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Treatability study of real life bakery wastewater in a suspended growth batch fed reactor

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In the present investigation batch kinetic studies were conducted to explore the efficiency of the microbial culture, for organic carbon oxidation and nitrification real life bakery wastewater. The wastewater contain COD, TSS and ammoniacal nitrogen (NH_4^+-N) within a range of 1300–1350, 550–600 and 60–65 mg/L respectively and pH was in the range of 7.4–7.5. Five sets of each carbon oxidation and nitrification study were carried out in fed batch reactor using real life sample under ambient temperature of 25–30°C. It was observed that more than 90% removal of COD could be achieved after a contact period of 24 h for 1320±30 mg/L of initial COD concentration. Similarly 84% of NH_4^+-N removal was found after an extended contact period of 30 h corresponding to the initial NH_4^+-N concentration of 60±5 mg/L. Finally experimental data set were utilized to determine various kinetic coefficients such as k, k_s, Y, k_d, for designing a activated sludge reactor for treatment of bakery wastewater.

Keywords: Bakery wastewater, batch fed reactor, carbon oxidation, ammoniacal nitrogen removal, kinetic coefficient.

Introduction

The bakery industry prepared varieties of bakery products like bread, pies, pasties, cake etc. The important machineries used in bakery industry are dough mixer, dough divider, dough moulder, bake ovens[1]. Wheat flour, yeast, water, shortening agent are the basic ingredients in bakery product production process. Flour contains a higher amount of gluten protein and starch. Water is used for preparation of dough. The ratio of flour to water is maintained about 10:6[2–5]. After the manufacturing operation, hot water mixed with detergents is used to wash the baking equipments. Effluent from bakeries is produced from cleaning operations such as machine equipment and floor washing. Wheat flour, sugar, shortening agent and yeast are the major elements in the wastewater[6,7].

In view of appropriate method of treating the organic load suitable bioreactor should be designed rationally after proper laboratory performance study with real life bakery wastewater. However, realistic data are not available particularly in Indian environment for design of bioreactor considering the application of kinetic parameters. A limited number of earlier studies have been conducted by some researchers to explore the feasibility of biodegradability of bakery effluent using suspended growth reactor[3,8,9]. In order to bridge the gap necessary for information as exist till date particularly in Indian context, a laboratory investigation was undertaken in the School of Environmental Studies, Jadavpur University, Kolkata to perform the biodegradation study of real-life bakery wastewater with an aim to evaluate kinetic constant for designing a suitable suspended growth bioreactor.

Materials and methods

(A) Collection of real life sample:

Real life sample of bakery wastewater was collected from a local bakery production unit. The concerned bakery plant produces patties, sandwich, burger, pastry etc. The average rate of effluent production in the plant is estimated as 40 m^3/day. Samples were collected in 5 liter plastic container. The samples that were collected at different time from plant outlet were checked for various parameters like pH, COD, BOD, TSS, TDS and ammoniacal nitrogen as described in Standards Methods[10].

(B) Seed acclimatization for carbon oxidation and nitrification:

A measuring cylinder of 1.0 L capacity was taken as an acclimatization unit. A non-acclimatized seed collected from nearby sewage treatment plant was mixed with 800 mL synthetic substrate in aerobic environment. The aeration was done continuously with the help of aquarium pumps. When initial growth was observed, the acclimatization process was carried out by introducing real life bakery wastewater in ascending volume. The biomass growth was measured by sludge volume index (SVI) and MLSS concentration. Seed acclimatization phase continues for two months and assumed to be ended when a steady performance of substrate removal vis-à-vis microbial growth was observed.

For acclimatization of nitrifires for ammonia nitrification a separate 800 mL synthetic solution was prepared and poured in a cylinder of 1.0 L capacity, in which NH_4Cl and $(NH_4)_2SO_4$ of a concentration of 0.5 g/L and 0.04 g/L was added as nitrogen source to stimulate the appropriate environmental conditions. Aeration was done with the help of aquarium pumps. pH was maintained between 7.2–8.0 by adding buffer solution. When initial growth of nitrifiers was observed, the acclimatization process was carried out by using real life bakery wastewater. The seed acclimatization phase continues for two months and assumed to be ended when a steady state equilibrium of NH_4^+-N reduction and MLSS concentration was observed.

