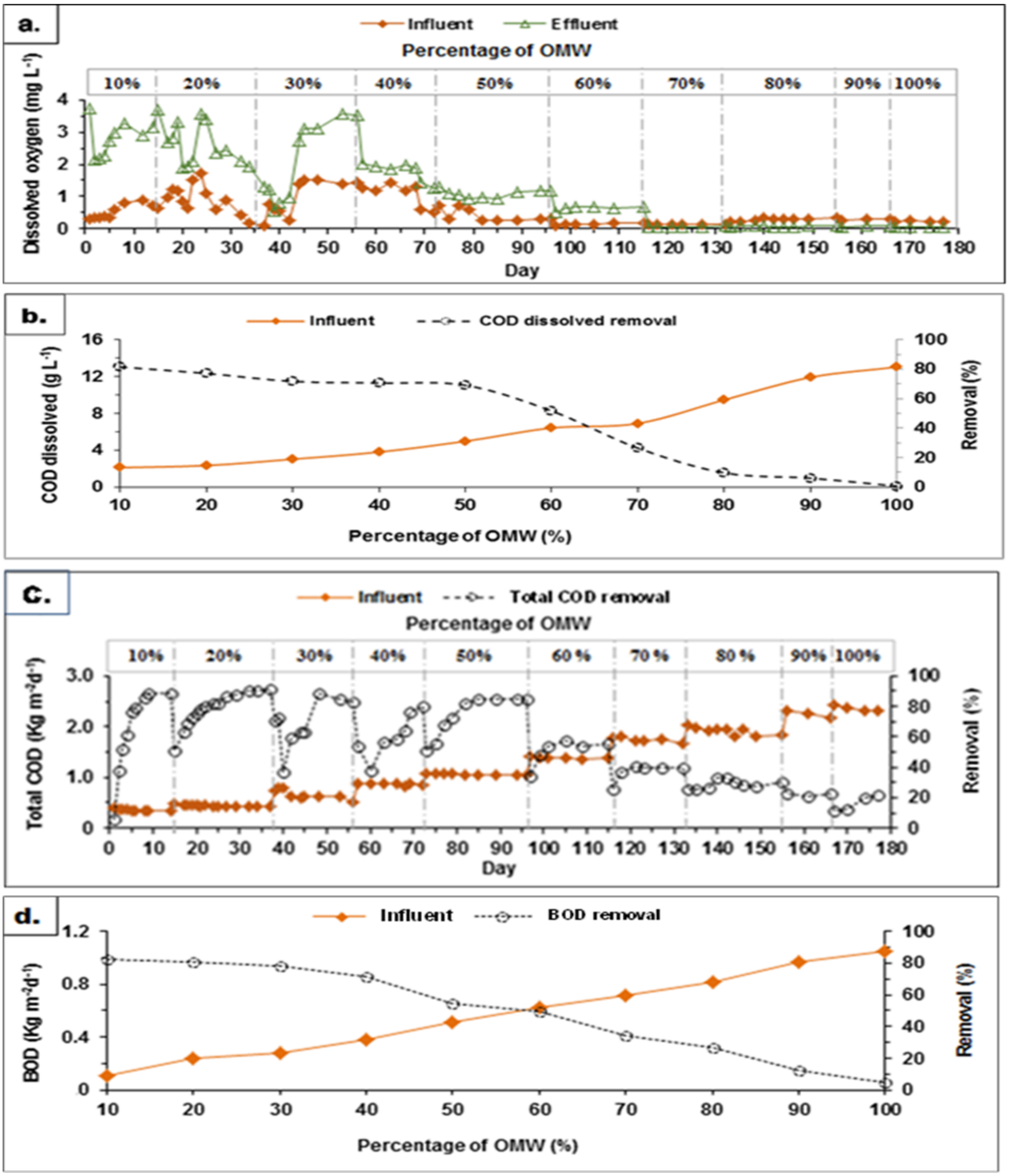

Figure 5: Temporal evolution of (a) influent and effluent dissolved oxygen, (b) influent and removal efficiency of dissolved COD, (c) influent and removal efficiency of total COD and (d) influent and removal efficiency of BOD_5

Several authors [29,55] have suggested that aeration is still significant for enhancing the functions and capability of the MSL to purify wastewater. Moreover, Luanmanee et al. [31] have found that COD removal needed more intensive aeration than the other parameters. Therefore, the increase of the aeration intensity in the MSL system can be used to improve the effectiveness of the OMW treatment.

