Journal of the Taiwan Institute of Chemical Engineers 45 (2014) 2427–2435

Contents lists available at ScienceDirect

Journal of the Taiwan Institute of Chemical Engineers

journal homepage: www.elsevier.com/locate/jtice

Efficiency of electrocoagulation method to treat chicken processing industry wastewater—modeling and optimization

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ARTICLE INFO

Article history:
Received 4 January 2014
Received in revised form 21 March 2014
Accepted 12 April 2014
Available online 14 May 2014

Keywords:
Chicken processing industry wastewater
Electrochemical method
Iron electrode
Box–Behnken design
Modelling

ABSTRACT

The main objectives of the present study is to investigate the efficiency of electrochemical method to treat chicken processing industry wastewater under different operating conditions such as amount of dilution (10–30%), initial pH (4–9), applied current (10–20 mA/cm^2) and electrolyte dose (500–1250 mg/l). From the experimental data, Box–Behnken experimental design (BBD) was used to develop the second order polynomial models. Optimum operating conditions was found to be; amount of dilution at 30%, initial pH of 6, applied current of 14 mA/cm^2 and electrolyte dose of 1075 mg/l and it shows the 93% of COD removal rate and 95% of COD removal with electrical energy consumption value of 3.48 KW h/l. These results indicate that electrochemical method can be used as a effective treatment technique to treat chicken processing industry wastewater.

1. Introduction

Industrial wastewater pollution has become one of the most serious environmental problems today. The treatment of chicken processing industry wastewater is of special concern, due to their recalcitrance and persistence in the environment [1]. Moreover, the contaminants present in the chicken processing industry wastewater are not biodegradable and tend to accumulate in living organisms and many organic matters are known to be toxic or carcinogenic [2]. Higher growth rate of this industrialization will increase the adverse impact on ecosystem, due to the discharge of untreated wastewaters, which could degrade the environment harmfully [3]. An extensive literature survey showed that, treatment methods such as screening, sedimentation, adsorption, chemicalcoagulation, ozonation and biological treatment techniques have been employed to treat various industry wastewaters [4]. But, these treatment processes requires higher treatment time, low removal efficiency of toxic matters and very high capital. Moreover, in these techniques addition of chemicals can generate a considerable quantity of secondary pollutants such as solid sludge, which also pose serious environmental problems [5]. Therefore, the research interest in use of alternative treatment processes for treatment of industry wastewater including chicken industry wastewater has nowadays intensified.

Last few decades, wastewater treatment research has demonstrated that electrochemistry offers an attractive alternative to the conventional methods for treating industrial wastewaters [6]. Among various kinds of techniques, electrocoagulation is based on the electrochemical production of destabilization agents that remove pollutants by charge neutralization and it has been used for treatment of various wastewaters such as electroplating wastewater, laundry wastewater, restaurant wastewater, paper industry wastewater and textile wastewater [7]. In this treatment process, metal ions are generated at the anode and react with the hydroxide ions formed at the cathode, and the metal hydroxides are produced which react with the suspended and/or colloid solids in the wastewater and forms the precipitate, thus removal of toxic matters were done (Eqs. (1)–(3)). The electrocoagulation reaction mechanism are as follows [8]:

At anode

$$M \rightarrow M^{n+} + ne^- \tag{1}$$

At cathode

$$nH_2O + ne^- \rightarrow \tfrac{n}{2}H_2 + nOH^- \tag{2}$$

where M = anode material and n = number of electrons involved in the oxidation/reduction reaction.

$$Mn^+ + nOH^- \rightarrow M(OH)_n \tag{3}$$

Moreover, advantages of electrocoagulation include high particulate removal efficiency, a compact treatment facility,

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http://dx.doi.org/10.1016/j.jtice.2014.04.011

relatively low cost, and the possibility of complete automation [9]. Meanwhile, treatment efficiency of electrocoagulation treatment technique mainly depends on the crucial operating parameters such as wastewater pH, applied current, electrode distance and electrolyte dose. Optimization of these parameters will increase the treatment efficiency as well as minimize the economy of process [10]. Even though the dynamic characteristics of the electrocoagulation treatment process is very complicated, an attempt in developing an experimental-based optimization methodology may help to provide a better understanding of the process in terms of the effects of independent variables and their interactions on the dependent variables [11]. But, in conventional optimization techniques, a large number of experiments are required which increases the usage of raw material, treatment time and man power. Moreover, there is a chance to misleading or poor results due to the unavailability of proper procedure Hence, response surface modeling (RSM) can be a useful approach for studying the effects of several factors influencing the responses by varying them simultaneously and performing a limited number of experiments [12]. RSM is a collection of statistical techniques commonly used to understand the performance of complex systems and modeling the various wastewater treatment process. This technique also be used to evaluate the relative significance of several affecting factors even in the presence of complex interactions between the independent variables [13]. Similarly, several literature reported that the statistical methods are believed to be effective and powerful approach for screening the key factors rapidly from a multivariable system for the optimization of a particular process [14,15].

