Chapter 13
Electrochemical Treatment of Water as an Effective and Emerging Technology

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ABSTRACT

Environmental pollution has been a major problem worldwide. This makes environmental pollution control an important ingredient to a healthy environment. During the last few years, water has become an increasingly important issue in developing nations. Progress in health and education is dependent on access to affordable sanitation and safe water. This chapter as a further study of the authors' previous studies presents a review of articles on designs, models, and applications of electrochemical processes with particular attention to the removal of environmental pollutants (conventional and emerging pollutants). The study revealed that electrical treatment processes can be in the form of electrochemical, electrocoagulation, electrophoresis, electro-flotation, electro-precipitation, electro-adsorption, and electrooxidation. It was concluded that electro-driven technologies can be used in many applications; electrochemical technologies have been proven to be quite useful approaches regarding wastewater treatment, and power sources of electrochemical can be wind and solar photovoltaic.

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INTRODUCTION

Electrochemical treatment processes are used in the treatment of wastewater through the application of direct or alternating current in the electrolyte-containing cell containing the electrodes. Noyes (1993) reported that electrodialysis, electrocoagulation, electro-precipitation, and electrochemical treatment processes are among the major applications of electrical treatment. Electrodialysis is an electrical treatment process in which charged membranes are used to separate ions from aqueous solutions under the driving force of the electrical potential difference. The process utilizes an electrodialysis stack, built on the filter-press principle and containing several hundred individual cells formed by a pair of anion and cation exchange membranes. The cells are arranged in an alternating pattern between an anode and a cathode to form individual cells. The basic principle of the process is that the solution is pumped through these cells and an electrical potential is established between anode and cathode. The cations (positively charged ions) migrate toward the cathode and the anions (negatively charged ions) migrate likewise to anode. The cations pass easily through the negatively charged cation-exchange membrane but are retained by the positively charged anion-exchange membrane (Oke *et al*., 2012a, b, c, 2017 and 2020).

Similarly, the positively charged anions pass through the anion-exchange membrane and are retained by the cation-exchange membrane. The overall results are ion concentrations increase in the alternate compartments, while the other compartments simultaneously become depleted of ions. The ion-exchange membrane used in the system mainly determines the efficiency of electrodialysis as a separation process. The operational costs are dominated by the energy consumption and investment costs for the plant of the desired capacity. The energy required in an electrodialysis process is an additive of two terms: the electrical energy to transfer the ionic components from solution through the membranes into another solution and the energy required to pump the solutions through the electrodialysis unit. These costs are a function of the membrane used in the process. It varies with various design parameters used. The major design parameters for the process are cell dimensions, feed flow velocity, and the pressure drop of the feed solution in the cell (Noyes, 1993). The capital cost of an electrodialysis plant is proportional to the membrane area required for a certain plant capacity, which is determined mainly by the feed solution concentration and the limiting current density. It has its principal application in the desalting of brackish wastewater. There are no fundamental limits of electrodialysis other than the limit to solution separation with a specified maximum concentration level. In addition, Grebenyuk *et al.* (1998) listed some of the usefulness of electrodialysis in the industrial world nowadays (Oke *et al*., 2012a, b, c, 2017 and 2020).

Electro-coagulation is the process of destabilizing suspended, emulsified, or dissolved contaminants in an aqueous medium by introducing an electrical current into the medium (Noyes, 1993). In the electrocoagulation process, the electrical current is applied through the electrodes constructed with metals that are selected to optimize the removal process. The most used metallic materials for electro-coagulation are iron and aluminum. In accordance with Faraday's law, metal ions of these electrodes will be split off into the liquid medium, which tend to form metal oxides that electromechanically attract the contaminants that have been destabilized. The Electro-coagulation treatment process utilizes the direct current to cause sacrificial electrode ions to remove the undesirable contaminants either by chemical reaction and precipitation or by causing the colloidal materials to coalesce and then be removed by the electrolytic flotation. The electrocoagulation system has proven to be able to cope with a variety of wastewaters (Noyes, 1993). Limitations of electrocoagulation as a treatment process are that sacrificial electrodes are required, it treats waste that can conduct electricity and the sludge volume has been reported to be higher (Eilen *et al.,* 1994; Oke *et al*., 2012a, b, c, 2017 and 2020).