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Response of pulse phenol injection on an anaerobic–anoxic–aerobic system

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Abstract

The performance of a three-stage suspended growth continuous system consisting of anaerobic–anoxic–aerobic reactors was evaluated after injection of a pulse phenol shock load in the anaerobic reactor. The synthetic feed contained phenol, cyanide, thiocyanate and ammonia-nitrogen. Anaerobic reactor required 22 days to regain its previous cyanide removal efficiency and the reactor achieved a new steady state in terms of phenol removal. The anoxic reactor achieved its previous phenol and the thiocyanate removal efficiency in seven to nine days. In the aerobic reactor, nitrification was severely inhibited due to the washout of nitrifying bacteria. The aerobic reactor was the most sensitive in terms of phenol shock load in the three-stage system.

Keywords: Pulse phenol injection; Nitrifying bacteria; Three-stage suspended growth system

1. Introduction

Biological treatment has proved to be a cost-effective viable method for handling several industrial wastewaters, utilizing consortia of heterogeneous microorganisms for degrading pollutants. Process effluents generated from coal gasification, coke and steel plant, synthetic fuel processing operations, coal carbonization, etc. contain high levels of phenolic compounds and inorganics like ammonia-nitrogen, cyanide, thiocyanate along with other toxic substances (Luthy, 1981; Zhang et al., 1998). Biodegradation is difficult and challenging due to the presence of these toxic and inhibiting pollutants. Activated sludge process (ASP) is the most common feature in most of the studies along with various pre-treatment options. However single- and two-stage ASPs are reported to be inefficient with inadequate nitrification (Pandey et al., 1991; Luthy, 1981). Two- and three-stage anoxic–aerobic/anaerobic–anoxic–aerobic sequential treatment enhanced process performance (Li et al., 2003; Zhang et al., 1997; Wen et al., 1991). The anaerobic stage was used as a pre-treatment step and anoxic–aerobic reactors were used for denitrification with organic removal and nitrification (Suidan et al., 1987; Melcer and Nutt, 1988; Liu et al., 1996). A three-stage anaerobic–anoxic–aerobic suspended growth continuous system was selected for the present study with synthetic feed containing phenol, cyanide, thiocyanate and ammonia-nitrogen.

Any wastewater treatment plant is subjected to influents of varying quality and quantity. In the case of high fluctuations in influent concentration breakthrough may happen in the bioreactors, which may be permanent, or for a short period. Since phenol is a major pollutant generated from coke plants, coal gasification, petrochemical wastewater, the present shock load study was conducted with it. The aim of the study was to characterize the

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response of pulse phenol overload on a lab-scale three-stage suspended growth anaerobic–anoxic–aerobic continuous system.

2. Methods

2.1. Synthetic feed

The experiment was conducted with synthetic wastewater containing phenol (1500 mg/L), cyanide (70 mg CN^-/L), thiocyanate (800 mg SCN^-/L) and ammonia-nitrogen (800 mg NH_4^+-N/L) as pollutants. The synthetic feed included yeast extract (20 mg/L), and trace metal solution (1 mL/L) as nutrients. The feed pH was maintained at 8.0–8.1 by phosphate buffer to minimize volatilization of cyanide and to add phosphorus in the feed. The Feed composition is given in Table 1.

2.2. Continuous three-stage system

The initial seed was collected from a sewage treatment plant at the Indian Institute of Technology Bombay. Settled sludge from the clarifier of an anaerobic digester in the sewage treatment plant was collected and sieved through a 0.2 mm size sieve to remove sand and other inorganic particles. This sieved settled sludge was added in the reactor (30% of reactor volume) for acclimation. Acclimation was conducted in three separate batch reactors (each volume 5 L) under anaerobic, anoxic and aerobic environments. Initial MLVSS (mixed liquor volatile suspended solids) concentration in the three reactors after seed addition was: 2700–2750 mg/L; and MLVSS to MLSS (mixed liquor suspended solids) ratio was 0.6. During acclimation, feed pollutants concentration was increased gradually. Acclimation periods were: anaerobic 90 days, anoxic 40 days and aerobic 35 days. After the acclimation period MLVSS to MLSS ratio increased to 0.75–0.8 with MLVSS concentrations: anaerobic 3100 mg/L; anoxic 3600 mg/L and aerobic 3200 mg/L. These acclimated cultures were used for continuous experiments.

