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Treatment of olive mill wastewater by an ecosystem

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ABSTRACT

Olive oil production generates a considerable amount of wastewater. The olive mill wastewater (OMW) is considered as a major environmental problem, particularly in Mediterranean countries, especially when it is rejected directly in nature, which is harmful. To solve this issue, the proposed method was to depollute the OMW by a new ecological and economic system, which consists of the use of the following components: gravel, sawdust, soil, activated carbon, bamboo, and the valorization of the solid residues, which could be considered as a potential source of natural product. The results obtained after the application of the proposed process exhibit a promising achievement, which would be considered as sufficient as a first step of treatment of OMW (60% of chemical oxygen demand and 22% of biological oxygen demand). Similarly, all the other parameters, such as salinity, conductivity, suspended solids, and total dissolved solids, were decreased in the order of 62%, 17%, 71%, and 63%, respectively.

Keywords: Depollution; Olive mill wastewater; Treatment; System; Physico-chemical

1. Introduction

The olive oil industry has a significant economic, environmental and social impact in the Mediterranean countries [1]. This sector faces crucial issues concerning waste management. Eighty percent of the olive mass comprises olive pulp and stones [2]. Thus, the extraction process yields an amount of waste four times higher than oil. Its composition depends on extraction technologies. Indicatively, 95% of global olive oil is produced in the Mediterranean. Specifically Greece, Italy, and Spain [3]. In addition, other countries such as Tunisia, Turkey, Morocco, and Algeria. Statistical data regarding olive oil production is presented in Fig. 1.

Olive mill wastewater (OMW) is the liquid reject generated during olive oil extraction. It is a major waste stream from several operations aiming to produce olive oil. The worldwide annual amount generated was estimated at approximately 30 million m^3/y in the Mediterranean basin [4]. OMW production seasonality and toxicity make implementing a sustainable management strategy a complex and onerous mission [5].

Despite the economic benefits, olive oil production is unfortunately associated with the generation of large quantities of olive mill wastewater and solid wastes, whose management, treatment, and safe disposal raise serious environmental concerns. A typical olive mill currently produces 1,000 metric tons of toxic liquid wastes per harvesting season. It's a mixture of nutritious agents appropriate for fertilizing or animal feed (inorganic salts, proteins, fat substances, etc.), as well as phenolic, tannins, and other substances with phytotoxic action [7].

OMW is generally rejected in nature without any prior treatment and is highly polluted, causing several environmental problems that impact human health. Several studies

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showed that OMW could have important negative effects on soil ecosystems, water resources, and air due to its richness in organic matter, especially polyphenols [5], rich in potassium, phosphorus, nitrogen, and sodium [8]. Most methods for OMW treatment have been developed and tested recently, such as chemical oxidation methods for treating real industrial olive oil [9].

The large number of publications and the different treatment methods examined for OMW indicate that an effective solution has been found. This can be attributed to the technical difficulties presented during the treatment of OMW (high organic and solid content, phenols, etc.) in addition to the cost of its treatment [6].

The OMW problem prompted many studies over many years. Some of them are experimental with simple methods such as using treating OMW in irrigation and examining its effect on soil and plants [10]; Ziati et al. [11] used activated carbon, Ait-hmane et al. [12] used system multi-soil-layering mixture blocks (soil-sandy texture, sawdust, metal iron, charcoal), Azzam [13] used mixed adsorbents of volcanic tuff, natural clay, and charcoal natural clay. Achak et al. [14] used a combined system of a sand filter and an aquatic plant system. Other investigators employed chemical methods, such as photocatalytic and Fenton-like reactions [15,16]. Electrochemical methods were also investigated [17].

In this work, using a new ecological and economic system effectively decrease chemical oxygen demand (COD), biological oxygen demand (BOD), and other parameters in the OMW. The valorization of solid residues could be a potential natural product source.

