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Continuous electrocoagulation process for the post-treatment of anaerobically treated municipal wastewater

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ABSTRACT

The potential of continuous electrocoagulation (EC) process with aluminium electrodes for the post-treatment of upflow anaerobic sludge blanket (UASB) reactor-treated municipal wastewater was investigated. In order to optimise the performance, influence of three parameters affecting EC, namely, chemical oxygen demand (COD), current density (CD) and residence time in the reactor was studied using response surface methodology (RSM) with Box–Behnken design (BBD) employing real UASB reactor effluent. The results of the modelling study gave the following optimum conditions: influent COD concentration 274 mg/L, CD 2 mA/cm^2 and residence time 5 min; and predicted effluent COD, phosphate and turbidity values of 87 mg/L, 0.59 mg/L, and 12.6 NTU, respectively. Confirmatory tests at these optimum conditions gave 90 mg/L effluent COD, 0.57 mg/L effluent phosphate and 15.2 NTU effluent turbidity, which were in close agreement with the predicted results. At optimum conditions, high removals of BOD and suspended solids were also observed, with effluent BOD and suspended solids concentration of 34 mg/L and 29 mg/L, respectively. High total coliform and faecal coliform removals of 99.81% and 99.86%, respectively, were also obtained at these conditions. The study thus suggests EC as an attractive post-treatment option for UASB reactor-treated municipal wastewater.

1. Introduction

Anaerobic technology presents a high potential in most developing countries for municipal wastewater treatment (Foresti, 2002). Among the different anaerobic treatment technologies, the upflow anaerobic sludge blanket (UASB) process offers great promise, especially in developing countries due to its various advantages (Foresti, 2002). UASB technology has been recognized as the most cost effective and suitable sewage treatment process considering the environmental requirements in India (Sato et al., 2007). Effluent from UASB reactors, however, rarely meets disposal standards/guidelines especially in relation to organic content, suspended solids, nutrients and pathogen content. (Chernicharo, 2006; Khan et al., 2011; Sato et al., 2006; Tawfik et al., 2010; Verstraete and Vandevivere, 1999). The nutrients generally remain unaltered and the residual pathogen concentrations are high. This necessitates post treatment of UASB reactor effluent before its reuse in irrigation or discharge into natural water bodies.

Various post-treatment methods used for UASB reactor effluent include anaerobic/aerobic biological treatment processes such as activated sludge process, rotating biological contactors, downflow hanging sponge, physicochemical processes like floatation, aeration and coagulation, and natural

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treatment systems such as constructed wetlands and stabilization ponds (Chernicharo, 2006; Khan et al., 2011; Tawfik et al., 2010). The use of coagulation-flocculation as a post-treatment method for UASB reactor effluent has been reported (Aiyuk et al., 2006; Diamadopoulos et al., 2007; Jayaprakash et al., 2007). Coagulation process was effective to meet all discharge standards except feacal coliforms. Sato et al. (2006) studied full-scale UASB systems of Yamuna River Basin in India, and observed that UASB reactor-treated sewage followed by final polishing unit was not capable of producing disposable effluent with respect to COD, BOD, nutrients, and faecal coliforms, and thus selecting a proper reliable and efficient post treatment method is a great challenge.

Electrocoagulation (EC) has been successfully employed for treatment of a variety of wastewaters from olive mill, surfactant, food processing, semiconductor, chemical and mechanical polishing, restaurant, metal plating, tannery, potato chips manufacturing, dairy, poultry, slaughterhouse, pulp and paper mill, and arsenic contaminated drinking water (Kobya et al., 2007). EC involves in situ generation of coagulants by electrolytic oxidation of an appropriate sacrificial anode (for example, iron and aluminium) upon application of a direct current (Irdemez et al., 2006). The metal ions generated during EC produce metal hydroxide ions and neutral metal hydroxides. The low solubility of these hydroxides mainly at pH values in the range of 6.0–7.0, promotes the generation of sweep flocs inside the treated waste and the removal of pollutants by their enmeshment into these flocs (Kobya et al., 2007). EC process removes pollutants principally by coagulation, adsorption, precipitation and flotation (Kobya et al., 2007).