(C) Experimental set up:

Suspended Growth Reactors was chosen for carrying out the experiments. The carbon oxidation study was carried out in a measuring cylinder of 1 liter volume. Aquarium pump of 0.5 hp capacity was used for necessary aeration purpose. The experiment for ammonia nitrogen removal was carried out in similar type suspended growth reactors. Pre-acclimated seed (nitrifiers) was added in a different cylinder of 1.0 L capacity and diffused aeration systems were adopted for oxygen supply within the reaction chamber. The experiment was carried out in a similar manner as stated in carbon oxidation study.

Results and discussion

(A) Characterization of bakery wastewater:

The real life wastewater samples were characterized in the laboratory as exhibited in Table 1. The COD and ammoniacal nitrogen values were found within a range of 1300-1350 and 60–65 mg/L, respectively. The average pH and TSS of real life composite sample wastewater were found to be 7.4±0.2 and 550±45 mg/L respectively. The temperature during collection of sample was observed in the range of 25–32°C. As regards to the high TDS value, the reason can be attributed for the presence of different ions which generally are major constituents of the different cleansing agents and disinfectants used during the operation and maintenance stages. As the raw effluent passes through the chemical treatment, a large portion of colloidal matter has been reduced due to the chemical coagulation and sedimentation.

Table 1. Characterizations of field sample

Sl. No.	Parameters	Average values
1.	COD (mg/L)	1300–1350
2.	BOD (mg/L)	800–900
3.	TSS (mg/L)	550–600
4.	Ammoniacal nitrogen (mg/L)	60–65
5.	pH	7.4–7.6

(B) Performance evaluation of batch reactor:

This study was conducted for exploring the removal kinetics of COD and NH_4^+-N with time, with the help of acclimatizing seed and also to determine the kinetic constants for designing of a suitable suspended type biological reactor for treatment of bakery wastewater sample.

(B.1) Time concentration study for carbon oxidation in batch fed reactor:

The carbon oxidation study of real life sample has been carried out under different valid COD and MLSS conditions in batch fed reactor. The result of carbon oxidation study with initial COD and MLSS concentration of 1320 and 2620 mg/L respectively, are shown in Fig. 1 and Fig. 2. From Fig. 1 it has been observed that COD value decreases with the progress of time. The plot also reveals that within a 22 h of contact time, maximum COD removal was achieved 89.02% beyond which the removal was decreases. Fig. 2 demonstrates that there is steady ascending trend in MLSS concentration up to a time period of 22 h, from initial MLSS concentration 2620 mg/L. After 22 h, the rate of increase of MLSS concentration found to be very much marginal and a steady state condition was achieved, which indicates enzymatic activity of carbonaceous microorganisms in the mixed culture are exhausted and fully utilized.

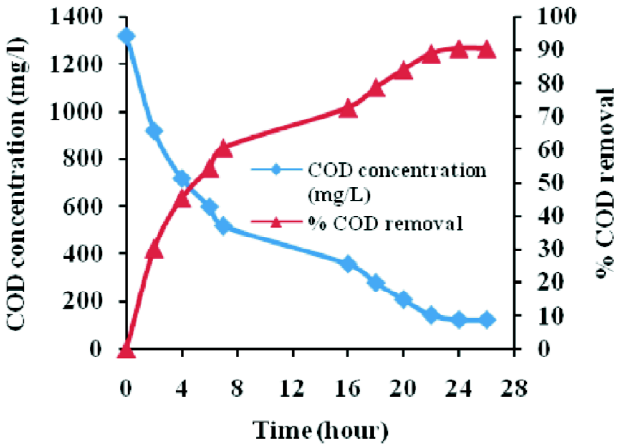

Fig. 1. Variation of COD concentration and percentage of COD reduction with time [Initial COD concentration = 1320 mg/L].

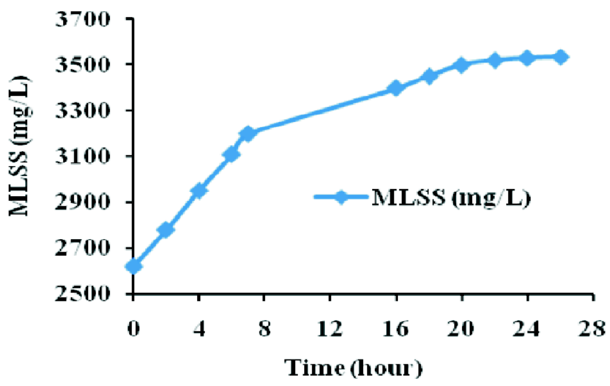

Fig. 2. Variation of MLSS with time [Initial MLSS concentration = 2620 mg/L].

