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Stability of Biological Activated Carbon-Sequencing Batch Reactor (BAC-SBR) to Phenol Shock Loading

Soydoa Vinitnantharat
Department of Environmental Technology, School of Energy and Materials, King Mongkut's University of Technology Thonburi, Bangmod, Bangkok, Thailand

Cha Woo-Suk
Asian Institute of Technology, P.O. Box 4, Klongluang, Pathumthani 12120, Thailand

Yoshinobu Ishibashi
Tohoku Gakuin University, Chuo 1-13-1, Tagajo, Miyagi, 985-8537, Japan

Sung-Ryong Ha
Department of Urban Engineering, Chungbuk National University, Cheongju, Replubic of Korea

Abstract

Experiments were conducted to study the buffer effect of granular activated carbon (GAC) added to sequencing batch reactor (SBR) in the case of phenol shock loading. The reactor was fed with phenol as the sole carbon source initial concentration of 500 mg/l and GAC dosage of 5 g/l. Three types of shock loading namely step-up shock load, short-term fluctuation, and step-wise augmentation were conducted to compare with conventional SBR over a period of 24 days of operation. The concentrations of phenol applied to the reactor were in the range of 500 - 3500 mg/l.

In the step-up shock load period, the BAC-SBR showed better tolerance than conventional SBR for the increasing phenol concentration from 500 mg/l to 2000 mg/l during the first two cycles. With time going on, both systems showed failure in degrading the phenol. In the short term fluctuation period, the BAC-SBR performed better removal of phenol at 3000 mg/l whereas the conventional SBR could not tolerate this concentration. Removal of phenol was also achieved in BAC-SBR during step-wise augmentation and was not achieved by conventional SBR with an initial phenol concentration of 2000 and 3000 mg/l. The experimental results showed that the BAC-SBR was superior to conventional SBR for all cases of shock loading and it played a role as a buffer through the period of shock loading without any refilling of the virgin GAC into the reactor.

Keywords : phenol, granular activated carbon, aerobic process, sequencing batch reactor, biological activated carbon, shock loading

1. Introduction

Phenol and derivatives are used extensively as pesticides, wood preservative and as intermediates in the manufacture of pesticides, pulp and paper. It is manufactured in phenol plants and from fossil fuel extraction and beneficiation processes [1]. Furthermore, phenol is toxic and carcinogenic to some animal species [2]. Recently, Biological treatment of toxic organic compounds has been in the limelight very much both in aerobic and anaerobic treatment. However, biological treatment systems have been inhibited by fluctuation in the influent composition. Disruption of biological activity will affect the removal efficiency and recovery from such disturbances can be extremely slow. Addition of activated carbon to the biological system so called "biological activated carbon (BAC) process" had been reported to enhance the toxic substances removal. The principal mechanism in the BAC process is carbon adsorption and biodegradation of organic compounds. In addition, the occurrence of bioregeneration of activated carbon which lead to a renewal of adsorptive potential, and a higher stability of the system has been reported by many researchers [3,4,5].

Gaudy and Gaudy [6] classified shock loading into 2 types, nature of change and mode of change as shown in Table 1.

Table 1 Various type of shock loading

Type	Definition
(1) Base on the nature of shock loading	
Qualitative shock load	Change in the nature of influent substrate
Quantitative shock load	Change in the concentration
Hydraulic shock load	Change in the influent flow rate with the concentration remained constant
pH shock load	Change in pH
Temperature shock load	Temperature change
Toxic shock load	Introduction of microbial toxicants, organic or inorganic
(2) Base on the mode of shock loading	
Step-up or step-down	Change of either concentration or flow rate from the previous steady state operation
Slug dose	Abrupt pulse change in the chemical composition
Cyclical changes	A series of changes of one or more types of magnitude applied at regular and repeating intervals
Random changes	Various sudden changes with no cyclical characteristics
Continual changes	Ever-shifting change with unpredictable or predictable magnitude and periodicity

Source : Gaudy and Gaudy [6]

The sequencing batch reactor (SBR) is becoming an outstanding treatment process due to its flexibility of operating modes, energy and space saving. Integration of BAC and SBR was noted to provide a significant potential for higher exploration of adsorptive capacity of activated carbon and for cost reduction [7]. The BAC-SBR could be a promising technology in the next few years.

