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Assessment of parameters influencing the electro activated water character and explanation of process mechanism

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ABSTRACT

The physicochemical properties of electro activated water (EAW) are highly affected by process conditions. In this context, the effects of parameters such as brine concentration, electrolysis time and current for EAW generation have been investigated using Response Surface Methodology (RSM). The predictive model for each response had high accuracy relative to R^2 values, namely, 0.85 for the oxidation reduction potential (ORP) and 0.94 for the free chlorine concentration (FCC). According to results, the brine concentration was the most significant factor that affected EAW character. Moreover, electrolysis time and brine concentration have synergetic effect on FCC. The mechanism of the EAW production was evaluated through the cyclic voltammogram (CV) of different brine concentrations on the graphite electrode. With the concentration increased anodic and cathodic peaks could be observed notably. Possible reaction pathways were evaluated on the cathode and anode sides. The formation of Cl_2, O_2, H_2, Cl^-, OH^-, H^+ were determined by CV measurements.

1. Introduction

Recently, applications of electro activated water (EAW) as a disinfectant or oxidizing agent have increased significantly. EAW technology has a wide variety of practices such as agriculture (Rahman et al., 2010; Sharma and Demirci, 2003), medical sterilization (Selkon et al., 1999; Shimmura et al., 2000), food safety (Rahman et al., 2010), fishery (Huang et al., 2006; Ozer and Demirci, 2006) and water treatment (Kerwick et al., 2005). Although EAW can be utilized to serve at cross purposes, the mechanism of EAW production is the same. The electrolysis chamber consists of an anode electrode, a cathode electrode and a cationic membrane. The EAW production involves electrolysis of a dilute solution of NaCl passing through the electrolysis chamber and results in the formation of water of different character at each electrode, namely; anolyte (alias EAW) and catholyte, which appear at the anode and cathode sides, respectively (Huang et al., 2006; Sharma and Demirci, 2003).

Oxygen gas and many active species such as chlorine, chlorine dioxide and free radicals are being formed in anolyte, while hydrogen gas and sodium hydroxide are being formed in catholyte. The properties of the catholyte are pH > 11 and ORP < −800 mV, while the properties of the anolyte are pH < 2.8, ORP > 1100 mV, and free chlorine concentration (FCC) can be between 40 and 1500 ppm (Hsu, 2003; Ozer and Demirci, 2006). EAW has been used as disinfectant agent because of its high oxidation potential and content of active species (Ezeike and Hung, 2004). However, the properties of EAW can vary according to generation systems. There are lots of the EAW production devices in the market that could produce EAW with different characteristics based on machine settings (Kim et al., 2000).

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A number of electrode configurations and materials for the EAW systems have been tried against different microorganisms. The effectiveness of the systems, relative to the reduction of bacteria, viruses, and protozoa, differs from one system to another one. These differences arise due to variable cell configurations, electrolyte concentrations and composition, electrode material, types of microorganisms, and other experimental parameters, such as flow rate, brine concentration and current density (Liato et al., 2015). The individual effect of certain parameters such as brine concentration, temperature, and flow rate on the EAW character has been investigated (Hsu, 2003; Kerwick et al., 2005; Kiura et al., 2002). However, the truer approach is to define interaction among processing parameters and to determine optimum conditions as those of Ezeike and Hung (2004) and Hsu (2005).

In this study, a new reactor including graphite electrodes was designed to produce EAW. We evaluated the effect of brine concentration, electrolysis time and current on the character of EAW. Furthermore, the interaction of the parameters and optimum conditions can be revealed by Response Surface Methodology (RSM). The oxidative power of EAW was determined in terms of oxidation reduction potential (ORP) and free chlorine concentration (FCC). The mechanism of the EAW production was evaluated through the data gathered from cyclic voltammetry.