3.4.4. Total Oxygen Demand (TOD)

TOD expresses the total amount of oxygen necessary to be available in the filter permitting both carbohydrate biodegradation and ammonium nitrogen oxidation. The Figure 6 shows the evolution of the TOD of OMW according to the different dilutions by urban wastewater. During the first phase (between OMW concentration 10%-60%), the difference between the TOD of the influent and the effluent is very high, indicating a satisfactory availability of aeration inside the filter that permitted a very high biodegradation of organic carbon and oxidation of nitrogen. While in the second phase (between 60% and 100%) this TOD is not satisfied at all. In this phase, the difference between the TOD of the influent and the effluent is very low especially when the whole organic load comes totally from OMW (100%). The total oxygen demand seems to be totally unsatisfied in the MSL.

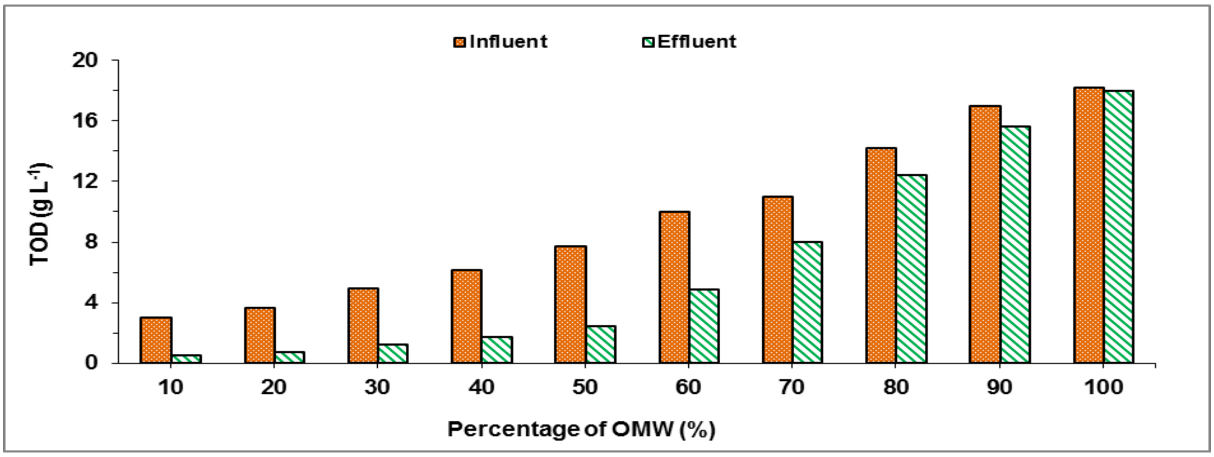

Figure 6: Evolution of TOD of the MSL inlet and outlet according to the percent of OMW in the inlet

The evolution of all parameters such as slight residual oxygen at the effluent, low COD and BOD removals, and low percentage of satisfied TOD of the influent are in concordance and showed clearly that the MSL was overloaded when the feeding was done over than 60% of OMW in the second phase. The maximum nominal value of 1.407 kg COD $m^{-2}day^{-1}$ (0.6 kg BOD_5 $m^{-2}day^{-1}$) recorded at the beginning of this second phase can be considered as a maximum limit value not to be exceeded when treating OMW in MSL system. When organic load exceeded this value, the biodegradation capacity of the system was completely overcome.
Moreover, acidic outlet pH could indicate also an evolution towards anaerobic conditions inside the filter and starting clogging signs.

3.4.5. Nitrogen and phosphates reduction

The Figure 7 shows the evolution over the time of the removal efficiency of ammonium and total phosphorus. This figure shows also the temporal evolution of influent and effluent nitrate.

