Electro-Oxidation as an Effective Technology in Removal of Persistent Organic Pollutants of Wastewater from Processing Pistachios

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Humans discharge a great amount of harmful synthetic compounds and chemicals into the environment through their daily activities. Some of these compounds and chemicals are able to enter the water cycle, thereby polluting it and threatening consumer health [1]. Treatment of wastewater containing chemical compounds is one of the solutions for reducing risks caused by them and environmental pollution [2]. Agriculture and the associated industries are among the major sources of wastewater production [3]. Iran is the largest producer of pistachios in the world, with a large share of its non-oil exports being allocated to pistachios. Accordingly, the US and Turkey are the second- and third-largest producers of pistachios in the world, respectively [4]. Pistachio processing industries have been developed similarly in the world countries [5, 6]. Wastewater from processing agricultural products is one of the environmental pollutants. Approximately, 6m³ of wastewater is produced for the processing of each ton of pistachios [5, 7]. Wastewater from processing pistachios contains persistent organic pollutants (POPs), such as phenolic compounds, with the removal of which from the wastewater being very difficult. Pistachios' outer green skin, making up about 40% of the fruit weight, contains phenolic compounds. Accordingly, it is worth noting that wastewater from processing pistachios contains a great amount of phenolic compounds, which is significantly higher than that in other industrial effluents [8]. Based on the classification made by the US Environmental Protection Agency (EPA), phenolic compounds, because of their low biodegradability, high toxicity, long-term ecological hazards, and bio-cumulative properties, are considered as persistent organic pollutants and inhibitors

of microorganisms in biological wastewater treatment systems [5]. Treatment efficiency of wastewater containing organic compounds resistant to biodegradation using conventional treatment methods is very low. Thus, non-microbial technologies are employed to treat or pre-treat this type of wastewater [9]. Extensive studies have been recently conducted on the use of electrochemical processes as simple, economical, safe, and environmentally friendly methods for removing various pollutants from aquatic environments [10, 11]. The removal of pollutants by means of electrochemical processes has many advantages. These advantages include low costs, high energy efficiency, as well as easy and safe performance due to simple equipment, which have turned these processes into optimal solutions for removing a wide range of pollutants [12]. Advanced oxidation processes (AOPs) have been extensively used as suitable and effective methods in breaking down toxic pollutants resistant to biodegradation [13]. AOPs have been mostly used as pre-treatment measures for degrading persistent organic compounds and converting them into biodegradable and non-toxic products [14]. Electrochemical processes most commonly used in wastewater treatment include the two processes of electrocoagulation and electrolysis (electro-oxidation) [15, 16]. The electrocoagulation process acts based on the production of coagulants through reducing the electrode at an anode, with the produced coagulant reacting with the pollutant and settling in the aftermath [5]. In electrolysis, the process of anodic oxidation of the pollutant breaks down and removes the pollutant from the solution. In addition, it has an advantage over electrocoagulation, in which the amount of the potential sludge produced is much less while the pollutant is broken down. An electrolysis-based electrochemical process could be integrated with other AOP processes to increase pollutant removal efficiency [7]. The electro-oxidation process, as a simple, economical, safe, and environmentally friendly technology, is able to degrade compounds resistant to biodegradation through direct and indirect anodic oxidation [14]. Indirect oxidation in the electro-oxidation process is caused by oxidizing compounds that are able to oxidize organic compounds non-selectively [17]. In oxidation processes, H2O2 is used as an oxidant, while in the Fenton process, it is used and added to the solution as a precursor for producing hydroxyl radicals [5]. If the reactor is designed correctly, this compound will be produced at the cathode surface to oxidize organic compounds. Electro-oxidation processes lead to the degradation and removal of organic compounds using two methods, with the first one being direct oxidation on the anode surface, and the other being indirect oxidation by means of

the products produced on the anode surface [18]. Anodic oxidation is one of the advanced electrochemical oxidation processes (EAOPs) able to efficiently oxidize organic compounds in aquatic environments. This process, due to the presence of hydroxide radicals produced at the surface of anode M and oxidation of water, acts based on Equation 1 [18]. The produced surface hydroxyl radicals M(˚OH) are non-selective highly oxidizing agents able to degrade organic pollutants, thereby mineralizing them in full [11].

(1) $$M + H_2O \rightarrow M(^{\circ}OH) + H^+ + e^-$$

The material and form of the electrode are among the most important parameters affecting the type and amount of the oxidants produced [18]. The use of stable electrodes leads to a reduction in the costs. Besides, an increase in the electrode surface increases the contact surface between the wastewater and the electrodes, thereby degrading more organic compounds [19].

The electro-oxidation process is able to degrade phenolic compounds existing in wastewater from pistachio processing industries. Besides, it increases the capacity of biological treatment of organic compounds left in the wastewater after the pre-treatment process performed by the electro-oxidation process. This process could be employed to effectively reduce toxicity and stability of organic compounds in wastewater from pistachio processing industries.

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