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Research article

Disposal of olive mill wastewater with DC arc plasma method

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ABSTRACT

Olive mill wastewater is an industrial waste, generated as a byproduct of olive oil production process and generally contains components such as organic matter, suspended solids, oil, and grease. Although various methods have been developed to achieve the disposal of this industrial wastewater, due to the low cost, the most common disposal application is the passive storage in the lagoons. The main objective of this study is to reduce pollution parameters in olive mill wastewater and draw water to discharge limits by using plasma technology. Plasma-assisted disposal of olive mill wastewater method could be an alternative disposal technique when considering potential utilization of treated water in agricultural areas and economic value of flammable plasma gas which is the byproduct of disposal process. According to the experimental results, the rates of COD (chemical oxygen demand) and BOD (biological oxygen demand) of olive mill wastewater are decreased by 94.42% and 95.37%, respectively. The dissolved oxygen amount is increased from 0.36 to 6.97 mg/l. In addition, plasma gas with high H_2 content and treated water that can be used in agricultural areas for irrigation are obtained from non-dischargeable wastewater.

1. Introduction

Olive production has a significant share in the agricultural sector, especially in the Mediterranean countries. Besides being consumed regularly, it is processed and turned into oil, which makes olive even more valuable. Different production techniques can be applied for olive oil production. The most common production techniques are batch production process (conventional method) and continuous production processes known as two-phase and three-phase. In Turkey, 71% of olive oil factories use 3-phase, 27% 2-phase and 2% use batch production processes (Hocaoglu, 2015).

Olive bagasse (olive solid wastes and olive kernel) and olive mill wastewater (liquid waste) emerge as the byproducts of olive oil production process. A summary of production processes and input-output balances are given (Table 1). Olive mill wastewater is a serious environmental hazard due to its phenolic compounds and has high organic, suspended solid, oil and grease content.

According to the reports of Olive Research Institute in 2016, there are 1031 factories in Turkey and 1,019,451.39 tons of olive was harvested to produce 177,365 ton olive oil. Currently, 741 of the 1031 olive oil plants in Turkey operate as 3-phase, 273 of 2-phase and 16 as stone press. In these facilities, 775,000 m^3 of water is used and 923,000 m^3 of wastewater is generated on average (Olive Research Institute, 2016). Olive mill wastewater produced as a byproduct of 3-phase olive oil production process is commonly stored in lagoons. One of the olive mill wastewater lagoons is shown in Fig. 1. The seasonal pollution load is around 70,000 tons of COD (Galli and Tomati, 2002) and in terms of pollution effect, 1 m^3 olive mill wastewater is equivalent to 100–200 m^3 domestic sewage (Tsagaraki et al., 2007). An alternative method for disposing of olive mill wastewater, in economical and practical terms, has not been developed yet. For instance, 2-phase production technique is applied in Spain and 4 million tones olive bagasse is produced annually (Hocaoglu, 2015). Thus, alternative disposal methods are investigated.

Olive mill wastewater (OMW) is an environmental threat risk, has become a problem that needs to be solved by the olive industry. OMW's dark color, high BOD, COD and phytotoxic content makes it impossible to be directly discharged to clean and coastal waters. When sugar, which is one of the main organic substances contained in OMW, is at high concentrations, microbial respiration can increase which can reduce the concentration of dissolved oxygen in this water. OMW causes color change and intensive blurring (effect

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Table 1
Comparison of mass-energy balances of one ton of processed olive.

Production Process	Input	Input Quantity	Output	Output Quantity
Batch Production Process	Olive	1 t	Olive oil	~200 kg
	Wash water	0.1–0.12 m^3	Solid waste (%25 water+ %6 oil)	~400 kg
	Energy	40–63 kWh	Wastewater (%88 water)	~600 L
Three- Phase Production Process	Olive	1 t	Olive oil	~200 kg
	Wash Water	0.1–0.12 m^3	Solid waste (%50 water+ %4 oil)	~500–600 kg
	Oil Impurities wash water	0.5–1 m^3	Wastewater (%94 water+ %1 oil)	~1000–1200 L
	Auxiliary Wash Water	~10 L		
	Energy	90–117 kWh		
Two -Phase Production Process	Olive	1 t	Olive oil	~200 kg
	Wash water	0.1–0.12 m^3	Solid waste (%60 water + %3 oil)	~800–950 kg
	Energy	<90–117 kWh		