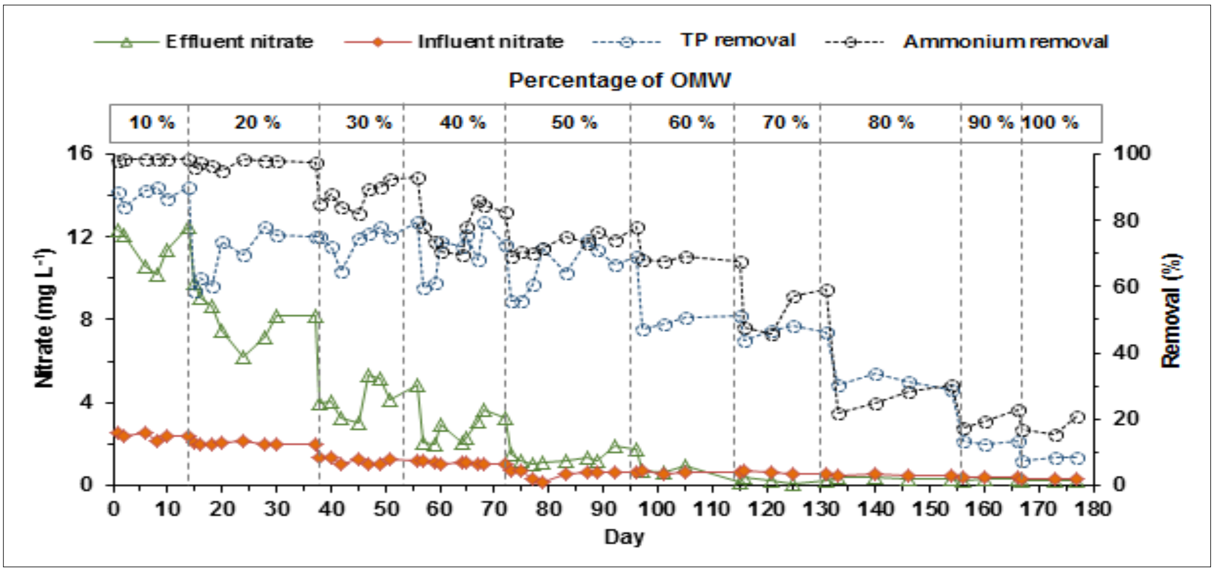

Figure 7: Temporalevolution of removal efficiency of ammonium and total phosphorus and evolution of nitrate concentrations in the influent and the effluent

Nitrogen evolution :
The evolution of nitrogen parameters was divided on two distinct phases:
Phase 1 (10%-50%): The maximum rate of ammonium reduction in this phase is 98.58% .
At the same time , Nitrate concentrations at the system outlet were increased in the beginning of this phase with a maximum of 12.52 mg L^{-1}. These concentrations were decreased at the end of this phase to reach a value of 1.018 mg L^{-1}.
Phase 2 (60%-100%): The maximum removal efficiency of ammonium in this phase was 69.15% . At the end of this phase, the important removal rateof ammonium decreased to 20.8% which is lower than the rate found by Achak et al. [26] using a sand filter treating OMW.
Since the end of the 60% of OMW, nitrate concentrations at the system outlet were decreased significantly and become lower than those of the influent.

The high removal efficiency of NH_4^+ in the beginning was due to the ability of the MSL materials to adsorb this element and to the existence of a significant nitrification processes. Nitrification consists of the NH_4^+ transformation into NO_2^- and finally into NO_3^-, which causes a decrease of the NH_4^+ concentration and consequently the increase of NO_3^- concentration in the effluent. This process is activated within the good oxygenation conditions inside the MSL in this period.
However, the decrease of removal efficiency for NH_4^+ and of NO_3^- concentration in the effluent during the second phase can be explained by the starting development of anaerobic conditions and denitrification process.
Organic matter such as sawdust and charcoal provide a supplementary carbon source for microorganisms involved in organic matter degradation and denitrifiers bacteria [41].
Phosphorus: the removal of phosphorus also presented two phases:
Phase 1 (10%-50%): where the maximum rate of P removal reached 90,06%.
Phase 2 (60%-100%): where the maximum removal efficiency of total phosphorus dereased in this phase and didn't exceed 51.21%. Metal iron added to soil mixture layers play a key role in P removal through precipitationprocess. The iron is oxidized to ferric ion (Fe^{3+}), which aids in associating co-precipitation of orthophosphates from the percolating wastewater [43].

3.4.6. Phenolic compounds
A high removal rates of phenolic compounds (91.47%-98.48%) were recorded between concentration of OMW 10% and 50% with a maximum when the phenolic compounds were yet very low at the start of treatment. However, a decrease of removal rates of phenolic compounds was noticed from the OMW concentration of 60% with a rate that varies between 71.19% at the beginning and 19.01% at the end of the treatment (Figure 8). A significant concentration of phenolic compounds (1.15 g L^{-1}) remains in the effluent of the OMW at the end of treatment.