(B.2) Time concentration study for nitrification in batch fed reactor:

The experimental results of nitrification study with initial NH_4^+-N and MLSS concentration value of 60.48 and 2000 mg/L are shown in Fig. 3 and Fig. 4. From Fig. 3 it has been observed that as time progresses, the NH_4^+-N concentration decreases with respect to initial NH_4^+-N concentration of 60.48 mg/L and finally after 30 h the residual NH_4^+-N concentration within the reactor reaches to a level of 10.12 mg/L which correspondence to 83.27% removal of NH_4^+-N from wastewater sample. During nitrification process, the MLSS concentration in the reactor increases upto 3140 mg/L from the initial concentration of 2000 mg/L within a period of 30 h of contact time. The increase of MLSS has been shown in Fig. 4.

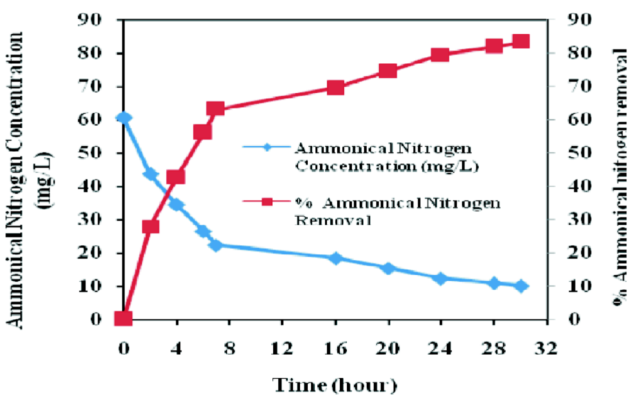

Fig. 3. Variation in ammoniacal nitrogen concentration and percentage of ammoniacal nitrogen reduction with time [Initial ammoniacal nitrogen concentration = 60.48 mg/L].

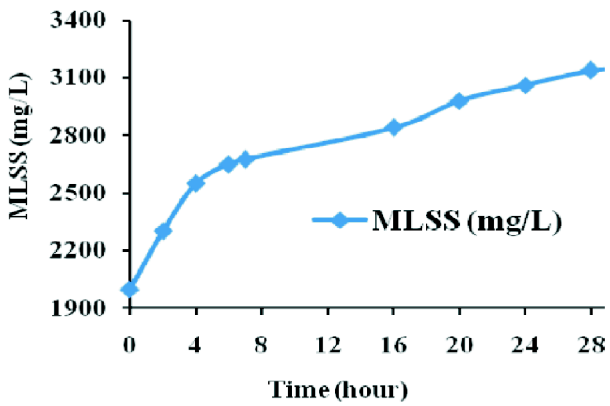

Fig. 4. Variation of MLSS with time [Initial MLSS concentration = 2000 mg/L].

(B.3) Kinetics for carbon oxidation:

Reaction kinetics plays a vital role in the evaluation of the performance of any reactor. Different experiments have been done to estimate the values of kinetic coefficients for carbon oxidation of organic carbon. The values of $1/U_C$ were plotted against $1/S$ using linear equation $1/U_C = [(K_s/k)(1/S)] + 1/k$ as shown in Fig. 5. The value of k is 4.69 per day whereas the half velocity constant (K_s) is 390.677 mg/L for an initial soluble COD of 1300–1350 mg/L. The value of K_s was found to be higher than the standard value[5], because of high influent COD concentration in the batch reactor, as shown in Table 1. Another graph was plotted between the reciprocal of reaction time ($1/\Theta$) with specific organic substrate utilization rate (U_C) as shown in Fig. 6. From Fig. 6 value of yield coefficient (Y) and endogenous decay rate constant (k_d) were found to be 0.680 mg of MLSS/mg of COD and 0.062 per day respectively, for an initial COD concentration of 1300–1350 mg/L.

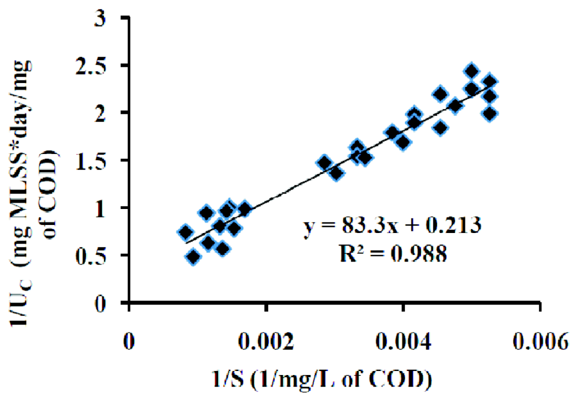

Fig. 5. Substrate utilization kinetic for carbon oxidation study of real life sample in batch reactor.