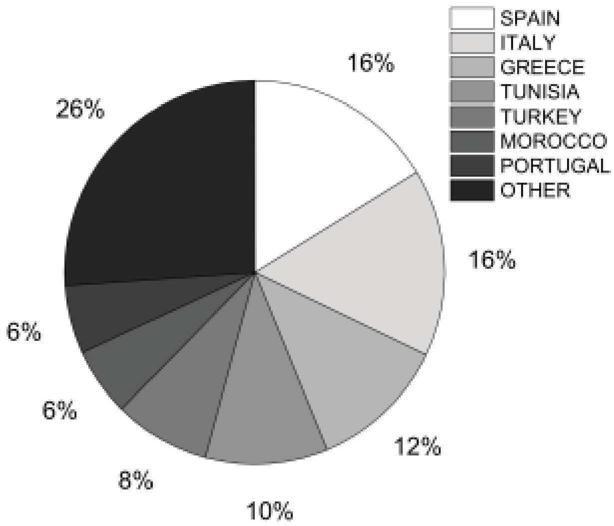


Fig. 1. Distribution of olive oil in 2022 [6].

2. Materials and methods

2.1. Place and sampling

The samples of OMW have been collected in an industrial mill of Béni Mellal-Khenifra. They were collected after the last stage of olives processing and kept in separate sealed plastic containers for the analyses. The olive oil is produced during the season of olive oil processing (November–January 2020). No chemical additives were used during the extraction of the olive oil.

2.2. Description of the system

Fig. 3 shows the structure of the laboratory system with a plastic box measuring 11 cm in width, 11 cm in length, and 20 cm in height that would be used in the present study. The system is composed of soil mixture layers, gravel, and pebbles.

Permeable gravel layers with a diameter of 3–5 mm improve water distribution and dispersion and reduce the clogging risk. This system structure facilitates the infiltration and distribution of the wastewater and makes the treatment of higher loading rates possible [18,19].

The soil mixture layers consist of sandy soil, sawdust (granulometry ≤ 2 mm), and charcoal (granulometry ≤ 3 mm) at a ratio of 60%, 30%, and 10%, respectively.

2.3. Substrate selection

Substrate selection is a crucial parameter in the design of the wastewater treatment system. The type of substrate

Fig. 2. Olive mill wastewater at an industrial of Béni Mellal-Khenifra.

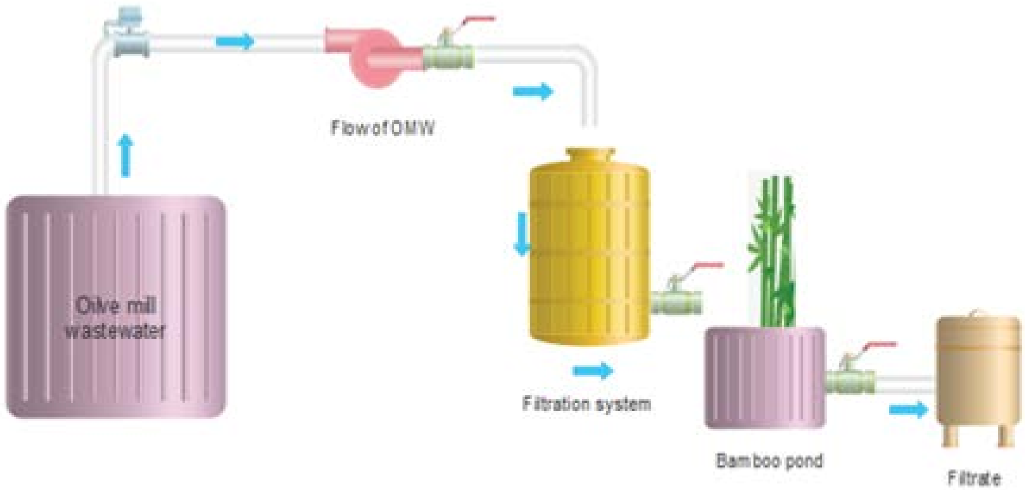


Fig. 3. Filtration of olive mill wastewater by an ecosystem.

