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Review

Trends and current practices of olive mill wastewater treatment: Application of integrated membrane process and its future perspective

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ABSTRACT

Olive oil production releases huge volume of environmentally detrimental wastewater. The wastewater is rich in biophenolic compounds that exhibit both phytotoxicity and pharmacology interesting bioactivities. This review analyzes recent developments made in the treatment of olive mill wastewater (OMWW) through analysis of patents, researches articles and industrial practices. Research articles and patents over the last 20 years are classified chronologically and geographically. Paradigm shift from simple detoxification to valorization based on used treatment strategies is illustrated. Clear time line in the main strategies followed to solve OMWW related environmental pollution is plotted. Special focus is given to the potential of integrated membrane process to valorize this stream. Progressive development and significant rise in the use of integrated membrane process, showed a huge potential for combined wastewater treatment and co-product valorization.

This review, whilst presenting general overview, also focuses critically on the most significant issues of integrated membrane process that limited its industrial scale applications: membrane fouling, pretreatments, consideration of membrane material, modules, process design and process economics, which all together forms the pillar for future developments within this field. It will thus benefit the community indicating why research efforts are not matching industrial practice and what could be done to alleviate these problems, so as to convert a recalcitrant wastewater to a vital alternative resource. Based on these, an insight to what a future strategy should include to enhance large scale use of hybrid membrane operations to valorize OMWW is provided.

Contents

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1. Introduction

Although water is a source of life and energy, millions of people worldwide suffer from access to fresh and clean drinking water. Pressure on fresh water source and severe water pollution is also intensified by sudden urbanization, fast industrialization, climate change and population expansion. One of the main sources of freshwater pollution is attributed to generation of huge volume of toxic industrial wastes and dumping of industrial effluents.

The food industry is by far the largest potable water consuming industrial activity per ton of food product. Example breweries consume 4–11 m^3 water/m^3 beer produced [1]. The water footprint, a parameter used to measure the extent and magnitude of local business and consumers impact on global water cycle, required to produce 1 ton of olive oil could reach up to 14.5 million L [2]. Water is involved in many steps and unit operations. Approximately 50% of the total water used in the food industry is tap water, groundwater and part of surface water. Acquiring this water needs money and effort such as for pumping, purification and licensing [3]. More than 50% of the utilized water eventually exits as a wastewater that urges an end-of-pipe treatment to meet discharge limits, incurring additional waste handling cost. Annually about 500 million m^3 of wastewater is discharged from the food processing industry alone. Of these, cleaning-in-place operations contribute 54–98% of the overall volume of discharged waste streams [4].

1.1. Olive mill wastewater (OMWW)

Vegetation wastewater is one among the numerous end-of-pipe treatment needing food based wastewaters very well known for its significant negative impact on the environment [5]. It is the huge volume of foul smelling acidic dark liquid generated during the extraction of olive oil. It is mostly named as olive mill wastewater (OMWW) [6], which is generated during press, two-phase centrifugal or three-phase centrifugal olive oil extraction [7,8]. Especially the latter two methods produce a huge amount of wastewater compared to the first one. The press method releases a solid fraction along with an emulsion containing the olive oil that is separated by decantation from the OMWW. The three-phase system generates a solid husk, oil, and OMWW while the two phase system releases a wet olive husk and oil. Relative to the two-phase centrifugation, the three phase system utilizes 0.6–1.3 m^3 of additional water during the three phase decantation that eventually increases the amount of OMWW.

In the Mediterranean region, there is an annual release of 30 million m^3 wastewater into the environment [9]. These effluents result from the mixture of "vegetation water" coming from the olives and water added during the basic stage of olive process like washing, grinding, beating and the extraction itself. The volume and composition of OMWW exhibit wide heterogeneity owing to factors like place, age, season and year of growth or method of olive oil extraction [10]. In general, it is composed of water (83–92 wt%), organic matter (4–16 wt%) and minerals (1–2 wt%). Presence of water soluble biophenolic compounds (98% of the total phenols in the olive fruit), which are partitioned to water from the olive fruit during the oil extraction, represent the highest polluting capacity [11–13].

The continuous illegal dumping of OMWW generated by both traditional and the three-phase system to the soil or into a nearby aquatic system for many years have brought about serious environmental problems [14]. The negative environmental and socioeconomic impacts of this industrial activity are more than obvious since a large number of processing facilities are located close to sea resorts and places of high tourist interest [15]. Treatment and disposal of such a huge volume of wastewater is a very critical problem.

1.2. Common practices of vegetation wastewater treatment

Since olive processing releases huge volume of environmentally detrimental waste, for instance in Italy an environmental law (art. 74 del Decreto Legislativo n.152/2006) has been enforced for olive producing companies either to treat or eliminate their wastes. In the Mediterranean countries, the most practical means is evaporation in open storage ponds. However, this method requires larger area together with production of black foul smelling sludge difficult to remove, pollutant infiltration to ground water and insect proliferation [14,7]. Many researchers also applied OMWW directly on soil and have tested its beneficial effects related to its high nutrient concentration, especially potassium. But application to soil have also revealed negative effects of OMWW associated with its high mineral salt content and low pH [14]. Especially OMWW is characterized by presence of more than 30 different types of biophenols and related compounds that are phytotoxic with strong antibacterial effects [6]. Therefore, excessive application into the soil may exceed the toxicity tolerance of soil microorganisms.

In recent years, many other management options have been proposed. Most of these methods aim at reducing OMWW phytotoxicity in order to reuse it for agricultural purposes [16], to make it suitable to be treated in conventional treatment facilities [6] or recovering the biophenolic fraction owing to their interesting pharmacological properties [7,17–19].

The increasing interest in OMWW treatment thus has resulted in the publication of several reviews addressing various aspects of this field. Reviews from Morillo et al. [20] and Roig et al. [14] traced the research on bioremediation and biovalorization of OMW in terms of second oil extraction, gasification anaerobic digestion and composting to produce fertilizers, antioxidants, enzyme and biopolymer. Possibly related to the great number of publications that have used membrane technology, recently there are few reviews which assessed the use of various membrane operations. In particular, the review by Mudimu et al. [21] has covered polyphenol recovery using membrane technology while two recent reviews [22,23] concentrated more on the limiting effect of membrane fouling.

Despite presence of the aforementioned reviews available on this topic, a comprehensive overview of OMWW treatment does