A few attempts have been made to assess the potential of EC for post-treatment of UASB reactor-treated effluent from different industrial wastewaters such as poultry manure wastewater (Yetilmezsoy et al., 2009) and unbleached Kraft pulp mill effluent (Buzzini et al., 2007). However, the use of EC for the post treatment of UASB reactor treating municipal wastewater has not yet been reported.

A number of factors affect EC process and among them major factors include electrolysis time, current density (CD) and wastewater characteristics (Kobya et al., 2003; Kobya et al., 2007; Merzouk et al., 2009; Yetilmezsoy et al., 2009). Optimization of these variables is necessary to reduce electricity consumption and overall treatment cost. Response surface methodology (RSM) has been used to obtain optimum conditions as it can predict the interaction effects between different variables along with the effect of individual variables (Montgomery, 2010). Use of RSM for optimization of EC process variables in water and wastewater treatment has been reported in the literature (Korbahti et al., 2007; Korbahti and Tanyolac, 2008; Kushwaha et al., 2010; Soloman et al., 2009). Most of the reported studies on EC used batch mode of operation with simulated wastewaters (Merzouk et al., 2009).

Thus the objective of this study was to assess the applicability of electrocoagulation as a possible post-treatment technique for UASB reactor-treated municipal wastewater. Continuous mode of operation with real wastewater was used in this study. RSM was used to optimize three important process variables namely, CD, residence time and initial COD concentration, with COD, phosphate and turbidity removals as responses. Microbiological removal, BOD and suspended solids removals were also monitored at optimum conditions.

2. Materials and methods

2.1. Sample collection and characterisation

All tests were conducted using UASB reactor effluent collected from a full-scale municipal wastewater treatment plant located at Bamroli, Surat, India. The samples were collected in 20 L plastic containers, transported immediately to the Environmental Engineering Laboratory of S.V. National Institute of Technology, Surat, India and preserved at 4 °C. Characterization was carried out immediately as the samples arrived in accordance with the Standard Methods (APHA, 1998). The characteristics of UASB reactor effluent are presented in Table 1.

2.2. Electrocoagulation experiments

The electrocoagulation tests were performed in a lab-scale continuous electrocoagulation unit with a total capacity of 8.3 L made from 5 mm thick plexiglass. The unit was divided into three compartments. The first compartment with 1.5 L volume, was provided with two anodes and two cathodes connected with monopolar series connection mode as shown in Fig. 1. Each pair of sacrificial electrodes was internally connected with each other.

Rectangular aluminium electrodes (185 mm × 75 mm × 5 mm) were used as anodes and cathodes with an effective electrode surface area of 255 cm^2 with respect to wetted surface with two active electric fields. The interelectrode distance was kept as 15 mm based on previous work and the values reported in the literature (Bayramoglu et al., 2007; Mameri et al., 1998). Electrodes were cleaned with 1 M HCl after each experimental run to avoid passivation (Vepsalainen et al., 2012). The UASB reactor effluent was continuously fed with a peristaltic pump. The required residence time was achieved by adjusting the flow rate. Wastewater from the first compartment entered the second compartment of capacity 3.4 L by overflow (Fig. 1). The scum was continuously removed from this compartment through overflow outlet. The third compartment with a volume of 3.4 L served as storage for treated effluent. The sludge from the sedimentation unit was taken out from bottom through sludge outlet pipe. Current and voltage were controlled by a digitally controlled DC power supply (TESTRONIX 92C, 0–30 V, 0–5 A).

A number of continuous EC tests were carried out to investigate the effect of various process variables such as current density, residence time and initial COD concentration on the process efficiency. The initial pH of the sample was adjusted to a desired value using 1 N HCl or 1 N NaOH. In tests based on

Table 1 – Characteristics of UASB reactor effluent.

Parameters	Values[a]
pH	7.1–7.9
Suspended solids (mg/L)	132–204
Turbidity (NTU)	166–294
COD (mg/L)	210–350
BOD (mg/L)	82–148
Phosphate (mg/L)	4.5–6.4
Electrical conductivity (mS/cm^2))	3.1–3.3
Total coliforms (MPN/100 mL)	7.8×10^6–9.9×10^6
Faecal coliforms (MPN/100 mL)	1.4×10^6–3.2×10^6

[a] Based on analysis of 3 samples.