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Performance study and kinetic modeling of hybrid bioreactor for treatment of bi-substrate mixture of phenol-*m*-cresol in wastewater: Process optimization with response surface methodology

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Abstract

Performance of a hybrid reactor comprising of trickling filter (TF) and aeration tank (AT) unit was studied for biological treatment of wastewater containing mixture of phenol and *m*-cresol, using mixed microbial culture. The reactor was operated with hydraulic loading rates (HLR) and phenolics loading rates (PLR) between 0.222–1.078 $m^3/(m^2 \cdot day)$ and 0.900–3.456 $kg/(m^3 \cdot day)$, respectively. The efficiency of substrate removal varied between 71%–100% for the range of HLR and PLR studied. The fixed film unit showed better substrate removal efficiency than the aeration tank and was more resistant to substrate inhibition. The kinetic parameters related to both units of the reactor were evaluated and their variation with HLR and PLR were monitored. It revealed the presence of substrate inhibition at high PLR both in TF and AT unit. The biofilm model established the substrate concentration profile within the film by solving differential equation of substrate mass transfer using boundary problem solver tool 'bvp4c' of MATLAB 7.1©software. Response surface methodology was used to design and optimize the biodegradation process using Design Expert 8 software, where phenol and *m*-cresol concentrations, residence time were chosen as input variables and percentage of removal was the response. The design of experiment showed that a quadratic model could be fitted best for the present experimental study. Significant interaction of the residence time with the substrate concentrations was observed. The optimized condition for operating the reactor as predicted by the model was 230 mg/L of phenol, 190 mg/L of *m*-cresol with residence time of 24.82 hr to achieve 99.92% substrate removal.

Key words: hybrid bioreactor; bi-substrate; phenol; *m*-cresol; response surface methodology; biofilm model
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Introduction

Aerobic biological treatments of wastewater are based on either suspended growth or attached growth system. However combination of the two types of growth in one system has created interest of the researchers. Incorporation of biofilm growth along with suspended growth system in a single hybrid reactor has been proven to be more efficient for wastewater treatment especially for removal of toxic substrate by microorganisms even at low temperature (Tsuno et al., 1992; Lessel, 1994; Hamoda and Al-Sharekh, 2000). As biofilm system is capable of handling shock load, so system stability and sludge properties are improved in reactor having biofilm (González-Martínez and Duque-Luciano, 1992; Wang et al., 2000). Combination of attached growth and suspended growth also offers simplicity of operation and economic advantage compared to other processes (Harison et al., 1984).

Some researches have been done on hybrid reactor combining an attached growth and activated sludge or anaerobic sludge blanket system for removal of toxic substrates from wastewater (Misra and Gupta, 2001; Majumder and Gupta, 2003; Zinatizadeh et al., 2006; Yeom, 2007). Limited researches have been carried out on removal of phenolic compounds by aerobic hybrid reactors using mixed culture bacteria. Co-degradation of phenol and cresols was studied by Ramakrishnan and Gupta (2006). They examined granulation and performance of four similar anaerobic hybrid reactors combining upflow anaerobic sludge blanket unit and anaerobic filter for treatment of synthetic coal wastewater containing phenol (490 mg/L); *m*-, *o*-, *p*-cresols (123.0, 58.6, 42.0 mg/L); 2,4-, 2,5-, 3,4- and 3,5-dimethyl phenols (6.3, 6.3, 4.4

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