International Biodeterioration & Biodegradation 64 (2010) 764–768

Contents lists available at ScienceDirect

International Biodeterioration & Biodegradation

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

Short communication

Studies on biodegradation of resorcinol in sequential batch reactor

Vipul Sharma, Vimal Chandra Srivastava, Jai Prakash Kushwaha, Indra Deo Mall*

Department of Chemical Engineering, Indian Institute of Technology Roorkee, Roorkee, 247667 Uttarakhand, India

ARTICLE INFO

Article history:
Received 20 July 2010
Received in revised form
26 August 2010
Accepted 28 August 2010
Available online 28 September 2010

Keywords:
Sequencing batch reactor
Activated sludge
Refinery wastewater
Sludge characterization
Thermal analysis

ABSTRACT

This paper reports optimization of parameters for the biodegradation of resorcinol bearing aqueous solution in a sequencing batch reactor (SBR). Various parameters studied include mixed liquor suspended solid concentration (MLSS), resorcinol initial concentration and fraction of fill phase used as aerated phase. Increases in MLSS concentration and aeration time were found to induce positive effect on resorcinol removal efficiency. The settling characteristic of sludge was measured in terms of sludge volume index. The heating value of the sludge was found to be 11.64 MJ/kg.

1. Introduction

Phenol and substituted phenol like resorcinol are important organic intermediates obtained during the production of various industrial and agriculture products (Körbahti and Tanyolac 2003). Resorcinol, a hydroxy aromatic compound, is one of the intermediate in the metabolic pathway during the biodegradation of numerous aromatics (Subramanyam and Mishra 2008). Resorcinol has higher toxicity than phenol and is an irritant for skin, eyes and mucous membranes. Methemoglobinemia and hepatic injury may be noted within a few days after intoxication by resorcinol (Othmer 1995). Resorcinol is usually employed to produce dyes, plastics and synthetic fibers (Hays et al. 2005). As a result, resorcinol is extensively present in the effluents generated during its production as well as during its usage. Resorcinol is a primary pollutant in wastewaters due to its high toxicity, high oxygen demand and low biodegradability (Phutdhawong et al. 2000; Duursen et al. 2004). Several methods for the treatment of resorcinol wastewater have been proposed in the literature. These include physico-chemical treatment processes, chemical oxidation and biological degradation (Subramanyam and Mishra 2008). For high strength and low volume of resorcinol waste waters, resorcinol removal by adsorption using granular/powdered activated carbon has been widely used (Kumar et al. 2003). However, high costs of activated carbons and 10–15 percent loss during regeneration make the utilization of adsorption process prohibitive.

Sequencing batch reactor (SBR) is one of the best available techniques for the biological treatment of industrial wastewaters having very high concentration of chemical oxygen demand (COD), biological oxygen demand (BOD), phenolic compounds and other hazardous pollutants (Silva et al. 2002; Kargi and Uygur 2003; Kulikowska et al. 2007; Tsang et al. 2007). SBR process is a activated sludge (AS) suspended growth in which all major steps occur in the same tank in sequential order. It is characterized by series of process phases mainly: fill, react, settle, draw and idle (Wilderer et al. 2001). The duration of each phase is determined by the past or research experience. It is essential and important to select appropriate cycle time and duration of different phases according to the kind of wastewater to be treated.

The aim of the present work is to determine the effect of various parameters namely mixed liquor suspended solids (MLSS) concentration, initial concentration of resorcinol (C_o) and ratio of aeration phase (T_a) to fill phase (T_f) for the removal of resorcinol from aqueous solution in SBR. Slurry of the SBR has been evaluated for sludge settleability and filterability characteristics. Sludge obtained in optimum condition run has been characterized for its proximate, microscopic, elemental and thermal analysis; and heating value to evaluate its disposal option along with energy recovery.

* Corresponding author. Tel.: +91 1332 285319 (Off), 285106 (Res); fax: +91 1332 276535/273560.

E-mail addresses: vimalcsr@yahoo.co.in (V. Chandra Srivastava), id_mall2000@yahoo.co.in (I.D. Mall).

0964-8305/$ – see front matter
doi:10.1016/j.ibiod.2010.08.009

2. Materials and methods

2.1. Synthetic wastewater

Synthetic wastewater of resorcinol (SWR) having $C_o = 50$ mg/L was used to study the effect of variation of MLSS and aerated fill time. For studying the effect of varying C_o, the range of resorcinol in SWR was 10–200 mg/L.

2.2. Seed activated sludge

AS used in the present study was collected from Haridwar sewage treatment plant, Haridwar, India. The sludge was first screened for the removal of coarse and bigger particles, and thereafter, it was aerated for acclimatization in SWR having $C_o = 200$ mg/L.

2.3. Experimental programme

The experimental set-up consisted of two identical well-mixed SBR each having a diameter of 13 cm and a working volume of 2 L. The schematic diagram of the lab scale setup of SBR is shown in Fig. 1. Both the reactors worked as individual reactor. Aeration was achieved by an air pump with sintered-sand diffusers at the bottom of the each reactor. The addition of SWR and the decanting of treated SWR were performed by peristaltic pumps. Dissolved oxygen (DO) concentration inside the reactor was maintained over 2 mg/L during the experiments by controlling the flow of air through air rotameter. The reactors were operated with temperature at 28 ± 2 °C. The reactor was operated on a fill-and-draw basis, with a cycle time (T_c) of 5 h consisting of 2.5 h fill time (T_f). Remaining 2.5 h was divided into react phase ($T_r = 1.75$ h) and settle phase ($T_s = 0.75$ h). To maintain appropriate level of MLSS concentration within the reactor some amount of sludge was wasted after every cycle which prevented the problem of sludge bulking and excessive growth of filamentous bacteria. For this purpose, sludge retention time was maintained constant at 10 day. All the experiments were carried out thrice. The results presented in the paper are average of these three separate runs. Results showed maximum deviation of 3% from the average values.

