Chapter 17
Principles of Electrocoagulation and Application in Wastewater Treatment

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ABSTRACT

Electrocoagulation has emerged a reliable technology for the treatment of various wastewaters. Its basic principle depends on the response of water particles to strong electric field in a redox reaction. Oxidation of the anode material releases coagulating agents that form metal hydroxide complexes which neutralize particulate materials to form agglomerates. The agglomerates either settle at the bottom or float to the surface depending on the removal path of the electrocoagulation reactor. The merits of electrocoagulation include minimal sludge generation, minimal operator attention, simple equipment, high pollutant removal capacity, and ease of operation. Therefore, this chapter explores the mechanisms of electrocoagulation, components of electrocoagulation, benefits, and demerits of electrocoagulation. Furthermore, the similarity between electrocoagulation and coagulation is explored. Application of electrocoagulation for the treatment of various wastewaters was explored. Feasibility of electrocoagulation was examined through cost evaluation with other treatment technologies.

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INTRODUCTION

The high cost of conventional wastewater treatment methods and their various constraints in wastewater treatment has been a concern for many stakeholders. The major conventional methods for the treatment of wastewater include biological processes (Nowak et al., 2019), membrane processes (Vo et al., 2019), adsorption processes (Sessarego et al., 2019), advanced oxidation processes (Brink et al., 2018), coagulation/flocculation processes (Kim et al., 2019) and ion exchange processes (Muhammad et al., 2019). Most conventional methods require high personnel training, high capital and operational cost, and produce high amount of sludge and secondary pollutants (Ezechi et al., 2019). While the volume of industrial and domestic wastes in many countries and regions have been increasing, waste management techniques such as landfills and wastewater treatment facilities are over-burdened (Ezechi et al., 2011). These constraints have led to the development of an environmentally friendly approach that is cheap and shows consistent pollutant removal capacity.

The application of electric current in the treatment of wastewater is increasingly gaining global interest due to its associated efficiencies and cost effectiveness. Electrocoagulation (EC) is the process of destabilizing suspended, emulsified or dissolved contaminants in an aqueous medium by the introduction of an electric current (Ezechi et al., 2015). It is an environmentally friendly approach that requires minimal personnel training, no chemical addition or expensive equipment and device (Changmai et al., 2019). EC is solely based on the oxidation of the sacrificial anode under the influence of electric current in an oxidation/reduction process. The electrodes are cheap and readily available, and can be used over a certain number of experiments when thoroughly washed and dried. EC has been widely used in the treatment and removal of various wastewater pollutants, and presents similar advantages to chemical coagulation. Its success largely arises from the interaction of charged particles with wastewater pollutants. Furthermore, it produces lesser amount of sludge.

Various wastewaters such as produced water, geothermal wastewater, restaurant wastewater, potato chips wastewater, textile wastewater, tannery wastewater, olive mill wastewater and electroplating wastewater have been successfully treated with electrocoagulation. Pollutants such as boron, phenol, heavy metals such as arsenic, cadmium, copper, chromium, nickel and zinc can interact with the coagulating agents from the sacrificial anode and flocculate during EC process. However, this interaction largely depends on the chemistry of the pollutants. For instance, boron appears as boric acid (H_3BO_3) and borax ($Na_2B_4O_7 \cdot 10H_2O$) in nature. In aquatic systems, it exists primarily as undissociated boric acid and borate ions (Bryjak et al., 2008). The chemistry of the pollutant can enhance or impede its interaction with the coagulating agents during EC process. Thus, electrocoagulation presents itself as an important treatment technology.

Electrocoagulation process is operated with different parameters. The efficiency of EC depends on the best combination of these parameters. Parameters such as pH, current density, treatment time, concentration, electrode gap, surface area, flow rate, temperature, electrode type, electrode pattern and applied potential are all important electrocoagulation parameters. During electrocoagulation, metal ions are generated at the anode while hydrogen bubble is released at the cathode. Hydrogen bubble is responsible for the flotation of formed flocs to the surface of the reactor where the flocs are concentrated and removed. The oxidation of a metal (M) in an electrocoagulation process can be represented as:

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