2. Material and method

2.1. *Design of the EAW production system*

The Electrode module is made of Plexiglas material with the dimensions of 25 × 20 × 5 cm. Graphite material was used for both anode and cathode with the dimensions of 20 × 15 × 0.2 cm. In order to get the uniform water distribution, there were 35 holes (1 cm^2 in diameter) on each electrode. An ion-permeable diaphragm was located between the electrodes, and the space between the electrodes and the diaphragm was 5 mm. The brine solution was introduced to the bottom left-hand corner of the module and was electrolyzed while moving through the chamber; it then left from the top right-hand corner of the chamber. The catholyte was collected in the reactor tank, and anolyte was brought in through a flexible pipe. The length of the pipe was 30 cm, and polypropylene was used as the pipe material, which is resistant to acidic solution. A measurement cell with the sensor holder and a sampling holder was located at the end of the pipe.

2.2. *Production of the EAW*

Electrolyzed water was generated from table salt and tap water at room temperature. A peristaltic pump was used to pump the brine solution into the reactor, and the brine solution was electrolyzed by feeding a direct current into the reactor. Digital power supply (0–20 A; 0–40 V) was used to provide energy during the experiments. The flow rate was adjusted to 36 L/h, and the system was running in an up-flow continuous mode. The pH value and temperature were controlled during the experiments. While temperature was not changing considerably, pH was decreasing with the electrolysis time increase.

A schematic representation of the experimental system is given in Fig. 1.

2.3. *Analytical measurements of EAW*

Free chlorine concentrations have been determined using an analyser (KROHNE-OPTISENS CL 1100), which has high selectivity due to its membrane-free gold (potentiostatic) electrode sensor. pH/ORP metre (HACH-Lange HQ40D) was used to determine pH and ORP of EAW. All these sensors were aligned in a closed measurement cell. Standard chlorine solution was purchased from La Motte and was used to check accuracy of the analyser.

2.4. *Cyclic voltammetry (CV) measurements*

CV measurements were performed using an advanced electrochemical system, a computer-controlled potentiostat CH Instruments at scan rate of 200 mV/s. The working electrode was graphite with the area of 0.28 cm^2. The counter electrode was Pt wire, where Ag|AgCl was used as a reference electrode. The electrode potentials were measured in three-electrode cylindrical glass cell filled with different concentrations of brine solution (20, 60 and 100 g/L).

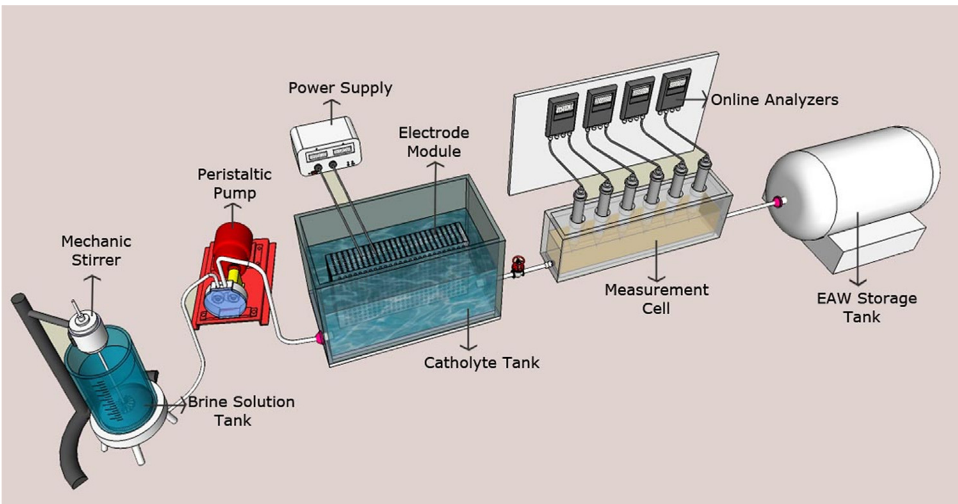

Fig. 1 – Schematic representation of the experimental system.