Table 1
Characteristics of the recipient

Volume	2,420 cm^3
Base area	121 cm^2
Volume/Surface area	20 cm^3/cm^2
Total area	1,122 cm^2
Density	0.5 g/cm^3

Table 2
Characteristics of the system

Characteristic	Vertical filter		
Type of power supply	Sequenced		
Ventilation	No		
Position of the layer	N°1	N°2 et N°4	N°3 et N°5
Number of layers	1 coat	2 coats	2 coats
Thickness in cm	3 cm	3 cm	2 cm
		3 cm	2 cm
Materials contained in the layer	Coarse gravel	- Sawdust - Activated carbon - Soil	Fine gravel
Diameter in mm	20–50 mm	<2 mm	3–5 mm

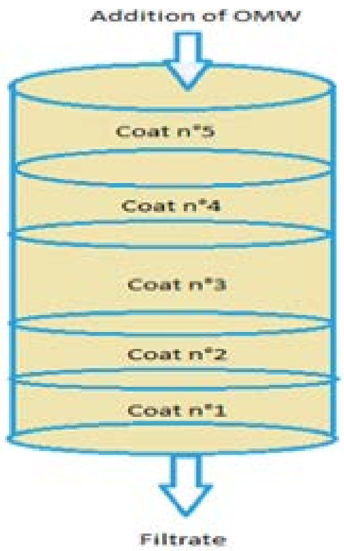


Fig. 4. Recipient of filtration containing a select substrate.

is directly related to the performance of the system. The most basic selection criteria are the degree of permeability and dimensioning.

Indeed, a material that does not have a good permeability capacity can clog the system.

2.4. Analyzed parameters

The samples were necessarily collected from the OMW storage pond and then quickly transported in 5-L containers to the laboratory and stored at a temperature of 4°C. Then pretreated and fermented on site. The samples were compared before and after the purification to determine the degree of depollution obtained. In order to characterize and compare the OMW before and after filtration, the pH, electrical conductivity (EC), total dissolved solids (TDS), salinity, and temperature of the samples were analyzed using a multi-parameter pH/EC meter of the consort C561 type.

To determine suspended solids (SS) content, samples were filtered through membranes with a pore diameter of 0.45 µm [20]. Principally, we aim to define the difference in weight before and after the filtration in an oven at 170°C for 45 min. Dilution was necessary due to the overloading of SS, which caused the filters to be clogged.

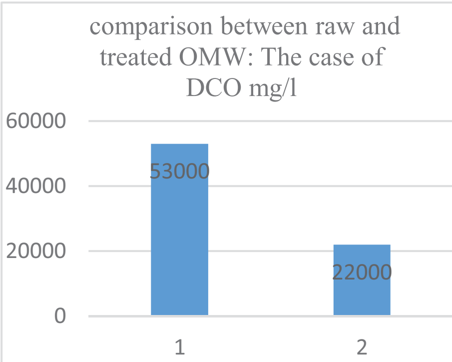
At a temperature of 20°C, the biological oxygen demand (BOD_5) is measured by the OxiTop and the COD by a multi-parameter photometer [21].

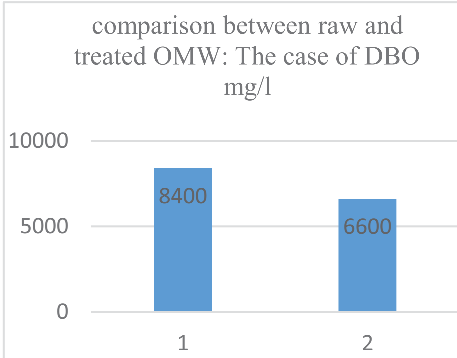
3. Results and discussion

The process consists of a physicochemical analysis before and after treating the liquid effluent OMW. The knowledge of the physicochemical characteristics of activated carbon, sawdust, and soil is necessary for adsorption, ion exchange, improved microbial activity, and absorption of effluents. Gravel is very effective for removing MES and heavy metals and reducing clogging problems.