2. Materials and Methods

2.1 Materials

The adsorbent used in this study was lignite based granular activated carbon (GAC) from Sigma chemical Co Ltd. It was seived to obtain 20 x 30 mesh fraction, resulting in an average diameter of 0.75 mm. GAC was rinsed with distilled water several times and dried in the oven at 105 °C over night. After being cooled in a dessicator, it was kept in a glass bottle. The GAC was boiled in distilled water again before being used to remove air in the pores.

2.2 Reactor Design and Operation Condition

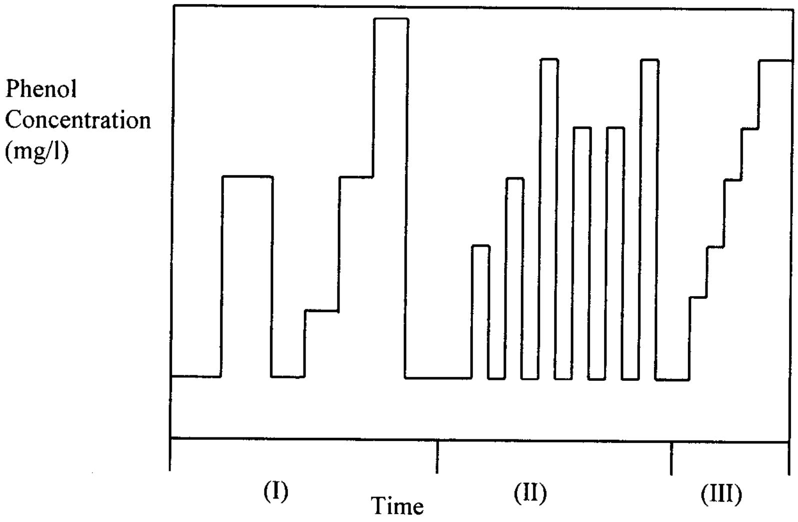
Two reactors, cylindrical in shape were used in this study. One reactor served as the control unit without GAC. The total volume of the reactor system was 12 L with a working volume of 10 L. 50 grams of GAC (or 5 g/L) were added to each reactor and then 1300 mg/l of acclimated sludge inoculated into the reactors. The GAC was allowed in the reactor until the end of study without replacing and withdrawing. Both reactors consist of five sequential steps: Fill 30 minutes, React 5 hours, Settle 1 hour and 30 minutes, Draw and Idle 1 hour, 3 cycles/day. The sludge wasting is accomplished by removing a portion of the sludge during the end of React period. The sludge wasting was passed through the wire net to prevent the GAC loss from the reactor. The portion of sludge wastage was calculated before wasting to provide the sludge retention time in the reactor of 10 to 20 days. Aeration and mechanical mixing were provided during React period only except at the begining from cycle 1 to cycle 40, mechanical mixing was not provided for economic advantage.

Three types of shock loading, step-up shock load, short term fluctuation and stepwise augmentation, were applied to each reactor to observe the response of dynamic change. Shock loading patterns are shown in Figure 1.

2.3 Analytical Methods

Mixed liqour suspended solids (MLSS) and phenol were measured daily by gravimetric and direct photometric method followed by Standard Method for the Examination of Water by and Wastewater[8]. DO, pH and MLSS were also checked daily.

To determine the degree of adsorption of phenol onto the GAC, samples of virgin activated carbon were tested. Varying amounts of the virgin GAC were added to a series of 500 ml glass stopper flasks containing 100 ml of the wastewater containing phenol 500 mg/l. The flasks were agitated for 7 days at 26 °C and the residual phenol concentration was determined.



(I) : Step-up shock load
(II) : Short-term fluctuation
(III) : Step-wise augmentation

Figure 1 Shock loading patterns

3. Results and Discussion

3.1 Adsorption characteristics

The phenol adsorption capacity of GAC can be described by Freundlich isotherm as shown in Figure 2 and the Freundlich parameters, K and n are 41 and 4.28 respectively. This indicated that the GAC has a great capacity to adsorb phenol in wastewater.