However, from the extensive literature analysis, it was found that there is no research reports are available on the treatment of chicken processing industry wastewater using electrocoagulation treatment technique *via* response surface methodlogy (RSM). Hence the primary objective of the present study has been made to investigate and optimize the individual and interactive effect of process variables such as amount of dilution, initial pH, applied current and electrolyte dose on the COD removal rate and COD removal from chicken processing industry wastewater. Finally, the applicability of proposed treatment technique is mainly based the economy. Considering this phenomena, electrical energy consumption (EEC) of the present electrocoagulation treatment technique is also calculated.

2. Materials and methods

2.1. Raw wastewater and chemicals

The wastewater used in this present study was collected from chicken processing industry in udumalpet, TamilNadu, India. To avoid changes in the physico-chemical properties of collected chicken processing industry wastewater, it was stored at 4 °C prior to the experiments. The charcterstics of chicken processing industry wastewater was determined and it is shown in Table 1. Hydrochloric acid (HCl) and sodium hydroxide (NaOH) was purchased from local suppliers Erode,TamilNadu. All the chemicals used in this study were anlaytical grade.

Table 1
Characteristics of chicken processing industry wastewater.

Characteristics	Value
COD (mg/l)	5500
BOD (mg/l)	2864
Total suspended solids (mg/l)	1958
Turbidity (NTU)	785
Total volatile solids (mg/l)	658
TKN (mg/l)	135
Ammonia (mg/l)	12

2.2. Experimental method

Schematic diagram of electrocoagulation reactor is shown in Fig. 1. The electrochemical reactor having working volume of 3 l was used to treat the wastewater with iron electrodes and the effective surface area of each electrode was 108 cm^2. The distance between the anode and cathode was fixed at 1 cm and it was connected to DC power source supply to adjust the desired current density. Distilled water was used to dilute the chicken processing industry wastewater and it was then adjusted to the required pH by using sodium hydroxide or hydrochloric acid. In each run, 1.6 l of wastewater was placed into the reactor and all the runs were performed at constant treatment time of 15 min and stirring speed of 250 rpm. The treated effluent were collected and used for determination of COD concentration.

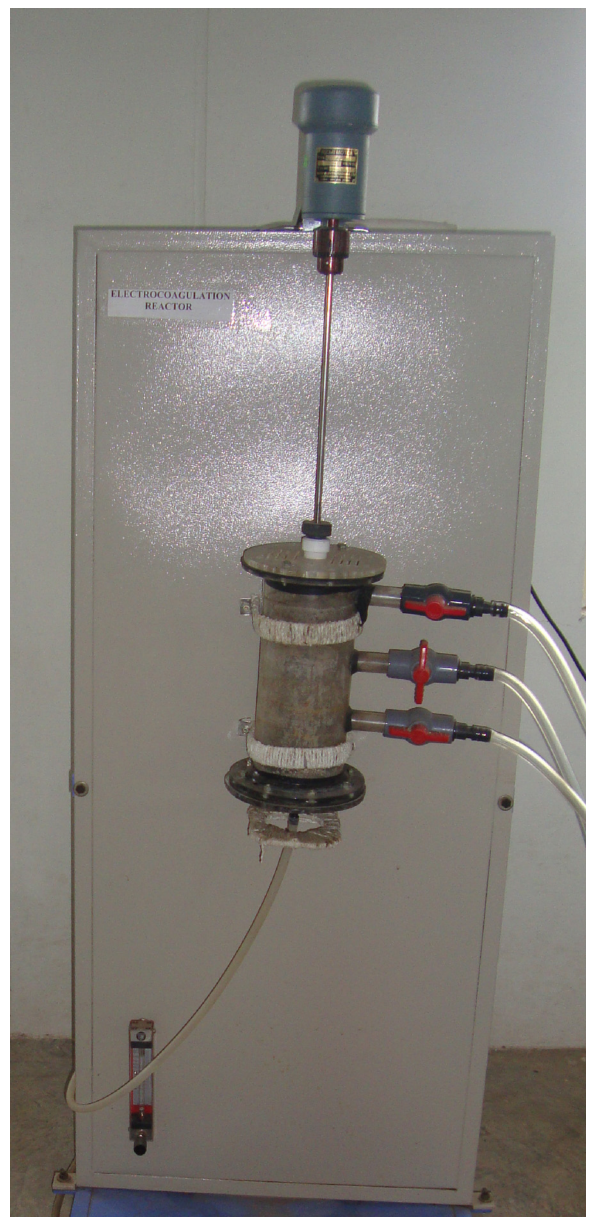

Fig. 1. Schematic diagram of electrocoagulation reactor.