The physicochemical results represent the values of the parameters of the region of Béni Mellal-Khenifra. The analysis of the results of the studied olive mill wastewater (Table 3) by an ecosystem shows that the effluent is acidic.

Before treatment, the organic matter estimated in COD and BOD presented relatively high values. The average values are 53,000 and 8,400 mg O_2/L, respectively.





A word about comparing the above technologies [22] can be mentioned here. An accurate comparison between the different investigated methods or technologies for the treatment of OMW is very difficult due to the high variability in the investigations. This variability comes from several factors, such as:

- Batch system condition: batch load, time, temperature, pH, size of batch system, batch setup, additives (chemicals) used in batch, etc.
- Continuous system conditions: flow rate (loading rate), size of setup (diameter, height, orientation), CSTR vs. fixed-bed, pH, etc.
- Treatment technology: physical, adsorption, chemical, photochemical, electrochemical, membranes, biological (aerobic vs. anaerobic), others not listed here, and combinations of the above.
- Adsorbents: type, properties, preparation protocols, single vs. mixed adsorbents, random mixing vs. adsorbents in series, etc.
- Conditions specific to treatment technology: for example, type of electrodes in electrochemical treatment, variety of microorganisms in biological treatments, type of chemicals in chemical treatments, etc.

Table 3
Analyses carried out before and after the purification of the OMW

Parameter	Raw OMW	OMW treated
pH	4.80 ± 0.05	5.20 ± 0.20
Salinity, g/L	3.16 ± 0.05	1.1 ± 0.05
TDS, g/L	3.63 ± 0.05	1.34 ± 0.04
SS, g/L	3.36 ± 0.05	1.1 ± 0.10
T, °C	23.7 ± 0.00	22.00 ± 0.00
EC, mS/cm	7.08 ± 0.07	5.76 ± 0.08

The substrates used have provoked a notable decrease in all the parameters due to their adsorption potential, the improvement of microbial activity, and the high filtration capacity. The main performance results of this treatment system showed the following removal rates: 22% (BOD_5), 60% (COD), 71% (SS), 63% (TDS), 62% (salinity), and 17% (EC). These results are higher than those reported by Sbai and Loukili [23] in terms of COD and total suspended solids, which were 42%, and 58%, respectively.

The mineral composition of the OMW studied shows that this wastewater has a high saline load due mainly to sodium chloride, probably related to the salting practiced to preserve the olives until their crushing.

The comparison between raw and filtered OMW shows that the concentration of salinity, BOD, EC, COD, SS, and TDS have decreased (Table 3).

These results are again higher than those obtained by Ait-hmane et al. [12], who have treated OMW with the MSL system. The same system used by Taouraout [24] with urban wastewater has found higher results than those obtained by Rais et al. [25].

Comparing with other studies which have used effectively as pretreatment methods adsorption by natural clay, volcanic tuff (VT), and charcoal Azzam [13], in which the reduction of COD is estimated in the range of 40% remain lower than ours. In addition, our results of pH and COD are more promising than those obtained by Al Bsoul et al. [26], which have also been effectively used as pretreatment methods. Allaoui et al. [27] used natural clay “Ghassoul” by adsorption of polyphenols by two methods. The result of this research shows good antiradical potential for polyphenols extracted with water.

4. Conclusion

OMW is a source of pollution for the environment. In this research study, the eco-technology system, under the configuration tested in this work, showed higher adaptability to treat all pollutants. As a low-cost treatment economical and ecologic system with fewer constraints of operation and maintenance, this system could be considered as a new effective solution to be adapted at the industrial scale of OMW treatment.

The ecosystem can have an improvement of pollutant removal rate by adding other natural, ecological, and economical substrates.

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