Ecotoxicology and Environmental Safety 161 (2018) 137–144

Contents lists available at ScienceDirect

Ecotoxicology and Environmental Safety

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

Pollutants removal from synthetic wastewater by the combined electrochemical, adsorption and sequencing batch reactor (SBR)

Amin Mojiri, Akiyoshi Ohashi, Noriatsu Ozaki, Tomonori Kindaichi*

Department of Civil and Environmental Engineering, Graduate School of Engineering, Hiroshima University, 1-4-1 Kagamiyama, Higashihiroshima 739-8527, Japan

ARTICLE INFO

Keywords:
Adsorption
Chromium
COD
Electrochemical
Phenols
SBR

ABSTRACT

Wastewater filtration is considered the main solution to water shortages. Here, we treated synthetic wastewater by combining treatment techniques, namely, electrochemical oxidation and adsorbent added sequencing batch reactor (SBR). One beaker with a working value of 1500 mL was applied in this contemporary study. In the upper part of the beaker, an anode and a cathode (Ti/RuO_2-IrO_2) were arranged in parallel for the electrochemical oxidation process. Sodium sulfate (Na_2SO_4) with a concentration of 2.5 g/L was added as the electrolyte. The voltage and current were set to 7.50 V and 0.40 A, respectively. Aeration was conducted at the bottom of the beaker. Then, 15% working value of the reactor was filled by activated sludge, and 85% working value of the reactor was added with synthetic wastewater. In addition, 1.50 g/L of powdered cockleshell was added in the reactor. Response surface methodology was used for statistical analysis. In synthetic wastewater, concentrations of COD, ammonia, phenols and chromium were 2500 mg/L, 2500 mg/L, 100 mg/L and 100 mg/L, respectively. pH and reaction time (h) were considered as independent factors. A total of 2430 mg/L biochemical oxygen demand, 2500 mg/L ammonia, 90.0 mg/L phenols, and 84.0 mg/L chromium were eliminated at the optimum reaction time (72.9 min) and pH (6.5). The energy consumption value was 6.5 ($kWh\,kg^{-1}$) at the optimum operating conditions. This study indicated that this combined treatment system exhibited high performance.

1. Introduction

Logical usage of water resources is deemed one of the world's critical environment issues. Wastewater treatment from human activities in various fields, such as agriculture, industries, and shipping, is considered a solution to water shortage (Burakov et al., 2018). These wastewaters contain several kinds of pollutants, such as heavy metals, phenols, ammonia, and biochemical oxygen demand (COD). Several biological and physical/chemical ways are used to treat wastewaters (Latif et al., 2010).

Advanced oxidation process (AOP) is one example of a physical/chemical treatment technique. Advanced oxidation procedures have attracted significant attention in recent years, and they achieve applicable water purification performance and can reduce persistent contaminants. Electrochemical oxidation is one example of an AOP (Woisetschläger et al., 2013). Särkkäa et al. (2015) expressed that electrochemical methods are simple to work and may degrade several harmful contaminants. They can also be called "green technology" ways since little or no chemicals are needed to do water treatment. Barrera-Díaz et al. (2014) expressed that elimination of contamination in industrial waste should not be done by electrochemical individually because it needs high amount of energy. Adsorption and ion exchange techniques are another type of physical/chemical treatment technique. Olusegun et al. (2018) stated that adsorption is a suitable means because it is inexpensive, easy to design, and effective in eliminating organic contaminants. Huang et al. (2017) investigated organic pollutant elimination from dye wastewater via adsorption. Several low-cost materials, such as activated carbon, bentonite, zeolite, cockleshell, and limestone, have been reported for use in wastewater treatment via adsorption and ion exchange methods (Mojiri et al., 2014). Mojiri et al. (2017a) reported that the shell of a cockle is rich in calcite that can be useful in ion-exchange and adsorption processes. So in the current study, cockleshell was used to do ion-exchange and adsorption in a same time. Beside it, cockleshell is a natural low-cost material which has been applied for organic and inorganic pollutants elimination in literature (Moideen et al., 2015). Apart from physical/chemical treatment methods, biological techniques exhibit high performance in treating wastewaters.