3.2 Step-up shock load

The first shock loading was conducted by increasing the influent concentration from 500 to 2000 mg/l. The BAC-SBR showed better tolerance for the first two cycles in terms of effluent phenol concentration. At the last cycle of shock loading, both systems showed a failure in degrading the phenol when the effluent phenol concentration in the conventional SBR and BAC-SBR was 1353 mg/l and 417 mg/l respectively. It should be noted that the biomass in BAC-SBR was increased as time passed whereas the biomass in conventional SBR was decreased during the first shock loading (Figure 3). The decrease of biomass in conventional SBR was due to the biomass foaming. It indicated that the microorganisms could not withstand the high phenol concentration. In constrast, the microorganisms in BAC-SBR could grow and were protected by carbon adsorption.

When the phenol concentration was continually steppes up to a shock load of from 500 to 3500 mg/l in the reactors, it was revealed that both systems showed stable performance up to 2000 mg/l of influent phenol without significant disturbance. However, at the influent phenol concentration of 3500 mg/l, both reactors could not tolerate the shock loading and failed to remove the phenol. With the gradual increase in phenol concentration, the biomass could grow steadily.

3.3 Short term fluctuation

The shock loading was applied in the reactors in the form of pulse change. The base phenol concentration was 500 mg/l and the peak loading was varied from 1500 to 3000 mg/l randomly for only one cycle. It was found that the BAC-SBR showed better phenol removal at phenol concentration of 3000 mg/l than conventional SBR. It was observed that the dissolved oxygen in BAC-SBR decreased consequently to the decrease in phenol removal in the next cycle. However, when air was supplied, the reactor showed complete phenol removal. It can be explained that the activated carbon granules became lightly coated with biological solids which indicated that biomass in the BAC-SBR was higher than in conventional SBR and it needed more oxygen. The effluent phenol concentration and MLSS in the reactor are shown in Figure 4.

3.4 Step-wise augmentation

The shock loading was applied step by step every cycle from 500 to 3000 mg/l. Regarding the effluent phenol, the BAC-SBR proved its excellent buffer effect. Its performance was better than conventional SBR with applied phenol concentration of 2500 and 3000 mg/l. The MLSS of the BAC-SBR continued to increase up to 5304 mg/l at the last cycle (phenol concentration of 3000 mg/l) while the conventional SBR showed the MLSS drop down caused by severe foaming (Figure5). Because of this, there was high sludge loading rate of 2.215 gCOD/gMLSS and only 70 % of phenol removed. The BAC-SBR has sludge loading rate of 0.718 gCOD/gMLSS and 99.9 % of phenol removed.

4. Conclusions

The BAC-SBR has high stability to phenol shock loading and could work as a buffer by adsorbing the high strength of influent phenol and as a supporting media for microorganisms. The conventional SBR could not remove phenol during shock loading and foaming was the most severe response with subsequent loss of biomass from the reactor.

5. References

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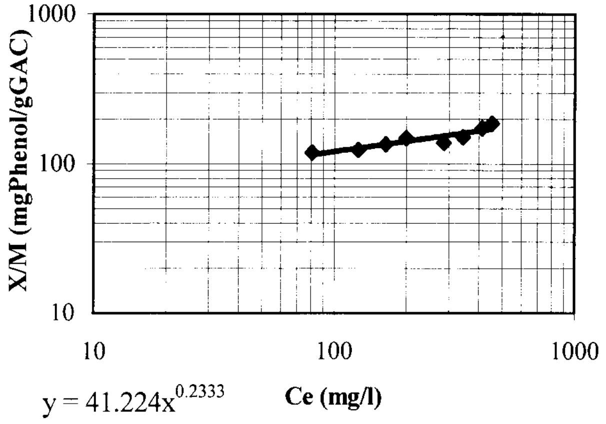