(B.4) Kinetics for nitrification:

The values of $1/U_N$ were plotted against $1/N$ for nitrification by using equation $1/U = (K_s/k).(1/N) + (1/k)$ as shown in Fig. 7. The value of k is 2.57 per day whereas the half velocity constant (K_s) is 28.16 mg/L for an initial NH_4^+-N of 60–65 mg/L as N as shown in Fig. 7. The K_s value was found to be higher because of high influent NH_4^+-N concentration. The values of $1/\Theta$ were plotted against U_N as shown in Fig. 8.

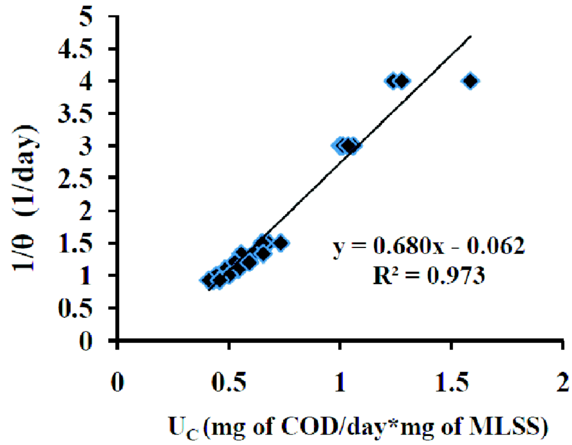

Fig. 6. Growth kinetic for carbon oxidation study of real life sample in batch reactor.

Table 2. kinetic coefficients for carbon oxidation and nitrification of real life bakery wastewater

Serial No.	Kinetic coefficients	Carbon oxidation	Nitrification
1	Y	0.680	0.472
2	k_d	0.062	0.045
3	k	4.69	2.57
4	k_s	390.677	28.16

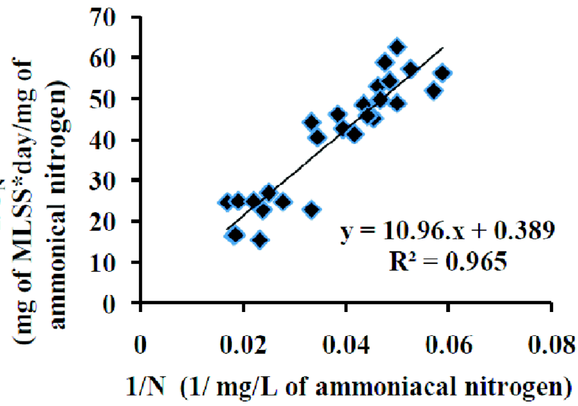

Fig. 7. Substrate utilization kinetic for nitrification study of real life sample in batch reactor.

From Fig. 8 values of Y and k_d were found to be 0.472 mg of MLSS/mg of NH_4^+-N and 0.045 per day respectively, for an initial NH_4^+-N concentration of 60–65 mg/L.

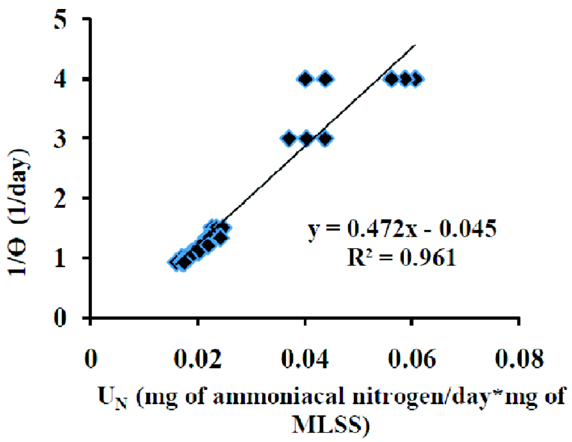

Fig. 8. Microbial growth kinetic for nitrification study of real life sample in batch reactor.

Conclusion

The batch study data exhibited that both COD and nitrogen content in bakery wastewater is successfully treated by the mixed bacterial culture as developed in the laboratory under aerobic condition. Kinetic coefficients evaluated based on the experiments showed that the results obtained during the present study were in accordance with those obtained earlier researchers.

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