Fig. 1. Olive mill wastewater occurred as a result of three-phase production (Olive Research Inst. Report, 2016).

of oxidized polyphenols) in the water environment in which it is discharged due to its color. In this case, light transmission in water can be reduced and the ability of the plants' photosynthesis in the water can be limited (Ekici, 2010).

Comparisons of pollutant parameters in olive mill wastewater and domestic wastewater are given in Table 2. Pollution coefficient was obtained by proportioning the concentration of pollutants in domestic wastewater with the concentration of pollutants in OMW (Yarali et al., 2012).

Despite the fact that there are many research and developmental studies on obtaining an efficient product from these wastewaters, there has been no solution found for the OMW, which leaves it in the research phase (Kilic et al., 2009).

Legal and technical principles necessary for the prevention of water pollution in order to ensure the protection and optimum utilization of underground and surface water resources of the country in accordance with sustainable development goals is specified in The Water Pollution Control Regulation.

This Regulation contains the quality classifications usage purposes of water environments, planning principles and prohibitions of water quality conservation, wastewater discharge principles and principles of discharge permit, principles related to wastewater infrastructure facilities and monitoring and control procedures for water pollution prevention. In this direction, discharge standards (in a receiving environment) of OMW, which is classified as food industry wastewater, is given in Table 3 (Official Gazette, 2004).

Many methods have been developed and implemented for wastewater disposal. Some of these methods are aerobic treatment (Tziotzios et al., 2007; Falas et al., 2016), anaerobic treatment (Beccari et al., 1999; Stamatelatou et al., 2009; Abbasi et al., 2016), chemical treatment (Ginos et al., 2006; Ahmed et al., 2017), electrocoagulation (Tezcan et al., 2006; Elabbas et al., 2016; Kobya et al., 2016), adsorption (Niaounakis and Halvadakis, 2006; Zhou et al., 2016; De Gisi et al., 2016), advanced oxidation processes (Ozdemir et al., 2010; Atalay and Ersoz, 2016), membrane processes (Coskun et al., 2010; Neoh et al., 2016), and glow discharge plasma process (Wang et al., 2012). Regarding OMW treatment, the COD value decreased by 64–85% with a combination of physical pretreatment and anaerobic processes (Beccari et al., 1999). Chemical oxidation and aerobic treatment with bacteria removed 70% COD (Kotsou et al., 2004). Electro-Fenton and Sedimentation processes was applied to reduce toxicity (Khoufi et al., 2006). Ginos et al. (2006), eliminated 40% COD and 80% phenol by chemical treatment and 60% COD by Fenton Process.

OMW can be also thought of as an energy source due to its organic materials, but because of the high-water content (approximately 90%) it is very costly to obtain energy from this wastewater by implementing conventional methods. With plasma treatment technology the moisture in the raw material does not play an important role and it provides raw material flexibility due to high energy density (Askarova et al., 2009).

The aim of the study was to develop a reactor for the treatment of OMW by using DC Arc Plasma method and obtain high H_2 content plasma gas as a byproduct. The second section describes the analysis of the raw material structure and the operation of the

Table 2
Olive mill wastewater and domestic wastewater pollutant parameters (Yarali et al., 2012).

Parameter	Unit	Olive Mill Wastewater	Domestic Wastewater	Pollution coefficient
pH	–	3–5.9	7.2	–
COD	mg/L	20,000–220,000	600	200
BOD_5	mg/L	23,000–100,000	300	205
Total Solid Matter	mg/L	1000-103,000	500	104
Oil and Grease	mg/L	1000-23,000	50	240
Polyphenols	mg/L	3000-80,000	–	–
Volatile Organic Acids	mg/L	800-10,000	–	–
Total Nitrogen	mg/L	300–1200	40	18.75