The mixture of liquid–solid suspensions from the SBR (SWR and AS) was mixed well, and the resultant slurry was tested for its settling characteristics and filterability. The sludge sedimentation tests were performed using a 1 L graduated glass cylinder. No stirring was done during the tests. The well mixed slurry was homogenized before pouring it into the glass cylinder and was

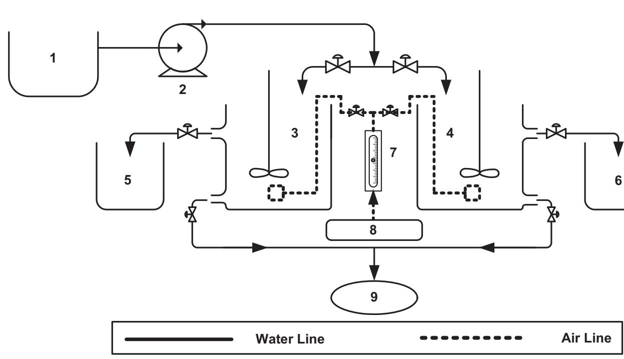

Fig. 1. Experimental setup of SBR. 1. Raw wastewater; 2.Peristaltic pump; 3. SBR1; 4.SBR 2; 5.Treated Effluent Collection Tank 1; 6.Treated Effluent Collection Tank 2; 7.Air Rota meter; 8.Air Pump; 9.Wasted Sludge Collector.

allowed to remain under quiescent conditions. The position of the upper interface was noted after 30 min. The filterability of sludge from SBR was determined using filter paper (Whatman filter paper no. 42 pore size of ca. 2.5 μm) supported over a ceramic Buechner funnel of 0.93 cm internal diameter and having filter area of 6.793×10^{-3} m^2; the slurry was filled up to 50–60% volume of the funnel.

2.4. Analytical methods

Analysis of the SWR was done as per standard methods (Cleceri et al. 1998). Samples were periodically analyzed for MLSS concentration (standard code: 2540D). The concentrations of resorcinol present in the solution were measured using a double beam UV/VIS spectrophotometer (model UV DR 5000; HACH, USA). Maximum absorbance wavelength corresponding to resorcinol was 273 nm. Calibration curve showed linear relationship between absorbance and the concentration in the solution for concentrations up to 50 mg/L with the correlation coefficient value of more than 0.9992. To fall within the linear range, sample concentrations were sometimes diluted to below 50 mg/L. The proximate analysis of the sludge was determined as per Indian Standards (Bureau of Indian Standards 1984). The heating value of the sludge was estimated using standard adiabatic bomb calorimeter equipped with a digital firing unit (Toshniwal, Bombay).

Energy dispersive X-ray (EDX) (SEM, QUANTA, Model 200 FEG, USA) was used to study the distribution of the elements in the sludge. For the EDX, the samples were first gold coated using Sputter Coater, Edwards S150 to provide conductivity to the samples, and then the EDX spectra were taken. Thermal analysis of the sludge SBR was carried out using a thermal analysis (TA) instrument (Perkin–Elmer Pyris Diamond). Thermogravimetric analysis (TGA), differential thermogravimetry (DTG), and the differential thermal analysis (DTA) were carried out from the data and plots obtained from the instrument. TGA/DTA scans were recorded in temperature range, ambient to 1000 °C. The thermo-analytical curves of the solid samples were obtained from this instrument under air atmospheres with an air flow rate of 0.2 L/min and at a heating rate of 10 °C/min.

3. Results and discussion

3.1. Effect of fraction of aeration during fill phase (T_a/T_f)

The effect of fraction of fill phase aeration during fill phase on the efficiency of SBR was studied by varying the time of aeration (T_a) during T_f which was kept constant at 2.5 h. The T_a in the fill phase was varied in the range of 0–2.5 h. Various T_a/T_f ratios considered in the present study were 0, 0.4, 0.8 and 1. The MLSS concentration was kept constant at 3170 mg/L whereas C_0 was kept constant at 50 mg/L. The final concentration of resorcinol (C_f) after the treatment and percent removal efficiencies with varying T_a/T_f ratio are shown in Fig. 2. The removal efficiency was found to be higher for the larger values of T_a/T_f, while the C_f at intermediate T_a/T_f ratio was high. This shows that higher removal efficiencies are obtained for SBR having longer aeration time. The ratio $T_a/T_f = 1$ was found to be optimum for maximum removal efficiency.

3.2. Effect of MLSS concentration

The effect of MLSS concentration on the performance of the SBR was studied at $C_0 = 50$ mg/L and $T_a/T_f = 1$ by varying the MLSS concentration in the range of 2010–4510 mg/L. The C_f values and corresponding removal efficiencies in the SBR with varying MLSS concentrations are shown in Fig. 3. It can be seen that the treatability