One example of a biological treatment procedure is sequencing batch reactor (SBR), which is a developed type of the activated sludge procedure. SBR can eliminate organic pollutants, nutrients, and suspended solids from wastewater in a single tank and has low operational

* Corresponding author.
E-mail address: tomokin@hiroshima-u-ac.jp (T. Kindaichi).

https://doi.org/10.1016/j.ecoenv.2018.05.053
Received 13 March 2018; Received in revised form 20 May 2018; Accepted 22 May 2018
0147-6513/

cost (Mahvi, 2008). Mohseni-Bandpi and Bazari (2004) reported 90% COD elimination from dairy wastewater by using SBR. Mojiri et al. (2014) expressed that performance of conventional biological methods is not high, because of the limitation in microbial activity in salinity conditions and low efficiency in high polluted wastewaters. Mojiri et al. (2014) expressed that SBRs are less efficient in treating landfill leachate and industrial wastewaters than in treating urban wastes due to the low BOD_5/COD ratio and the high amount of heavy metals and ammonia of industrial wastewaters. So treatment of industrial wastewaters and landfill leachate are difficult by using biological methods. Thus, physical/chemical and biological treatment methods should be combined. To achieve maximum elimination during wastewater treatment, researchers have suggested a combined treatment method (Mojiri et al., 2017b).

Electrochemical oxidation and biological methods in wastewater treatment have been stated in the literature (Yeruva et al., 2015). Wang et al. (2013) eliminated 89.1% COD, 86% ammonia, and 51.3% total nitrogen by using an electrochemical membrane bioreactor. In addition, several studies (Santos and Boaventura, 2015) on wastewater treatment via addition of adsorbents in SBR were reported. Gisi et al. (2016) stated that adsorption processes were applied in wastewater treatment plants (WWTP) to remove dissolved pollutants that remained from subsequent biological phases or after chemical oxidation treatments.

This contemporary study principally aimed to treat synthetic wastewater by combining electrochemical and powdered cockleshell (PCS) supplemented SBR. The researchers designed a combined wastewater treatment technique that has optimum performance. No existing designed technique is stated in the literature. In this study, three kinds of treatments, namely, electrochemical, ion exchange/adsorption, and SBR, were employed to increase the effectiveness of contaminant elimination in the same time.

2. Materials and methods

2.1. Combined reactor

One beaker (height = 25 cm and diameter = 10 cm) with a working value of 1500 mL was applied in this contemporary study. In the upper part of the cylinder, anode and cathode plates (Ti/RuO_2-IrO_2, 8 cm × 4 cm) were utilized for the electrochemical oxidation process. The plates were prepared parallel (distance was 3 cm) to each other and were dipped in contaminated water. Sodium sulfate (Na_2SO_4) with a concentration of 2.5 g/L was added as electrolyte to the reactor before each experiment. Electronic power (digital DC power supply) was applied as the power source. Fajardo et al. (2017) investigated electrochemical oxidation of phenolic wastewater using Ti/RuO_2. Kop (2014) reported 3 cm distance between electrodes during domestic wastewater treatment with electrochemical oxidation.

Air was supplied from the bottom of the reactor by using an air pump because it was an SBR-based reactor. The periods of fill (10 min), settle (45 min), and draw and idle (10 min) were set based on preliminary experiments. In addition, 1.50 g/L of PCS was added in the SBR for adsorption. These conditions were consistent with the findings of Mojiri et al. (2017b). In this study, the PCS size ranged from 75 µm to 150 µm, and PCS was added as adsorbent in the reactor. The characteristics of PCS were monitored with the autosorb (Quantachrome AS1wintm, version 2.02) test. Cockleshell surface area (m^2/g), external surface area (m^2/g) and micropore area (m^2/g) were 260, 236 and 60.9, respectively. Mojiri et al. (2014) removed pollutants from landfill leachate by using a beaker with a working value of 2 L as the SBR. They supplied air from the bottom of the reactor. So in the contemporary study, aeration (1.5 L/min) was supplied from bottom of reactor.

