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Process Biochemistry 40 (2005) 165–175

PROCESS BIOCHEMISTRY

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Evaluation of biokinetic parameters for pharmaceutical wastewaters using aerobic oxidation integrated with chemical treatment

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Received 6 August 2002; accepted 28 November 2003

Abstract

Pharmaceutical industries in and around Hyderabad produce a wide variety of products using both organic and inorganic substances as raw materials thereby generating a large quantity of complex toxic organic liquid wastes containing high concentrations of inorganic TDS. These wastes are highly toxic to biological life and are usually characterized by high BOD, COD and a high COD:BOD ratio. In the present study an attempt has been made to evaluate the treatability of a bulk drug pharmaceutical wastewater using a lab-scale activated sludge reactor with acclimatized mixed consortia. The application of chemical coagulation as a pretreatment for the removal of sulphates from the effluent was examined with lime as a coagulant to reduce the TDS levels. A 44–48% removal of sulphates was achieved which helped in increasing the efficiency for achieving better biological treatment. The treatability studies with mixed consortia revealed that the acclimatized bacteria were highly effective in treating the waste by achieving a maximum reduction of 86.6% from as high as 4000 mg/l COD concentration. At an HRT of 4.5 days maximum reduction in the COD concentration is found in all the concentrations studied. The biokinetic parameters like Y, K_s, k, μ_{max} and k_d which will be useful to design a prototype activated sludge reactor are evaluated.

Keywords: Hydraulic retention time (HRT); Mixed consortia; Activated sludge; Biokinetic constants; Mean cell residence time; Decay coefficient; Yield coefficient; Substrate utilization; Specific growth rate

1. Introduction

Pharmaceutical industry produces a wide variety of products. This industry uses both inorganics and organics as raw materials the latter being either of synthetic or of vegetable and animal origin [1,2]. Antibiotics and vitamins are produced by fermentation of fairly complex nutrient solutions of organic matter and inorganic salts by fungi or bacteria [1,3]. If a crude waste from an antibiotic plant is discharged into a stream it not only imparts objectionable odor to the stream but also adversely affects the biological population in it. Synthetic drug plants also utilize large number of both organic and inorganic chemicals and usually produce a variety of drugs [4,5]. The volume and composition of the liquid waste not only vary from plant to plant but also from section to section in a plant, producing different type of drugs from raw materials and using varieties of processes [6]. In general most of the wastes are toxic to biological life and are usually characterized by high BOD, COD and a high BOD:COD ratio [1,7]. Wastes from these plants are either highly alkaline or acidic. Wastes from the manufacture of drugs also contain toxic components including cyanide. Highly alkaline wastes originate from the manufacture of Sulfa drugs and Vitamin B_{12}. Manufacture of certain organic intermediates give rise to highly acidic waste [1]. Activated sludge process is a continuous or semi-continuous aerobic treatment method through which waste undergoes carbonaceous oxidation and nitrification. Many mathematical models exit for activated sludge wastewater treatment that range from simple to multi-component multi species to more complex species [8]. A few kinetic studies for activated sludge process design and operation are available in literature [9–11]. However, information on the design of activated sludge plants using biokinetic parameters for pharmaceutical effluents under Indian conditions is very limited. The prime objective of this study was to evaluate the biokinetic

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doi:10.1016/j.procbio.2003.11.056

parameters, which helps to understand the metabolic performance of the microorganisms when fed with the substrate and other components in pharmaceutical effluent in an activated sludge system. Further an attempt was made to evaluate the treatability of bulk drug pharmaceutical wastewater using lab scale acclimatized mixed consortia. A lab scale extended aeration activated sludge unit was set up with a mixed consortia developed from soil micro flora. Bacteria in the mixed consortium were acclimatized with the waste initially and then the treatability was studied.

