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Municipal waste water treatment by natural coagulant assisted electrochemical technique—Parametric effects

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HIGHLIGHTS

- A novel natural coagulant was synthesized from *Pisum sativum*.
- Municipal waste water was characterized.
- Optimal conditions were identified: pH 5.0, coagulant dose-4.0 g/L,voltage 20 V and current 1.5 A.
- An empirical relationship between COD removal efficiency and coagulant dose was proposed.

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ABSTRACT

Municipal waste water treatment was investigated in an electrocoagulation reactor employing a novel natural coagulant synthesized from *Pisum sativum*. The influence of operating variables, namely, type of electrode (copper, steel and aluminum), effluent pH (3.0–9.0), initial COD of the effluent (190–760 mg/L) ,coagulant dosage (1.0–6.0 g/L), voltage (10–30 V) and current (1.0–2.0 A) on the COD removal efficiency was investigated. Aluminum electrode proved to be an effective choice for this application and resulted in enhanced flocs formation though aluminum hydroxides. The optimal conditions for better COD removal efficiency were identified as pH 5.0, coagulant dose-4.0 g/L, voltage 20 V and current 1.5 A. An empirical relationship between COD removal efficiency and coagulant dose was proposed ($R^2 = 0.966$). This research study proved the feasibility of parallel plate electrocoagulation reactor with a natural coagulant as a sustainable method for treating municipal waste water.

1. Introduction

Due to rapid industrialization and economic growth, population migration in developing countries has resulted in unforeseen water requirement in urban areas. The volumes of water used and waste water produced in domestic communities has increased significantly in the last few decades and a need for effective municipal waste water treatment is required to ensure the environmental compliance and resource reuse. Domestic waste water quantity and quality varies with respect to the population density and life style. Oman, located on the southeastern coast of Arabian Peninsula, has an approximate land area of 310,000 sq km. The collection of domestic sewage was practiced through septic tankers in most of the places and sewer systems in certain localities. The waste water treatment units use physical, chemical and biological techniques in their multistage treatment and the treated effluents have been used for landscape irrigation and recharging ground water

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Table 1
Characteristics of Municipal waste water.

Variable	Value
pH	7.10
Total Solids (TS) mg/L	1350
Total Suspended Solids (TSS) mg/L	505
Total Dissolved Solids (TDS) mg/L	845
Chemical Oxygen Demand (COD) mg/L	760

to resist salt water intrusion in coastal areas (Baawain et al., 2011; Jaffar Abdul Khaliq et al., 2017). Municipal waste water has unique properties compared to industrial waste water due to their diversified contents which are natural and chemical in origin. Research investigations on the use of modified photo-Fenton treatment to degrade micro pollutants in municipal wastewater have been carried out at neutral pH conditions (Klamerth et al., 2012). A sustainable way of treating municipal waste water through biological nutrient removal and reduction of carbon foot print has been discussed (Hu et al., 2012). In the midst of conventional waste water treatment methods like adsorption, flocculation, filtration, froth floatation and aerobic biodegradation, electro coagulation is identified as an effective technique to treat medium strength waste water as it combines the principles of electrochemical oxidation and coagulation for the removal of pollutants. Electrocoagulation is a simple method which involves the generation of a flocculating agent from oxidation of an electrode. Conventional chemical coagulation involves the addition of chemicals like aluminum sulfate or ferric chloride as a coagulant. In electrocoagulation, electrodes perform the role of chemical coagulants and they tend to agglomerate the particulates as flocs (Butler et al., 2011; Ahangarnokolaei et al., 2017; Song et al., 2015). Several studies on application of electrocoagulation for textile dye waste water treatment (Hossain et al., 2013; Ubale and Salkar, 2017), removal of dyes (Ghalwa et al., 2016; Adeogun and Balakrishnan, 2017; Nandi and Patel, 2017), dairy waste water treatment (Bazrafshan et al., 2013), hospital waste water treatment (Veli et al., 2016) and treatment of tissue paper waste water (Un et al., 2016) were reported. With this background, the objectives of this study are to demonstrate the application of an electrocoagulation process utilizing a novel natural coagulant for the treatment of municipal waste water and optimize the operating variables, namely, type of electrode, effluent pH, initial effluent concentration, coagulant dosage, voltage and current. The coagulant characterization was done using Fourier Transform InfraRed Spectroscopy (FTIR).

2. Materials and methods

2.1. Physico-chemical characterization of Municipal waste water

The Municipal waste water was collected from the waste water treatment plant located nearby and the essential physico-chemical characteristics were evaluated using standard methods (APHA, 2005) and presented in Table 1.

2.2. Synthesis of a natural coagulant

Pisum sativum, the common pea, is an herbaceous member in the Fabaceae (formerly Leguminosae) family and selected as a biomass for the production of coagulant. The peas were sundried for 72 h and crushed into fine powder in a blender and the particle size of 600 μm was selected. The powdered form of the natural biomass was used as a natural coagulant. The powdered coagulant was characterized for surface functional groups.

2.3. Experiments

The electrocoagulation process was carried out in a single compartment reactor equipped with a magnetic stirrer operated at 200 rpm throughout the experiments. The reactor was made of glass with a total volume of 5.0 L and working volume of 2.0 L. The reactor was equipped with a DC power supply and two monopolar plate type electrodes, one cathode and the other anode. The dimensions of both the electrodes were identical (12 cm $\times$ 10 cm $\times$ 2 mm). The total effective electrode area was 120 cm^2 per electrode and the distance between electrodes was 2 cm. The electrocoagulation experiments were conducted under batch conditions at room temperature of 298 K. In the first set of experiments, the effect of type of electrode on electrocoagulation performance was studied by choosing three different materials namely copper, steel and aluminum and the operating variables such as initial pH, coagulant dose, current and voltage were fixed. All the experiments were conducted with the actual undiluted effluent for an equilibrium time of 90 min at optimal pH unless or otherwise specified. The second sets of experiments were aimed to identify the optimal pH suitable for better COD removal efficiency. The effects of contact time and effluent concentration were investigated by varying the effluent concentrations in the range of COD values 190–760 mg/L. The time versus COD data was recorded at periodic intervals of time. In the second set of experiments, the influence of coagulant dose was studied in the range of 1.0–6.0 g/L with an initial COD value of 760 mg/L at optimal pH and room temperature. The influence of voltage on the COD removal efficiency was studied in the range of 10–30 V and the studies on effect of current was conducted in the range of 1.0 −2.0 A . The treated effluent samples were filtered and then