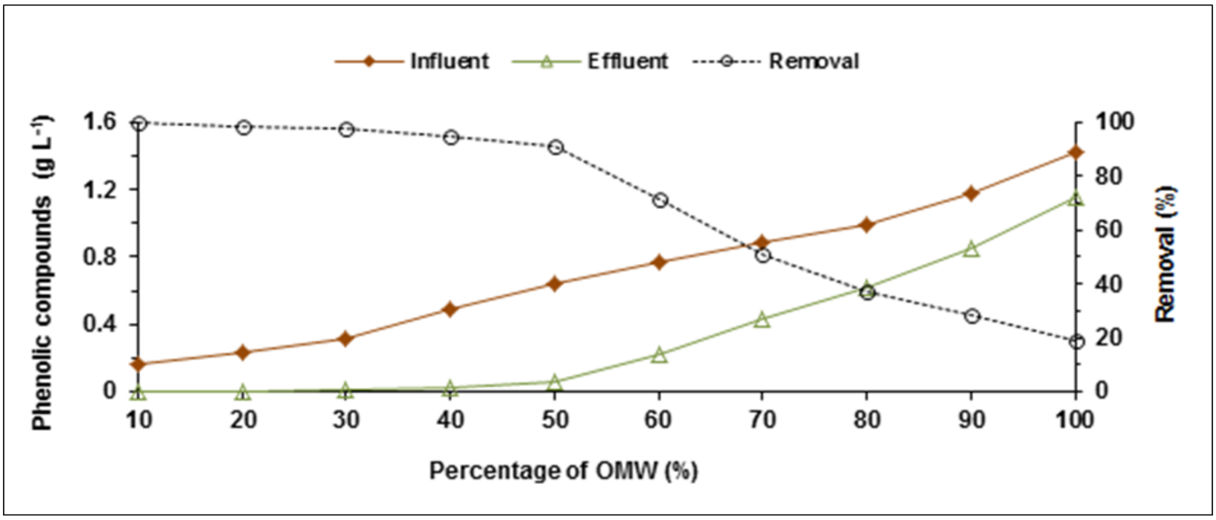

Figure 8: Evolution of removal efficiency of phenolic compounds in the MSL according to the percent of OMW in the inlet

The maximum removal rate recorded at 50% exceeds that found by Achak et *al.* [26]using an OMW influent diluted at 50% with urban wastewater treated by a sand filter. Moreover, this rate exceeds also that found by several authors [51,56,2]who have used other methods of treatment such as soil filter or SBR reactor respectively. Many microorganisms, including bacteria and fungi, were described able to degrade phenolic compounds of olive mill wastewater [57,58].
Indeed, the decrease of phenolic compounds would be related to the greatest activity of the aerobic microorganisms in the MSL or those coming from the urban wastewater which seems to be responsible of the phenolic compounds degradation. Dommergues et al. [59]showed that the degradation of the phenolic compounds by bacteria can be accelerated by a rise in the pH and/or an improvement of ventilation. This data may explain the strong removal rate of phenolic compounds found in the first phase (10% to 50%) where values of pH and dissolved oxygen concentration were high.
However, from the 60% of OMW, the concentration of phenolic compounds reaches probably a toxicity threshold (0.774 g L^{-1}) for the microbial biomass of the MSL. Moreover, the pH becomes very acid and the oxygenation of the system has decreased, which may limit the activity of the biofilm. Moreover, if we supposed that some phenolic compounds could be eliminated via adsorption on clay fraction of soil [60]in the MSL during the first phase, the acidic pH could favor the release of the already adsorbed phenolic fraction on the soil

in the second phase and so could partly explain their concentration increase in the treated effluent and by the way the reduction noticed of phenol removal.
If we consider the evolution of the removal efficiencies inside the same concentration of OMW, we can notice a sequential increase of the TSS removal (Figure 4). At each application of a new increased concentration of OMW, the removal seems to decrease in the beginning and to be improved during the time till the next application of a new increased concentration of OMW. The same evolution is noticed for COD removal (Figure 5b). This could probably indicate an evolution of the biomass that became gradually adapted to the applied OMW concentration but after increasing this concentration, the biomass seems to be destroyed and could explain the reduction of TSS removal (Figure 4) and of the biodegradation that became slower (decrease of COD removal (Figure 5b)). During the feeding with the same OMW concentration, apparently there is an acclimation of the biomass and the performances became higher during the whole period. This phenomenon seems to be repetitive at each new application of increased concentration of OMW till the concentrations over 60% of OMW, where the biomass in the MSL seems to be overloaded or perhaps inhibited by an accumulation of toxic elements brought by OMW. The concentration of phenolic compounds at this concentration reached 0.774 g L^{-1} in the inlet (Figure 7) and could be considered as limiting for biomass growth and degradation.

Conclusion

Olive mill wastewater treatment by the MSL ecotechnology under the configuration tested in this work showed a high adaptability to treat phenolic compounds and organic load. The mixture of OMW with urban wastewater at a concentration of 50%, corresponding to maximum superficial organic load of 1.4 kgCOD $m^{-2}day^{-1}$, ensures an efficient treatment with good performances for all pollutants.
However, when the percentage of OMWexceeded 50%, the efficiency of the system decreased for all parameters, under an HLR of 100 L $m^{-2}day^{-1}$.
As a low-cost treatment ecotechnology with fewer constraints of operation and maintenance, the MSL system could be considered as a new effective solution to be adopted at industrial scale for OMW treatment but after mixture with urban wastewater.

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