2. Material and methods

2.1. Wastewater source and characterization

The wastewater for this study was obtained from the equalization tank of a bulk drug pharmaceutical unit in Hyderabad and characterized using standard methods [12] (Table 1). The wastewater contained a large number of aromatic and aliphatic organic chemicals in addition to inorganics. The BOD:COD ratio of the wastewaters was in the range 0.45–0.6, which is amenable to biological treatment. All the chemicals used were of analytical reagent grade. Water used in all the experiments was. Laboratory distilled water with pH (7.2–8.0), Alkalinity (40–120 mg/l), chlorides (20–30 mg/l). Tap water from a ground water source is used for the dilution of raw effluent.

2.2. Inoculum

The inoculum required for the study was generated from the soil micro flora of the surrounding bulk drug ETP. After attaining the desired quantity of sludge the seed was initially transferred into the reactor and was then retained in order to facilitate the building up of MLSS concentration seed was not wasted in order to facilitate the MLSS concentration to build up.

2.3. Reactor

Aerobic oxidation was performed in the laboratory scale glass fabricated ASP unit of 11 L capacity (Fig. 1). The reactor consisted of two chambers, one for aeration (9 L) and the other for settling (2 L). The reactor was equipped with an internal recycling facility for sludge to maintain MLSS. Submerged aeration was given to the mixed liquor in the reactor using air compressor. Arrangement was made at the bottom of the aeration tank with a perforated PVC pipe for effective and uniform mixing.

2.4. Chemical analysis

All chemical analysis was carried out by standard methods (pH, electrical conductivity, total solids as mg/l, total dissolved solids as mg/l, total suspended solids as mg/l, Chemical Oxygen Demand (COD) as mg/l, Biochemical Oxygen Demand (BOD) as mg/l, nitrates as mg/l, phosphates as mg/l, alkalinity as mg/l, sulphate as mg/l) [12].

2.5. Start up of reactor

Aerobic oxidation was carried in a laboratory scale activated sludge reactor of 9 l capacity. The activated sludge required to start the reactor was generated from the soil micro flora near the industry where the wastewater is collected. To initialize growth a solution of glucose + L-glutamic acid was prepared. The COD concentration was maintained between 500 and 1500 mg/l besides the C:N:P = 100:5:1 ratio [13]. Micronutrients were also provided during the seed generation phase. The reactor was monitored for outlet COD, pH, MLSS and MLVSS daily to understand the activity of the reactor [14]. The percentage COD removal, during the aeration period is presented in Fig. 2a. It can be concluded that COD uptake gradually increased from 10 to 85% over a period of 12 days and it reached steady state after 18 days of the start up. The reactor was operated for 25 days with syn-

Table 1
Characteristics of waste before and after chemical treatment

S. no.	Parameter	Pre-chemical treatment		Post-chemical treatment	
		$\bar{X}$ ± S.D.	S.E	$\bar{X}$ ± S.D.	S.E
1	Color	Dark brown	–	Light brown	–
2	pH	7.9 ± 0.32	0.141	12.9 ± 0.28	0.128
3	EC	44850 ± 316	141.42	25230 ± 158.1	70.7
4	Total solids	35886 ± 854.3	381.17	20030 ± 317.4	142.0
5	Total dissolved solids	28814.2 ± 262.74	117.5	16190 ± 108.4	48.5
6	Total suspended solids	7131.8 ± 611.3	273.4	3720 ± 192.35	86.0
7	COD	12378.4 ± 553.4	247.47	8480 ± 414.73	185.47
8	BOD	5992 ± 142.6	63.76	4800 ± 316.23	141.2
9	Phosphates	Nil	–	–	–
10	Nitrates	3200 ± 141.4	63.25	1400 ± 306.2	121.42
11	Alkalinity	2600 ± 154.1	68.92	1100 ± 128.6	68.50
12	Sulfates	9000 ± 316.2	141.42	4900 ± 207.5	185.45
13	Chlorides	1150 ± 158.1	70.71	950 ± 64.1	49.4

Note: All the values except color, pH and electric conductivity are expressed as mg/l. All the values are expressed as a mean of five values.