Continuous runs were started connecting these three acclimated batch reactors (each of working volume 5 L) under anaerobic (R1), anoxic (R2) and aerobic (R3) environments. A schematic of the experimental assembly is shown in Fig. 1. Two peristaltic pumps (model Gibson-minipuls-3, and Watson Marlow-501z) were used to deliver fresh feed to R1 and to provide the recycled effluent from R3 to anoxic reactor R2. An acrylic up flow clarifier (each capacity 1 L) was connected with each reactor. Supernatant liquid from each clarifier was allowed to overflow to the next reactor by gravity. Settled sludge from the clarifier was recycled to the respective reactor (twice a day for R2 and R3 and at three day intervals to R1). R1 was operated

Table 1
Composition of synthetic feed

Parameter	Concentration
Phenol	1500 mg/L
CN^-	70 mg/L[a]
SCN^-	800 mg/L[b]
NH_4^+-N	800 mg/L[c]
pH	8.0[d]
Yeast extract	20 mg/L
Trace metal solution	1.0 mL/L[e]

[a] Added as 175 mg/L KCN.
[b] Added as 1337 mg/L KSCN.
[c] Added as 3055 mg/L NH_4Cl.
[d] Phosphate buffer (KH_2PO_4 68 mg/L and Na_2HPO_4 437 mg/L) of 0.0036 M strength and pH = 8.0.
[e] Trace metal solution: $CaCl_2 \cdot 2H_2O$ 2000 mg/L; $MgSO_4 \cdot 7H_2O$ 2000 mg/L; $CuSO_4 \cdot 5H_2O$ 1500 mg/L; $ZnSO_4 \cdot 7H_2O$ 1000 mg/L and $FeCl_3$ 300 mg/L.

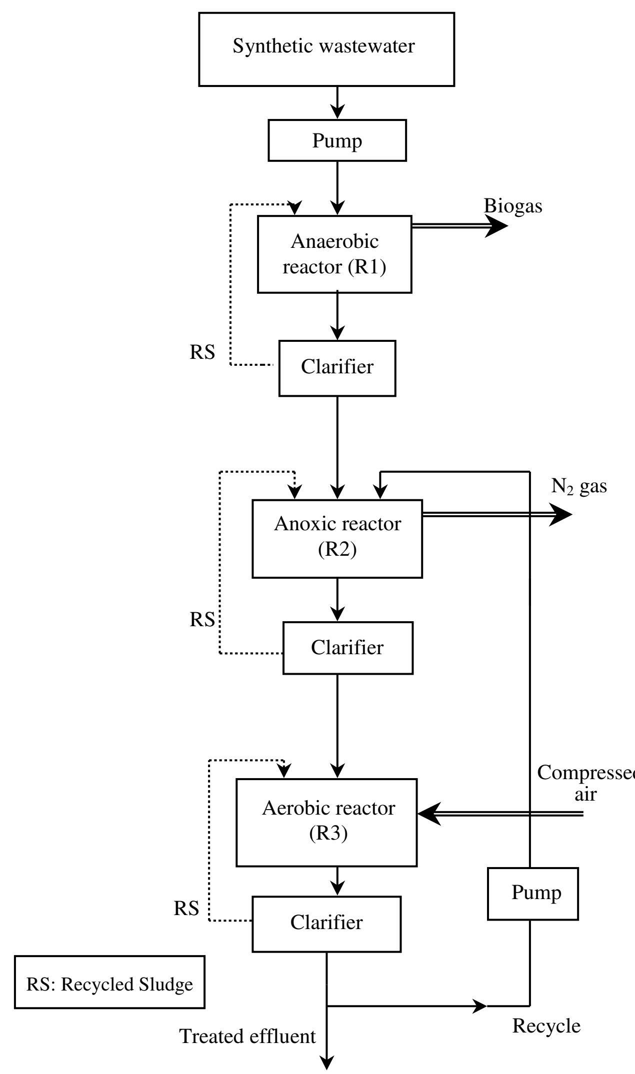

Fig. 1. Schematic of reactor assembly in the three-stage continuous system (Chakraborty and Veeramani, 2002).