Figure 2 Adsorption isotherm of phenol

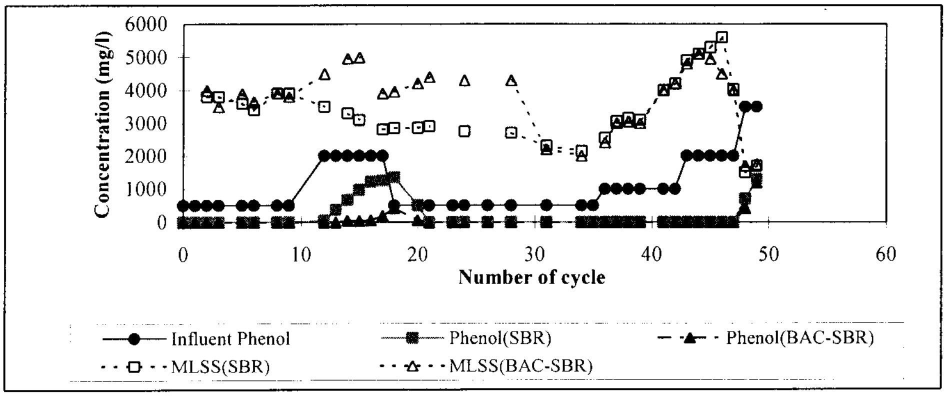

Figure 3 Effluent phenol concentration and MLSS during step-up shock load

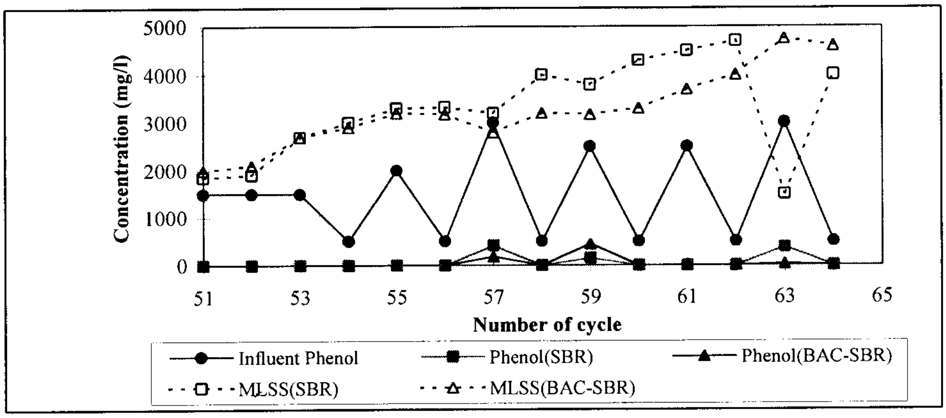

Figure 4 Effluent phenol concentration and MLSS during short term fluctuation

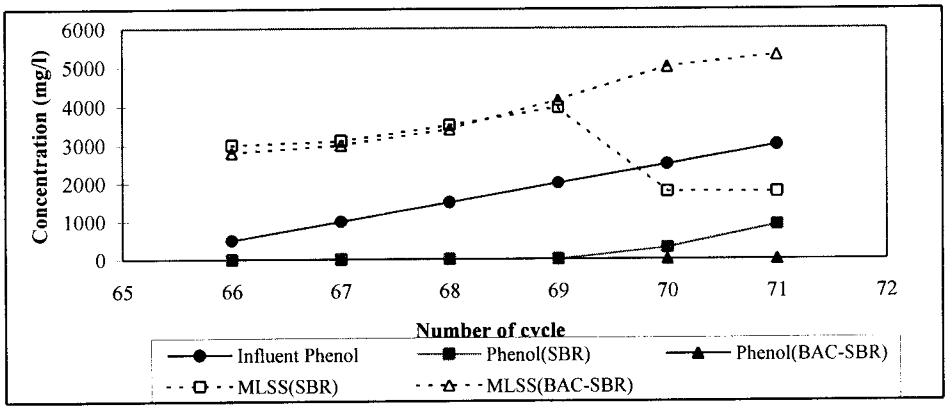

Figure 5 Effluent phenol concentration and MLSS during step-wise augmentation