2.2. Synthetic wastewater production

In this study, tap water was polluted with contaminants. The pollutants were prepared by dissolving their chemical grade in water. To achieve ammonia concentration, ammonium hydroxide was dissolved in water (Ashrafizadeh and Khorasani, 2010). Chromium (VI) was obtained by dissolving $K_2Cr_2O_7$ (Hossini et al., 2015). To achieve COD, different carbon sources, including urea, peptone, Na-acetate, starch, yeast, and milk powder were added to the tap water (Nopens et al., 2001). For phenol concentrations, phenols with 99.9% purity and 94.11 g/mol molecular mass were gained for laboratory analysis (Najafpoor et al., 2016).

2.3. Experimental procedure

A 1500 mL beaker was used in this study. The reactor was filled with 1275 mL synthetic wastewater, representing the 85% working value of the reactor. A total of 225 mL activated sludge from a 16 years old domestic WWTP (wastewater treatment plant) was added in the reactor, representing the 15% working value of the reactor. In this contemporary research for activated sludge, MLSS (mg/L), MLVSS/MLSS and suspended solids (mg/L) were 5011, 0.82 and 8904, respectively. Mojiri et al. (2014) used activated sludge from domestic WWTP in SBR as 10% working value to supply bacteria and improve biodegradability in treating landfill leachate. The voltage and current in the preliminary experiments were set to 7.50 V and 0.40 A, respectively. In the current research, two independent factors, namely, contact time (reaction time; 30–120 min) and pH (5.50–7.50) were investigated. COD and ammonia concentrations were set to 2500 mg/L. Phenol and Cr (VI) concentrations were set to 100 mg/L. Fajardo et al. (2017) treated synthetic phenolic wastewater with 100 mg/L concentration by using the electrochemical oxidation method. Yadu et al. (2018) reported 100–2500 mg/L COD concentration during ammonia and COD treatments by batch reactors.

2.4. Analytical methods and electrochemical oxidation parameters

Chemical, physical, and biological analyses for the produced wastewater were conducted based on standard methods (APHA, 2005). Phenols, metals, COD, and ammonia were tested by using spectrophotometry in accordance with Standard DR/2800 HACH.

2.5. Statistical analysis

The removal effectiveness is computed based on Eq. (1).

$$\text{Removal}(\%) = \frac{(C_i - C_f)}{C_i}.100, \tag{1}$$

where C_i and C_f are the preliminary and final concentrations of the features, respectively.

Response surface methodology (RSM) was used for statistical analysis. RSM is a mathematical and statistical method used in designing experiments, building models, and assessing the impact of process variables. The responses can be linked to the factors by using linear or quadratic models in RSM. The quadratic model, which also comprises the linear model, is used in Eq. (2).

$$Y = \beta_0 + \sum_{j=1}^{k} \beta_j X_j + \sum_{j=1}^{k} \beta_{jj} X_j^2 + \sum_i \sum_{<j=2}^{k} \beta_{ij} X_i X_j + e_i, \tag{2}$$

where Y is the response; X_i and X_j are the variables; $ß_0$ is a fixed coefficient; $ß_j$, $ß_{jj}$, and $ß_{ij}$ denote the interface coefficients of the linear, quadratic, and second-order terms, respectively; *k* denotes the quantity of considered factors; and *e* denotes the error.

The design comprised k^2 factorial points reinforced by 2 k axial points and a center point, where k denotes the number of variables. At the central points, four replicates were done to fit the second order polynomial models and evaluate the experimental error for this contemporary research. Each of the four operating variables was considered at three levels, namely, low (−1), central (0), and high (+1).